University of Belgrade

Faculty of Mechanical Engineering

Course catalog

Master (M.Sc.) Academic Studies – Mechanical Engineering

Belgrade 2024.

M.Sc. Thesis

Course of M.Sc. Thesis

M.Sc. Thesis

ID: 1503
Responsible/Holder professor - -. -
Teaching profesor(s): ALL TEACHERS OF STUDY PROGRAMME M.SC. MECHANICAL ENGINEERING
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 13
Final exam: oral
Parent department: -

Goals

The preparation of M.Sc. thesis helps the student to acquire experience in academic paper writing and develop the ability to publicly present the results of independent work, as well as to provide answers to the questions related to the topic of the thesis.

Learning outcomes

Upon the successful defense of the M.Sc. thesis, engineers should be able to:
• Present the results of independent work in written form;
• Create documentation in accordance with technical standards;
• Publicly present the results of their independent work and express their own views on the M.Sc. thesis topic;
• Communicate efficiently with the engineering community and society as a whole;

Theoretical teaching

In agreement with the mentor, the student compiles the M.Sc. thesis in written form, according to the prescribed Faculty standards. The student prepares and publicly defends the written Master thesis upon agreement with the mentor. M.Sc. thesis should include at least two of the following areas: the report on studied and processed topic, own numerical computation, own experimental work and/or own design.

Practical teaching

Student prepares M.Sc. thesis text, technical documentation and presentation for public defense using modern technologies.

Prerequisites

Successfully passed exams in all courses defined by the curriculum of the study programme and exam in the course which the M.Sc. thesis belongs to.

Learning resources

Existing laboratory equipment at the Faculty, textbooks and library references.

NUMBER OF HOURS

Total number of hours: 15

ACTIVE TEACHING	OTHER

active teaching (theoretical)	**0**	**knowledge checks**	**15**
lectures	0	assessment of calculation tasks	0
elaboration and examples (revision)	0	check and assessment of lab reports	0
active teaching (practical)	**0**	check and assessment of seminar works	0
auditory exercises	0	check and assessment of projects	13
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	2
project design	0		
discussion and workshop	0		
research	**150**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	70
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 70

References

Current textbooks, journals, library references in the field of the topic of the Master thesis.

Course of M.Sc. Thesis

ID: 1504
Responsible/Holder professor - -. -
Teaching profesor(s): ALL TEACHERS OF STUDY PROGRAMME M.SC. MECHANICAL ENGINEERING
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 13
Final exam: written
Parent department: -

Goals

Applying engineering knowledge, techniques and skills in order to identify, formulate and solve the given engineering task; understanding the principles of project and equipment design and the environment necessary for their production; designing systems, components or processes bearing in mind practical limitations, such as economic, ecological, social, ethical, health and security limitations; using computing and statistical methods, simulations and information technologies for analysis and synthesis of technological systems; implementing standard tests and measuring and providing an overview of the results.

Learning outcomes

Upon the successful completion of Course of M.Sc. Thesis, engineers should be able to:
• Identify, formulate, analyse and solve complex engineering problems;
• Derive and implement new technical solutions based on knowledge in sciences, engineering sciences and information technologies;
• Design a system, component or process and respond to specified needs;
• Consider and take into account social, economic and ecological aspects and ethical principles when developing and implementing solutions;
• Apply numerical and statistical methods, simulations and information technologies for the analysis and synthesis of technical and technological systems;
• Apply standard tests and measurements: conduct, analyse and interpret the results;
• Plan and conduct experiments, analyse and interpret the results and draw appropriate conclusions;
• Work efficiently and as individuals or leaders in a team in a multidisciplinary environment, with the ability of lifelong learning;
• Consider different solutions critically and self-critically;
• Apply the acquired knowledge in practice;
• Adapt to newly arising situations in practice.

Theoretical teaching

It is developed individually in accordance with the needs and the field encompassed by the topic of the Master thesis. The student studies the referent literature, bachelor and master theses with similar topics and conducts analyses in order to find solutions to the specific task defined by the topic of the Master thesis.

Practical teaching

Within the given topic, the student may conduct standard testing and measuring; he/she may conduct, analyse and interpret experiments and implement experimental results to process improvement. He/she may use the methods and tools for analysis, synthesis and design, such as: CAD, CAM, CAE, FEA, FMEA et al.

Prerequisites

Successfully passed all exams defined by the curriculum of the study programme and the exam of the course which the Master thesis belongs to.

Learning resources

Existing laboratory equipment at the Faculty, textbooks and library references.

NUMBER OF HOURS

Total number of hours: 15

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**150**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	13
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	70
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 70

References

Current textbooks, journals, library references in the field of the topic of the Master thesis.

AEROSPACE ENGINEERING

Aeroelasticity

Aircraft armement systems

Aircraft control and systems

Aircraft Design

Aircraft maintenance

Aircraft Performance

Aircraft propulsion

Applied Aerodynamics

Avionics

Bionics in design

Composite Structures

Computational Aerodynamics

Flight Dynamics

Helicopters

High Speed Aerodynamics

Project Management & Air Regulation

Rocket Motors

Skill Praxis M - VAZ

Structural Analysis

Wind Turbines 2

Aeroelasticity

ID: 0645
Responsible/Holder professor MIRKO R. DINULOVIĆ
Teaching profesor(s): DINULOVIĆ MIRKO; PETRAŠINOVIĆ DANILO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: aerospace engineering

Goals

1. introduction to modern aeroelasticity problems and their analysis and practical methods to solving aeroelasticity problems in real aircraft structures
2. introduction to experimental dynamic analysis of aircraft structures
3. introduction to dynamics of thin walled structures

Learning outcomes

After successful competition of the course students should be able to:

1. Determine forms of oscillation of thin walled structure
2. calculate the torsional divergence speed of lifting surface
3. Calculate the command reversal speed (ailerons) on the wings
4. Estimate flutter speed of the lifting surface using Teodorsen method
5. Generate finite element models of lifting surfaces of the aircraft for static and dynamic aeroelastic analysis .

Theoretical teaching

In the theoretical part of the course following topics are covered: Introduction to aeroelasticity. Types of aeroelastic phenomena on aircrafts and structures in general. Static, dynamic aeroelasticity. Differntial equations and solution methods. Galerkin's method, collocation at the point, collocation at subdomain. Oscillations, types, mathematical models. Wing divergence, Command reversal, Flutter. Oscillations of continual distributed mass.

Practical teaching

During practical part of the course covered topis in theoretical part are demonstrated in practice. Typical practical problmes are analyzed through numerical examples. Students are required to complete practical project work using computer modeling and analysis. All required material is available in the form of lecture notes, books and past exams and tests.

Prerequisites

Mathematics, Resistance of materials

Learning resources

Computing Laboratory for Theory of elasticity and Aeroelasticity

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	0	final exam	40
calculation tasks	10		

Requirements to take the exam (number of points) 40

References

An introduction to the theory of aeroelasticity, Y.C. Fung, Dover publication 1993

Aircraft armement systems

ID: 1082
Responsible/Holder professor ALEKSANDAR M. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ ALEKSANDAR; PEKOVIĆ OGNJEN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

The study of this course is to ensure adoption of procedures and methods for problem solving related to aircraft armament calculations. Students will be capable of independently study aircraft rocket, bomber and firearms armament elements in order to obtain maximum effectiveness for the given conditions of application for each of these types of aircraft weapons. Particular attention will be faced towards development trends of modern aircraft armament.

Learning outcomes

By mastering of the course curriculum student obtains following subject - specific skills:

- thorough knowledge and understanding of different types of aircraft weapons and their application
- calculation of air weapons characteristics and possibility of their integration into the aircraft with the use of scientific methods and procedures
- linking basic knowledge in mathematics, programming, mechanics and fluid mechanics and their application in design and calculation of aviation weapons and its integration;

Theoretical teaching

-Introduction to aircraft armament field -Division and classification-Historical development-Development trends- Aircraft bomber armament - Determining the actual coordinates of the aim-Aerodynamic integration of bombs, carriers and aircraft - Underslung load influence on aircraft characteristics-Aircraft underslung load removal calculations- Trajectory stabilization-Determination of forces and moments on the underslung loads-Parachutes and braking devices-Aircraft missile systems-The basic components of missiles and their arrangement-Structure calculations and structure types-Slender bodies aerodynamic characteristics-Aerodynamic interference-Steering elements design features-Stability derivatives-Damping of the pitching and rolling-Firearms-Definition and division of firearms-The basic components and mechanisms-Determination of forces and loads-Dynamics and shock in the automatic mechanisms, equipment and parts-Existing solutions of integration-Depreciation recoil force in accordance with the construction of aircraft-Connections in aircraft- container system.

Practical teaching

-Division and classification of aircraft armament-Aircraft bomber armament, air bombs classification - Aerodynamic bombs, carrier and aircraft integration-Stabilization path-

Parachutes-Aircraft missile armament-Missile classification-Design characteristics-Aerodynamic schemes-The basic components of missiles and their rearrangement-Rocket structure and construction calculation -Aerodynamic interference-Steering elements design features-Stability derivative-Aircraft firearms- Firearms definition and division-The main components and mechanisms-Determination of forces and loads-Dynamics and shocks in the mechanisms-Existing integration solutions-Depreciation recoil force

Prerequisites

There is no necessary requirement for attendance of Aircraft Armament.

Learning resources

Additional materials (written handouts, problem setting, guidelines for problem solving),

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Jankovic S. Aerodinamika projektila, Faculty of Mechanical Engineering, Belgrade, 1979,КДА (in Serbian)

Aircraft control and systems

ID: 1079
Responsible/Holder professor NEBOJŠA B. PETROVIĆ
Teaching profesor(s): PETROVIĆ NEBOJŠA; PEKOVIĆ OGNJEN; IVANOV TONI
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: aerospace engineering

Goals

Course goal is to introduce students to integrated flight control computer systems, their functions, structures and principles. Course topics enable students to gain detailed insight into modern integration of aircraft systems and its components in aircraft control.

Learning outcomes

Upon course completion, students gain knowledge and understanding of existing aircraft integrated control computer systems. Course topics prepare students for studies of more advanced topics of aircraft control systems and further specialization in this area, or, in the case that they are oriented to other aeronautical fields to fully understand complex problems of aircraft control systems.

Theoretical teaching

Functions and structure of integrated aircraft control computer systems; System components; Various type of aircraft control systems; Sensors, busses, processors; Displays; Actuators; Flight control systems; Autopilots; Stabilizators; Dynamic models of flight; Longitudinal and lateral dynamic models; Transfer functions; Autopilot synthesis; Autopilot structure; Short period approximation; Gust model; Control command model.

Practical teaching

Practical teaching is related to presenting samples, analysis and discussion with students in the fields previously treated theoretically. System components. Various type of aircraft control systems. Sensors, busses, processors. Displays. Actuators. Flight control systems. Autopilots. Stabilizators. Dynamic models of flight. Longitudinal and lateral dynamic models. Transfer functions. Autopilot synthesis. Autopilot structure. Short period approximation. Gust model. Control command model. Simulation model of short period longitudinal motion. Longitudinal dynamic model of F-14. Dynamic model of short period dynamics controller for F-14. Hydraulic dynamic model of horizontal stabilizator for F-14.

Prerequisites

Students must have corresponding semestar in which this subject is teaching.
learning resources

Learning resources

Written handouts from the lectures.
Written handouts from auditory exercises.

Internet.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	5
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Aircraft Equipment and Systems - Automatic Flight Control Systems, Janković J., Faculty of Mechanical Engineering, Belgrade 1996.
Aircraft dinamics and automatic control, Duane McRuer, Dunstan Graham, Irving Ashkenas, Princeton University Press, 2014.

Aircraft Design

ID: 1132
Responsible/Holder professor ALEKSANDAR M. GRBOVIĆ
Teaching profesor(s): GRBOVIĆ ALEKSANDAR; SVORCAN JELENA; PETRAŠINOVIĆ DANILO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

This course aims to provide a comprehensive overview of the conceptual design of an aircraft. A holistic teaching approach is taken to explore how the individual elements of an aircraft can be designed and integrated using up-to-date methods and techniques. The course includes analyses of existing airplanes and assessments of their strong and weak points with the aim of selecting the optimum concept. Students are thought how to define basic geometric parameters of an aircraft, to select appropriate configuration and propulsion system, define loads and specific thrust/power. Performances and stability of the airplane are also covered.

Learning outcomes

After attending all lectures and completion of projects students will be able to analyze, specify, and develop aircraft concept according to required performances and purpose. They will have the ability to define and select the optimal aerodynamic scheme and determine essential design parameters. Also, they will know how to design aircraft parts and components efficiently and to prepare documentation for manufacturing.

Theoretical teaching

Definition of aircraft purpose and mission. Statistical analysis and definition of trends. Basic geometric parameters of the aircraft. Definition or selection of the propulsion system. Integration of propulsion, equipment, and avionics. Landing gear definition. Determination of aircraft loads and preliminary sizing of aircraft elements. Production technology, selection of standard elements, selection of materials. Properties of materials used in aircraft design. Static stability of the aircraft. Dynamic flight properties, flying qualities. Basic performances, special performances, takeoff, and landing. Cost of the project.

Practical teaching

Practical work with lecturer serves to illustrate concepts through examples and to help students to complete their projects. After project completion students present their work to professors and other students of the department. Final grades depend on the quality of the finished projects, student's activity during the school year, and the quality of presentations. During practical work, students use object-oriented programming for statistical analysis of known aircraft, learn how to use mechanical computer-aided design software, learn how to use and develop instruments for experimental testing, write programs for machines with computer numerical control and create a presentation of their project work.

Prerequisites

As defined by curricula of study program.

Learning resources

SimLab laboratory, application VAZMFB (https://vazmfb.com).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	10
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	15	seminar works	0
test/colloquium	0	project design	55
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

A. Grbovic, M. Milos: Software Tools in Design, Faculty of Mechanical Engineering, Belgrade, 2017
Handouts and presentations, 2023.

Aircraft maintenance

ID: 1081
Responsible/Holder professor NEBOJŠA B. PETROVIĆ
Teaching profesor(s): PETROVIĆ NEBOJŠA; PETRAŠINOVIĆ DANILO; DAVIDOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: aerospace engineering

Goals

Within the course "Aircraft maintenance" students will gain basic knowledge concerning contemporary theories and praxes in the maintenance and revitalization of both military and civil aircrafts. Furthermore, a part of the course is dedicated to exploration of maintainability, reliability of fighting tenacity, as well as the basic structural characteristics of the system that are defined in the early stages of design and development of modern aircrafts.

Learning outcomes

After mastering the curriculum, students will be capable of creative thinking and decision making in the domain of aircraft maintenance. By gaining sufficient theoretical and practical knowledge, they will be able to participate equally in a working team designing or maintaining the aircraft and to further improve important flight characteristics such as reliability, maintainability, fighting tenacity or durability (particularly in cases of forced landings).

Theoretical teaching

Introduction. Basic assumptions in aircraft maintenance. Technical maintenance. Safety and reliability in air-traffic. Maintenance concept. Maintenance activities. Maintenance levels. Maintenance in an airline. Line maintenance. Quantitative indicators of maintainability. Mathematical models of aircraft maintenance. Economical working life of equipment and systems. Necessary spare parts. Optimal number of checks. Minimal total cost. Reliability, usability and time-to-failure of regularly maintained systems. Defining the interval of preventive maintenance of parts and systems. Maintainability prediction. Aero-technical safety. Maintenance technologies. Determination and control of aircraft condition.

Practical teaching

Maintenance activities and levels. Airliners line maintenance. Probability distributions in maintainability and repairability. Maintenance cost optimization. Maintainability functions. Repairability functions. Maintenance period. Maintainability index. Safety indicator. Human activities indicator. Equipment availability factors: nominal, achieved and usable availability. Computational assignments derived from the course material. Maintainability prediction. Structural maintainability. Computational assignments. Diagnosis – nondestructive testing methods. Contemporary concept of aero-technical safety. Aircraft fighting tenacity. Aircraft vulnerability. Consultations.

Prerequisites

No specified conditions.

Learning resources

Rasuo, B, Aero-technical safety, Serbian Military Headquarters, Belgrade, 2004;
Additional materials (handouts, assignments etc.)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	20
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	10
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	15	seminar works	55
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Aircraft maintenance, N. Petrovic, P. Kalicanin, G. Vorotovic, C. Mitrovic, Faculty of Mechanical Engineering, 2016.
Bruce R. Aubin, Aircraft Maintenance, SAE International, 2004
Aviation Maintenance Techician Handbook, FAA, 2023,

Aircraft Performance

ID: 0948
Responsible/Holder professor ALEKSANDAR Č. BENGIN
Teaching profesor(s): BENGIN ALEKSANDAR; KOSTIĆ IVAN; KOSTIĆ OLIVERA; PEKOVIĆ OGNJEN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

Introducing students to the complex movement of aircraft in atmospheric flight. During the course will be studied the performance of the aircraft, i.e. will be studying the movement of the aircraft's center of gravity under the action of forces. Within the Course Term Project Assignment, that covers and integrates the entire course material, students will be able to obtain performance of the aircraft, individually with the use of modern software packages, such as Matlab, Mathcad, Excel, etc.

Learning outcomes

Mastering the course, the student acquires enough theoretical knowledge to be able individually and creatively to define performance capabilities of modern aircraft and all restrictions that result from them. In this course, students will gain full sublimation and verification of previously acquired knowledge and skills they have acquired within the Aeronautical module from the group of aerodynamic courses.

Theoretical teaching

Introduction. General assumptions in the calculation of the aircraft performance. Coordinate systems and coordinate transformation. Types of movement. The forces acting on the aircraft during the flight. Performance of the aircraft powerplants. Propellers. Geometric and aerodynamic characteristics of the propellers. Selection of the propeller. The equations of motion of aircraft. Basic aircraft performance. Basic flight performance (horizontal and vertical speed, time of the climbing, theoretical and practical flight ceiling). Special aircraft performance. Take off and landing. The effect of wind on the flight performance. Range and endurance, radius of action. The effect of wind on the range and radius of action. Unsteady movement in the vertical plane. Dive and pulling out of a dive. Aircraft maneuvers. Dynamic flight ceiling. Loop. Immelman. Roll. Pugachev's Cobra. Bell. Herbst maneuver. Optimization of the flight path of the aircraft. Spatial movement of aircraft. Introduction to the mechanics of cosmic flight.

Practical teaching

Aircraft powerplant. Selection of the propeller. Aircraft powerplants performance. Estimating of the basic aircraft performance. Estimating of the airplane special performance. Calculation of the range and endurance. Estimating of movement in the vertical plane. Aircraft gliding. Gliding airspeeds polar curve. Calculation of dive. The maximum dive speed. Calculation of the pulling out of a dive. Load factor in pulling out. Calculation of the sudden

pitch and jumping of the aircraft. Calculation of dynamic ceiling. Calculation of the loop, Calculation of aircraft turning flight. Slipping turn. Banked turn (steady coordinated turn). Banked turn with slipping. Limitations of the turn performance. Combat turn. Extreme flight regimes. Flight at high angle of attack and spin. Maneuvering flight envelope. Extreme flight regimes. Consultations.

Prerequisites

Without prerequisites, but it is recommended to pass the exam of the course Aerodynamic constructions previously.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	40
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

Rendulić Z., Mehanika leta, Vojnoizdavački i novinski centar, 1987.
Hull D.G., Fundamentals of Airplane Flight Mechanics, Springer, 2007.
Cook M.V., Flight Dynamics Principles, Second Edition, Butterworth-Heinemann, 2007.
Stengel R. F., Flight Dynamics, Princeton University Press, 2004.

Aircraft propulsion

ID: 1473
Responsible/Holder professor ALEKSANDAR M. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ ALEKSANDAR; IVANOV TONI; DAVIDOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

The main goals of the subject are the students knowledge obtaining of the work principles, types, main elements, characteristics and usage areas of air-breathing engines. One of the principle goal is establishment of the corelation among the aircraft types and appropriate propulsion systems in order to achieve given aircraft mission goal in optimal way according to the goal functions and existing constraints.

Learning outcomes

Students are going to achieve the ability to perform decomposition, to analyse and to make synthesis of the propulsion system together with the aircraft. The student gets the knowledge of different types of air breathing engines, and their main energetic components. The knowledge obtained by student is related to the design and determining of the performance of
the appropriate engines needed for engine quality estimation. Gained knowledge enables further student professional development in the field of aircraft propulsion.

Theoretical teaching

Thermodynamic cycles and thrust. Propulsion efficiency and basic engine performances. Propulsion circuit and its basic elements. Ideal ramjet, turbojet, turbojet with afterburner and turboshaft engines, ideal turbofans with separate and common nozzle. Real elements of propulsion circuit: intake and nozzle. Compressor and turbine. Mixer, combustion chamber and
afterburner. Working lines of turbojet and turboshaft engines. Engine starting. Engine performances: altitude, speed and throttling. Working envelopes of various engine types. Advanced propulsion types. Contemporary problems in airbreathing propulsion and future trends.

Practical teaching

Practical parts of the classes consists of examples, analysis and discussion with the students in the areas that are discussed in theory. Thermodynamic cycles and thrust. Propulsion efficiency and basic engine performances. Propulsion circuit and its basic elements. Ideal ramjet, turbojet, turbojet with afterburner and turboshaft engines, ideal turbofans with separate and common nozzle. Real elements of propulsion circuit: intake and nozzle. Compressor and turbine. Mixer, combustion chamber and afterburner.
Working lines of turbojet and turboshaft engines. Engine starting.
Engine performances: altitude, speed and throttling.

Working envelopes of various engine types.
Advanced propulsion types.
Contemporary problems in airbreathing propulsion and future trends.
Practical classes on on real engine cross-section turbojet with afterburner.

Prerequisites

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Learning resources

Handouts, textbook, various tables needed for numerical examples, turbojet engine cross-section.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	20	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Aircraft propulsion, Vasko Fotev, Belgrade 2011
Mechanics and Thermodynamics of Propulsion - Hill & Peterson 1992
Aerothermodynamics of Gas Turbine and Rocket Propulsion - G. Oates 1984
Aircraft engine design - Matingly 2002

Applied Aerodynamics

ID: 0946
Responsible/Holder professor IVAN A. KOSTIĆ
Teaching profesor(s): KOSTIĆ IVAN; KOSTIĆ OLIVERA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

The course objective is that students develop an understanding of practical applications of subsonic aerodynamics and to provide an introduction to compressible flows (lower transonic domain). The course initially covers concepts of airfoil theory, and the analysis of symmetric and cambered airfoils using analytical and numerical tools. The course also covers wing theory, lifting-line theory, elliptic wings, twisted wings, and their practical applications in the design of wings to meet the assigned aerodynamic requirements. Finally, students are involved in practical calculations of aerodynamic characteristics (lift, drag and the derived parameters) of the entire aircraft in configurations for take-off, landing and cruising flight in subsonic and lower transonic speed domains.

Learning outcomes

After accomplishing the course, students should be capable of understanding and explaining various aspects of the relations between the body shape (airfoil, lifting surface, air vehicle) and its aerodynamic characteristics. In addition, the students must be able to recognize the opportunities for the application of the acquired knowledge for the solution of different, both aeronautical, and non-aeronautical practical problems.

Theoretical teaching

In the theoretical part of course the following topics are analyzed. Two-dimensional problems: airfoil characteristics: the method of singularities, thin airfoil theory, method of droplets, panel methods, empirical methods and the determination of aerodynamic loads. Three-dimensional problems: vortex wing models, the theory of lifting line, analysis of elliptic wing, twisted non-elliptic wings, influence of geometric parameters on aerodynamic characteristics, loading of wings of arbitrary shape. Aerodynamic characteristics of complete aircraft. Wing airfoils selection, lifting characteristics and drag of wing and complete aircraft in take-off and landing configurations, and in cruising flight at subsonic and lower transonic speeds. Role of the CFD in the analysis and determination of aerodynamic characteristics.

Practical teaching

In the practical part of the course professor demonstrates the numerical examples in various areas. Practical work of students is accomplished through a virtual laboratory, available 24 hours (program MOODLE). In the workshop students have access to the professor's lectures (handouts), assignments for practice and tests. Practical training includes the preparation of project (calculations of aerodynamic characteristics of a selected aircraft). Project is performed by each student individually.

Prerequisites

None. Students who did not take any of aerodynamics courses on bachelor studies are referred to the additional handouts by professor.

Learning resources

This course has a virtual classroom on the Internet. At the first lecture students are enrolled and trained for work in Moodle software package. In the workshop, students have access to lectures and exercises, guidelines for project design, internet resources, etc.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

I. Kostić, O. Kostić: Applied Aerodynamics, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade 2022.
H. Ashley: Aerodynamics of Wings and Bodies, McGraw Hill, 1995.

Avionics

ID: 0311
Responsible/Holder professor NEBOJŠA B. PETROVIĆ
Teaching profesor(s): PETROVIĆ NEBOJŠA; VOROTOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: aerospace engineering

Goals

Objectives of the course are to introduce students to aviation electronic equipment and systems, their functions, structures and basic principles. The subject should provide students a detailed a detailed view of the latest trends in avionics technology and development.

Learning outcomes

Successful completion of course students acquire the ability to understand the existing solutions aviation electronic equipment and systems.The student acquires knowledge about the structures of various types of avionics equipment and systems.
The knowledge that allow students to opt for other aviation issues to understand the electronic aviation equipment and systems,and for those who want to specialize in these issues are fundamental to the acquired knowledge for further work.

Theoretical teaching

Avionics elements,AS 15531/MIL-STD-1553B, ARINC 429.Commercial standard digital bus. Head-Up displays, Head-mounted displays.Flight deck design.Batteries, Characteristcs, Types.Avionics functions.Fly By Wire-Electrical flight controls, system architecture, modes of the system,pitch control, roll control, yaw control, failure detection. Navigation and Communications,sattelite communications and navigation systems,ATC. Flight management systems,automatic direction finding,distance measuring equipment,TACAN.Visualization.Traffic collision an Avoidance system.Instruments landing system.Certification of civil avionics.Software,Ada,RTCA DO-178B/EUROCAE ED-12B. Implementation,B-777,A330/340,MD-11,F-22

Practical teaching

Practical work includes the presentation of examples, analysis and discussion with students in areas that were previously presented theory.
Avionics elements,AS 15531/MIL-STD-1553B, ARINC 429.Commercial standard digital bus. Head-Up displays, Head-mounted displays.Flight deck design.Batteries, Characteristcs, Types.Avionics functions.Fly By Wire-Electrical flight controls, system architecture, modes of the system,pitch control, roll control, yaw control, failure detection. Navigation and Communications,sattelite communications and navigation systems,ATC. Flight management systems,automatic direction finding,distance measuring equipment,TACAN.Visualization.Traffic collision an Avoidance system.Instruments landing system.Certification of civil avionics.Software,Ada,RTCA DO-178B/EUROCAE ED-12B. Implementation,B-777,A330/340,MD-11,F-22

Prerequisites

The condition of attending the course is student enrollment in the semester in which this subject is taught.

Learning resources

Written sources from the lecture.
Written sources from the auditory exercises.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

The Avionics Handbook, Cary R. Spitzer, RC Press LLC. 2001.
Civil Avionics Systems,I.Moir and A.Seabridge

Bionics in design

ID: 1471
Responsible/Holder professor MAJA B. ROSIĆ VITAS
Teaching profesor(s): ROSIĆ VITAS MAJA; SEDAK MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: aerospace engineering

Goals

Introducing students to the process and the procedure of synthesis (create) a combination of mechanical systems engineering design (design) and industrial and bionic design. Besides, the goal of this course is to develop creative skills of students in the design of machines. Understanding the methodology and procedures to create innovative mechanical system through the phase of designing, selection of parameters, dimensions and shape of machine parts, alignment features (functional and aesthetic) with the environment, living and working environment.

Learning outcomes

The student is introduced to the procedure of abstract thinking and creative idea generation, the development methodology of the new principal, conceptual, based on bionic solutions. Dressed in designing machine parts and assemblies based on bionic principles, functional, technological, aesthetic, ergonomic, and others. Trained to implement budgets for the mutual adjustment of parameters of machine parts with the limitations, the development of forms and sizes.

Theoretical teaching

History and Development bignic system. Experience in engineering: flying, navigation, civil engineering, architecture, and military construction. Inclusion bionic aspects in the design process and construction of mechanical systems. Mathematical principles of bionic system. Fibonacci sequence. Fibonacci spiral.
"Gold" section (the relationship) and "Golden" angle. The influence of the golden ratio in engineering design. The concept of fractals and fractal geometry. Cantor set. Euclid's natural forms. The effects of scale, form and similarity in nature and their impact on the development of modern machine design and systems. Energy efficiency of natural systems as models in the design of modern engineering structures, the experience of flight, navigation, energy, process engineering, military technology and others.
Natural (bionic) building materials. Modern composite materials. Thermoplastic and thermosetting materials in engineering.
"Smart" and functional materials in engineering structures and modern design.

Practical teaching

Influences Leonardo da Vinci, Sir George Cayley, Otto Lilienthal, Gustave Eiffel, Raoul France and Graf von Zeppelin. Bio-strategy application process in fulfilling the spirit of laws rules of

biological evolution, which should translate into an acceptable technical solution. Ten basic principles of natural structures.
Implementation bionic humanoid proportions and impact on the ergonomic design. Some typical relations (numbers) that characterize the specific effects of similarity and scaling in nature. Bionic Design - views and role models. Wood, vegetable fiber, animal: wool, silk, spider web, etc.. Natural resins. Artificial resins - matrix (binder) materials: Epoxy, Polyester, Vinyl ester, phenolic, polyimide, bismaleimide et al. Cellular materials, and intelligent optical fiber. Electrical and magnetic restatic.
Semiconductor spintronics. Magnetic materials. DNA nano-products.

Prerequisites

No special conditions.

Learning resources

Laboratory for Design in Mechanical Engineering, Books, Werner Nachtigall, Biologisches Design, Springer-Verlag Berlin Heidelberg 2005, include necessary material for lectures, exercises, assignments, projects and term papers. Require additional materials (handouts,setting assignments, term papers, etc..) Are given at the web site or reproduced on paper. Large-scale electronic materials can be made available to students in direct contact.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	10
elaboration and examples (revision)	2
active teaching (practical)	**12**
auditory exercises	6
laboratory exercises	0
calculation tasks	0
seminar works	6
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	60
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Б. Рашуо, Бионика у Дизајну, Машински факултет Универзитета у Београду, 2012;

Composite Structures

ID: 0639
Responsible/Holder professor MIRKO R. DINULOVIĆ
Teaching profesor(s): DINULOVIĆ MIRKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: aerospace engineering

Goals

1. introduction to modern approach in stress analysis of composite material structures on aircraft, it's application to practical problems solutions as well as experimental methods applied to structural verifification of composite structures.
2.Introduction to specifics of thin walled structures and application of composite materials for these structures.
3.Introduction to computer simualtion and stress analysis of composite structures on aircrafts.

Learning outcomes

1. Starting from the mechanical properties of fibers and matrices to calculate the properties of the composite elastic lamina .
2. calculate the load capacity of the composite lamina applying the HILL, Wu and Tsai criteria
3. Using classical laminate theory (CLT) determine stress strain state in composite laminate for a given external load
4. use commercial software for calculation of strength of aircraft composite structures

Theoretical teaching

Basic Definitions. Polymer Matrix and fiber characteristics. Prepregs. Fabrication processes. Autoclave polymerization. Characteristics of composite materials. Elastic stres-strain behavor of composite materials modeling. Plane stress. Principal stresses, principal deformations. Temperatre deformations. Deformations in respect to humidity. Failure Criteria applicable to composite media. Kirchoff and Midlin plate theories. Effective mechanical characteristics of laminates. Composite Beams. Interlaminar stresses. Composite buckling. Delamination, structural analysis of composte material constructuctions using finite element method.

Practical teaching

In the practical part of the course, stress-strain theory applicable to composite media is demonstrated. Real practical problems are analyzed. Practical work is carried out using computers and finite element analysis software for composite materials structures. Students are provided with all necessary materials in the form of lecture notes, books and past exam and test papers.

Prerequisites

Recommendation: Theory of elasticity, Strucural analysis of aircraft structures

Learning resources

Course notes in electronic form, media materials, computer simulation models available after class, internet resources.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	0	final exam	40
calculation tasks	10		

Requirements to take the exam (number of points) 40

References

Engineering Mechanics of Composite Materials, D.Ishaii, Oxford Universiy Press 1994
Composite Airframe Structures, Michael Chun-Yung Niu , Michael Niu, Conmilit Press Ltd. 1992

Computational Aerodynamics

ID: 1078
Responsible/Holder professor ALEKSANDAR M. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ ALEKSANDAR; SVORCAN JELENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: aerospace engineering

Goals

The goal of the course is to train students in modeling flow problems. After attending the course, finishing all exercises and giving the final presentation, students should be able to recognize the type of the problem, formulate necessary boundary and initial conditions, choose an appropriate discretization scheme and write a program for calculating flow inside or around simpler geometric shapes, such as a nozzle or an airfoil.

Learning outcomes

By successfully adopting the program of the course, a student: acquires theoretical knowledge sufficient to recognize the type of the problem as well as the type and number of additional conditions necessary to completely and uniquely define the problem that is being simulated; recognizes basic approximation schemes of the typical problems; masters the principles and foundations of programming related to simulations of continuum; observes the structure of the simulation software that consists of pre-processing, simulation and visualization.

Theoretical teaching

Derivation of the transport equation and its application to the basic laws of the fluid flow. Finite difference and finite volumes approximations of the partial differential equations. Basics of the generation of computational grids and their classifications. Transformation of the Navier-Stokes equations in general curvilinear coordinate systems. Metrics calculation and simplification of the boundary layer equations and parabolic Navier-Stokes equations. Computation of the Navier-Stokes equations for thin viscous layers. Approximation, boundary and initial conditions formulation, computation algorithm of direct numerical simulations. Compressible inviscid flow presented by an approximation of the Euler equation. Calculation of the transformation metrics for general curvilinear coordinate systems. Basics of turbulent flows modeling.

Practical teaching

Practical training accompanies materials presented during theoretical lectures. In the beginning, students are registered and they familiarize with working in Linux operating system. After that, illustrative examples are completely presented starting with the problem formulation, presentation of the appropriate equations and their approximation, stability and convergence studies, code and reading of the necessary input data, finishing with presenting solutions graphically. Students solve their homework independently and present it to their colleagues.

Prerequisites

Defined by the curriculum of the study program/module.

Learning resources

1. KPN
2. KLR
3. MPI software

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	20
calculation tasks	5
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	15	seminar works	0
test/colloquium	0	project design	55
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Petrović Z. Stupar S., Computer design, Faculty of Mechanical Engineering, 1992, KPN(in serbian)

Flight Dynamics

ID: 1472
Responsible/Holder professor ALEKSANDAR Č. BENGIN
Teaching profesor(s): BENGIN ALEKSANDAR; KOSTIĆ IVAN; KOSTIĆ OLIVERA; PEKOVIĆ OGNJEN

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

The main objective of the course is to develop understanding of the stability and controllability of the aircraft. This course directly prepares student to apply knowledge of the stability, maneuverability and aircraft control in the design of the aircraft. Within the project assignment that encompasses and integrates the whole curriculum, the students will be able to fully master the analysis of stability and maneuverability in the design of aircraft by using modern software packages.

Learning outcomes

Having mastered the planned curriculum, the student acquires sufficient theoretical knowledge to be able to independently define the state of the static and dynamic stability and maneuverability of modern aircraft and any flight restrictions that arise from it. In this course, students will receive full sublimation and the verification of previously acquired knowledge and skills that they have required within the aviation modules from the group of aerodynamic subjects.

Theoretical teaching

- Introduction.
- Revision of mechanics of aircraft flight.
- Basic concepts of stability and controllability of the aircraft.
- Differential equations of stability.
- Stability criteria.
- Aerodynamic stability derivatives.
- Static stability and controllability of the airplane.
- Dynamic stability and controllability of the aircraft.
- Aircraft parts contributions to the longitudinal stability (wings, horizontal tail, fuselage and nacelle contributions).
- Power plant influence on the longitudinal static stability.
- Neutral point of the aircraft.
- Angle of horizontal stabilizer setting.
- Balancing with the deflection of elevator.
- Marginal rear and front position of the aircraft center of gravity permitted.
- Longitudinal static stability of the aircraft.
- Static stability of the aircraft in maneuvering flight.
- Lateral static stability and maneuverability of the aircraft – Dihedral effect.

- Dynamic stability of the aircraft.
- Longitudinal dynamic stability.
- Lateral-directional dynamic stability.

Practical teaching

Criteria of stability and controllability of the aircraft movement. Calculation of the certain aircraft parts contribution to the total longitudinal stability with the control held. Rear position of the center of the aircraft gravity. Calculation of the longitudinal controllability of the aircraft. Calculation of the longitudinal static stability with the control released. Calculation of forces acting on the stick in steady flight. Calculation of the longitudinal static stability in maneuvering flight with the control held. Calculation of the longitudinal static stability in maneuvering flight with the control released.
Derivatives and parameters in the equations of the aircraft motion. Experimental determination of stability derivatives. Computation tasks from the contents taught in the course. Tutorials follow the theoretical lectures. Consultations.

Prerequisites

No special conditions.

Learning resources

Necessary material for lectures, tutorials, assignments, projects and term papers will be available to the students on the following website http://vaz.mas.bg.ac.rs/moodle.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	20
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	40
laboratory exercises	10	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 35

References

M. Nenadović, Stabilnost i upravljivost letelica, I i II deo, Beograd (1981/1984)
Jan Roskam, Airplane Flight Dynamics and Automatic Flight Controls, Part 1, 2001.
M.V. Cook, Flight Dynamics Principles, Second Edition, Butterworth-Heinemann, 2007.
R. F. Stengel, Flight Dynamics, Princeton University Press, 2004.

Helicopters

ID: 1131
Responsible/Holder professor ALEKSANDAR M. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ ALEKSANDAR; SVORCAN JELENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: aerospace engineering

Goals

1. Introduction to rotary lifting surface vehicles.
2. Introduction to rotor aerodynamic theory.
3. Design of helicopters.
4. Performance of helicopters.

Learning outcomes

1. Understanding of aerodynamic VTOL schemes.
2. Selection of the aerodynamic scheme in helicopter design.
3. Mastering theoretical foundations of rotary wing aerodynamics.
4. Ability to calculate aerodynamic and performance characteristics of the helicopter.
5. Ability to design rotor blade.
6. Ability to conceptually design helicopter.
7. Ability to apply modern software tools in design of helicopters.
8. Ability to optimize helicopter design parameters.

Theoretical teaching

In theoretical part the following is taught: VTOL aircraft, Theory of ideal rotor, Blade element theory,
horizontal flight of a helicopter, vertical flight performances, horizontal flight performances, Stability of a helicopter,
design schemes of a helicopter, helicopter control, Design of rotor blade. EASA regulaations for helicopter and transmission design.

Practical teaching

Theory is applied to chosen helicopter. Practical work of the student is monitored by MOODLE. Lectures are downloaded using online access.
Homework and other materials to master lectures are supplied. Students do projects in a group and finally present results to other students.

Prerequisites

Suggested: Aerodynamic design

Learning resources

Lectures in electronic form. Simulations and movies are accessible via MOODLE and internet.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	5
seminar works	5
project design	5
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	15	seminar works	55
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

J. Gordon Lishman, Principles of Helicopter Aerodynamicss, Cambridge Universithy Press, 2016.
A. R. S. Bramwell, Helicopter Dynamics, Edvard Arnold,, 1976
J. Seddon, Basic Helicopter Aerodynamics, BSP Professional Books, Oxford, 1990

High Speed Aerodynamics

ID: 0950
Responsible/Holder professor IVAN A. KOSTIĆ
Teaching profesor(s): KOSTIĆ IVAN; KOSTIĆ OLIVERA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

The aim of this course is to introduce students to basic concepts of high speed aerodynamics. Emphasis is given to transonic and supersonic flow problems. External flows (supersonic airfoils, wings and complete aircraft lifting configurations) and internal flows (supersonic intakes, nozzles and diffusers).

Learning outcomes

Upon completion and passing the course the student should be capable of understanding the basic concepts and problems in the field of aerodynamics at transonic and supersonic speeds. It is expected that the student knows how to apply the acquired knowledge in this field to solve practical engineering problems.

Theoretical teaching

The theoretical part of the course covers the following topics: Classification of flow and flow model (Navier-Stokes equations, the Euler, the potential of small disturbances, Prandtl-Glauert and Laplace). Singularities and discontinuities in the flow field. The method of characteristics and conical flow field. Airfoil in transonic and supersonic field (linear airfoil theory and the theory of higher order). Wing in supersonic flow (influence of tips, sweep, delta wing, supersonic and subsonic leading edge). Computational analysis of complete aircraft lifting configurations in transonic and supersonic flow fields. Intakes, nozzles and diffusers.

Practical teaching

Practical part of course demonstrates numerical examples in all areas. Practical work of students is accomplished through a virtual classroom, available 24 hours (program MOODLE). In the workshop students have access to the professor's lectures (handouts) and tests for practice. Practical training includes preparation of three projects. Each student works individually, and student qualifies for the final exam after completing at least two of the three projects.

Prerequisites

Attended course in Applied Aerodynamics, or a course in fluid mechanics which provides satisfactory background knowledge (with professor’s approval).

Learning resources

The students have access to the virtual classroom on the Internet. At the first lecture students

are enrolled and trained for work (Moodle software). In the workshops students have access to the lectures and exercises, guidelines for project preparation, internet resources, etc.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

I. Kostić, O. Kostić: High Speed Aerodynamics, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade 2023.
R. T. Jones: High Speed Wing Theory, Princeton University press, 1999.
H. Ashley: Aerodynamics of Wings and Bodies, McGraw Hill, 1995.

Project Management & Air Regulation

ID: 1474
Responsible/Holder professor NEBOJŠA B. PETROVIĆ
Teaching profesor(s): PETROVIĆ NEBOJŠA; DAVIDOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: aerospace engineering

Goals

Course objective

- Understanding the importance of project management in aviation.
- The creation, introduction and use of aviation projects.
- Determining the functionality of your own projects.
- Preparation, analysis and project management.
- Understanding and preparing the necessary documents for the implementation of projects.

Learning outcomes

The acquired knowledge enables the student to:
- Prepare, create and show their own skills,
- Determine the functionality of the aviation project,
- Prepare, perform and manage the development of the aviation project,
- Determine technology of designing an aviation project,
- Recognize the requirements of the local aviation industry in projects,
- Make the necessary documentation of aviation project,
- Implement and collect aviation project.

Theoretical teaching

MODERN APPROACHES IN DESIGN (feasibility study, the methodology of improvement, modeling)
Project management (requirements, quality, time, cost, standards)
IMPLEMENTATION OF PROJECTS (initialization, implementation, monitoring and control, cost efficient)
SPECIFICS IN AIRCRAFT DESIGN (strategy in the region; aviation terminology)
WEIGHT AND PERFORMANCE REQUIREMENTS (zones on the aircraft, the speed limit requirements; flight performance)
Aviation law (aviation regulations, certification, airworthiness)
REGULATIONS REGARDING SECURITY (human factors, safety precautions,emergency procedures)
REGULATIONS OF MONITORING AND FLIGHT (planning, defining and tracking the flight operations manual, flight plan revision)
PRACTICAL CONSTRUCTION PROJECT (information gathering, development,simulation of project)

Practical teaching

Parameter identification and selection of software for designing. Determination of technology and pricing of the project. Defining the requirements of aircraft weight and performance. The requirements in terms of technological and structural concepts of the aircraft. Aviation security. Aeronautical terminology. Development of wind rose. Speed limit requirements. Aerodynamic design of aircraft performance and sizing, performance requirements takeoff, landing and the other flight regimes. Category airworthiness of the aircraft. Analysis of air regulations. Application of CAD technology. Define data visualization. Defining the contours of the aircraft. The design of the aircraft. Modeling of aircraft structure. Systematization of documentation. Research on aircraft accidents. Analysis of the project.

Prerequisites

'defined curriculum of study program / modules'

Learning resources

To cope with the case, it is necessary the use of textbooks, manuals for the project, a handout, Internet resources. IT equipment (hardware, CAD workstations, software (CAD, SSO, RRO) pcs. Equipment) ICT, available in the laboratory Aerotechnical Institute).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	6
calculation tasks	0
seminar works	5
project design	15
discussion and workshop	4
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	2
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	30	project design	20
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Aviation Project Management, Triant Flouris and Dennis Lock
Air Law , JAA - Joint Aviation Authorities, Theoretical Training Manual, Oxford, 2004
European Aviation Safety Agency, Certification Specifications for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes CS23, February 2009
Aviation regulations, textbook in preparation, Faculty of Mechanical Engineering, Č. Mitrovic

Rocket Motors

ID: 1383
Responsible/Holder professor NIKOLA S. DAVIDOVIĆ
Teaching profesor(s): DAVIDOVIĆ NIKOLA; IVANOV TONI
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: aerospace engineering

Goals

Introducing students with rocket motor with solid and liquid propellant. Students are introduced with different types of rocket motors, their theoretical basis and performances. Experimental part consists of engine test demonstration and determination of burning velocity of rocket motor with solid propellant.

Learning outcomes

By mastering the curriculum a student gains specific skills:
-knowledge and understanding of rocket motors
-calculation of rocket motor performances
-design of geometry of propellant grain of solid rocket motor

Theoretical teaching

• Area of application of rocket motors
• Types of rocket motors and method of functioning
• Performances of ideal rocket motor
• Processes in combustion chamber and nozzle
• Real performances of rocket motor with solid propellant
•Determination of parametric dependence of burning velocity of rocket motor with solid propellant
• Design methodology of rocket motor with solid propellant
• Selection criteria of pressure in combustion chamber
• Basic shapes of propellant grain
• Internal ballistics of rocket motor with solid propellant
• Determination of analytical expression for heat flux at combustion chamber and nozzle
• Heat transfer and thermal protection
• Physical model of erosive burning
• Rocket engines with liquid propellants (characteristics, design and performances)

Practical teaching

• Area of application of rocket motors
-Analysis of application of jet motors
• Types of rocket motors and method of functioning
-Analysis of chosen world rocket motors
• Performances of ideal rocket motor
-Numerical example of calculation of performances of ideal rocket motor

• Processes in combustion chamber and nozzle
-Numerical example of calculation of processes in combustion chamber and nozzle
• Real performances of rocket motor with solid propellant
-Numerical example of calculation of performances of real rocket motor
•Determination of parametric dependence of burning velocity of rocket motor with solid propellant
-Demonstration of rocket motor with solid propellant test. Analysis of test data and determination of burning rate law.
• Design methodology of rocket motor with solid propellant
-Seminary work: Design of rocket motor with solid propellant
• Selection criteria of pressure in combustion chamber
-Seminary work: Design of rocket motor with solid propellant
• Basic shapes of propellant grain
-Seminary work: Design of rocket motor with solid propellant-choice of geometry of propellant grain
• Internal ballistics of rocket motor with solid propellant
-Seminary work: Design of rocket motor with solid propellant-internal ballistics
• Determination of analytical expression for heat flux at combustion chamber and nozzle
-Seminary work: Design of rocket motor with solid propellant-heat transfer
• Heat transfer and thermal protection
-Seminary work: Design of rocket motor with solid propellant-calculation of nozzle wall temperature
• Physical model of erosive burning
-Seminary work: Design of rocket motor with solid propellant-erosive burning rate

Prerequisites

There are no necessary conditions for attending the subject.

Learning resources

1.Additional materials (lecture hand-writings)
2.Jet Propulsion Laboratory of EDePro company, Belgrade
3.Commercial software for calculation for rocket motor performances

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	10
calculation tasks	5
seminar works	10
project design	0
discussion and workshop	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	20	project design	0
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

В.Е. Алемасов, Дрегалин А.Ф,Theory of Rocket Motors,1980.
Баррер М., Rocket Motors,1962.
Dieter T. Huzel, David H. Huang, Design of Liquid propellant rocket engines,1967.
Фахрутдинов И.Х., Котельников А.В., Construction and design of Solid propellant rocket motors,1987.
Manual for design of Sounding rockets, Part 2, B.Jojic, Dj. Blagojevic, A.Pantovic, V.Milosavljevic,1978.

Skill Praxis M - VAZ

ID: 1216
Responsible/Holder professor ALEKSANDAR Č. BENGIN
Teaching profesor(s): BENGIN ALEKSANDAR; PEKOVIĆ OGNJEN; IVANOV TONI; SVORCAN JELENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: oral
Parent department: aerospace engineering

Goals

Practical experience and stay in environment in which the student will realize his professional career. Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of an mechanical engineer in such a business system.

Learning outcomes

Student gets practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, within the context of his future professional competence. Establish the personal contacts that will be able to use in further education, or entering into future employment.

Theoretical teaching

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Practical teaching

Practical work involves working in organizations that perform various activities related to mechanical engineering. Selection of thematic areas and commercial or research organizations carried out in consultation with the concerned teacher. Generally, a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations concerned with maintaining mechanical equipment, and public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice may also be made abroad. During practice, students must keep a diary in which to enter a description of the tasks performed, the conclusions and observations. Following the practice must make a report to defend the subject teacher. The report is submitted in the form of the paper.

Prerequisites

There aren't any compulsory conditions for course attendance.

Learning resources

Resources available at the place of professional practice.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	90

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 70

References

Bengin A., Mechanical Engineering Praxiss - VAZ, Faculty of Mechanical Engineering, 2022, eBook

Structural Analysis

ID: 0947
Responsible/Holder professor DANILO M. PETRAŠINOVIĆ
Teaching profesor(s): PETRAŠINOVIĆ DANILO; DINULOVIĆ MIRKO; GRBOVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: aerospace engineering

Goals

1. Introduction to problems and modern calculation methods in stress analysis of aircraft structures, as well as their application to solving real problems.
2. Introduction to experimental stress analysis of aircraft structures.
3. Introduction to thin walled structures and composite materials.
4. Introduction to modern computational methods for stress analysis related to airframe structures.

Learning outcomes

1. Mastering basic structural analysis theories.
2. Application of theoretical knowledge to solve practical problems.
3. Understanding the basis of aircraft design process.
4. Understanding modern methods in structural analysis for stress analysis of aircraft structures.

Theoretical teaching

In the theoretical part of this course following topics are presented: Variational principle. Principle of virtual work. Minimum energy principle. Rayleigh-Ritz method. Galerkin Method. Collocation method. Finite element method formulation. Convergence criteria. Finite element formulation for rods and beams. Stiffness matrices and equivalent force matrices. Finite elements for plane stress and plane strain, axial symmetric and volume finite elements. Automatic mesh generation. Finite elements software. Elastic material models. Real structures modeling. Element selection. Mesh density selection.

Practical teaching

Substructure modeling. Substructure interaction. Thermal stresses. Initial deformations. Residual stresses. Non-linear models for constitutive equations. Solution methods. Large deformations and large rotations tensor. Stress tensor formulation for large deformations. Local and global problems in stability analysis. Methods for solving non-linear problems. Results analysis. Adaptive meshes. Structure optimization. Quasi-static and dynamic problems.

In practical part of the course, previous theories are demonstrated in real applications. Numerous problems are analyzed. Practical student work is carried out through mandatory exercises using computers for modeling and analysis. Practical part of the course also includes the visit to the laboratories for static and dynamic experimentation of the VTI

institute.

Prerequisites

Recommended: Theory of elasticity, Structural Analysis of Flying Vehicles

Learning resources

Handouts in e-format, demonstration films and computer simulation, Internet resources, application VAZMFB (https://vazmfb.com).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	0	final exam	40
calculation tasks	10		

Requirements to take the exam (number of points) 40

References

T. Megson, Introduction to Aircraft structural Analysis, Butterworth-Heinemann, 2017.
F. Hartmann, C. Katz, Structural Analysis with Finite Elements, Springer, 2007.
R. D. Cook, D. S. Malkus, M. E. Plesha, R. J. Witt, Concepts and Applications of Finite Element Analysis, Wiley, 2001.

Wind Turbines 2

ID: 1130
Responsible/Holder professor JELENA M. SVORCAN
Teaching profesor(s): SVORCAN JELENA; IVANOV TONI
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: aerospace engineering

Goals

The course provides an overview of key aspects in wind energy engineering as well as design principles of wind turbines. Throughout the course the student will be acquainted in detail with the most fundamental disciplines of wind energy research such as: wind measurements and resource assessment, possible wind turbine designs and their modeling, aerodynamics, structural mechanics, wind turbine manufacturing technology and materials, electrical systems etc, which will be realized through the use of different, simpler analytical, empirical and numerical methods.

Learning outcomes

The student will gain a rational understanding of wind energy engineering and different wind turbine concepts and design methods.
Through hands-on exercises, the student will learn to perform wind energy calculations based on simple models.
Working with the different course disciplines (applied mathematics, programming, CFD, structural mechanics, optimization, manufacturing technologies) will enable the student to identify the most interesting and/or relevant aspects of wind energy engineering to be pursued in his/her future studies or professional career or applied on similar structures (propellers, helicopter rotors).

Theoretical teaching

- Introduction to wind energy
- Wind resources (wind speed variability); Test and measurements
- Wind turbine technology (historical development, different wind turbine designs and components)
- Aerodynamics (fundamental principles and simple computational models)
- Materials; Structural mechanics (blade mass and structure, loads acting on the blade, stress-strain analysis)
- Wind turbine blade optimization
- Mechanical drive train and nacelle; Electrical system (power transmission, integration of the very variable power production with the electrical grid, rotor speed control)
- Blade manufacturing
- Additional topics: Support structure design, Vibration problems, Offshore wind energy engineering, Wind turbine aeroelasticity, Blade testing, Wind turbine economics

Practical teaching

- Introduction to variable wind speed profiles modeling; Measuring equipment
- CAD of basic wind turbine components (including various types of wind turbines)
- Blade design (computation of fluid flow around the blade)
- Thrust and power calculations of wind turbines (by writing and using numerical codes)
- Overview and definition of blade structure and materials
- Wind turbine blade stress-strain analysis
- Wind turbine blade optimization
- Manufacturing blade model or segment and/or blade mould
- Blade testing (static and/or dynamic)

Prerequisites

There are no mandatory conditions/prerequisites for course attendance.

Learning resources

Classroom, projector, computer (laptop), computational software tools, CNC mill, 3D printer, measuring equipment.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	15	project design	0
laboratory exercises	15	final exam	35
calculation tasks	15		

Requirements to take the exam (number of points) 30

References

Hau E, Wind Turbines - Fundamentals, Technologies, Application, Economics, 2nd ed., Springer-Verlag, Berlin Heidelberg, 2006.
Manwell J.F., McGowan J.G., Rogers A.L., Wind Energy Explained - Theory, Design and

Application, John Wiley & Sons, Chichester, 2002.
Pešić S. Wind energy - Aerodynamics of wind energy systems with horizontal axis of rotor (in Serbian), Faculty of Mechanical Engineering, Belgrade, 1994.
Petrović Z, Stupar S, Fundamental Equations of Aerodynamics, Faculty of Mechanical Engineering, Belgrade, 1997.
Additional materials (handouts, exercises and instructions for their solution), 2022.

AGRICULTURAL ENGINEERING

Design of agricultur machines and equipment

Design of plants and process and energy systems

Drying process techniques and technologies

Geoinformation and remote control of biotechnic systems

Microclimate management in agricultural and industrial facilities

Plant design for food production and processing

Skill Praxis M - PPM

Tractors and self-propelled agricultural machinery

Design of agricultur machines and equipment

ID: 1243
Responsible/Holder professor VOJISLAV D. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ VOJISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: agricultural engineering

Goals

1. Achieving competence and academic knowledge relating to agricultural machinery and equipment. 2. Mastery of specific and practical skills for carrying out of agricultural machines and equipment. 3. Findings to a multidisciplinary approach to achieve optimal results in the design of agricultural machines and equipment.

Learning outcomes

After successful completion of this course, studenty should be able to:
• Define the project management plan,
• Define the forces and moments that are plaguing the machines,
• Calculation of pressure and dynamic load of agricultural machinery and equipment,
• master the methods and processes of agricultural machines and equipment,
• Estimates of the outcomes of the project in relation to the initial request,
• Be efficient in teamwork.

Theoretical teaching

1. Technical and economic requirements in the design of agricultural machines and equipment. 2. The theory of cutting tillage. 3. The forces acting on the plugging of the body. The stability of the plow. 4. The main parameters of working elements and machines for additional processing of land. Design of machinery with an active working elements. Disc machines with working elements. Conceptions of cultivators, harrows and rollers. The main parameters and design machines to perform several tasks in one pass. 5. Characteristics and design of machinery for fertilizing, seeding and planting. 6. Machines for chemical pesticides and irrigation equipment. 7. Designing machines to harvest the yields.

Practical teaching

1. Auditory exercise: a review of contemporary solutions of agricultural machinery for soil preparation. Displaying solutions machine fertilizing, seeding, planting, plant protection and irrigation. Displaying solutions for machine sorting of agricultural crops: forage, grains, yields of root and tubers, vegetables and fruits. 2. Development of the project: The project in the field of agricultural machinery and equipment. Determination of basic parameters. Budget, schedule and technical documentation. 3. Development of arithmetic problems: The task of designing working surface plow body. The task in the field of cutting device. The task in the field of combine harvester. 4. Laboratory Exercise: Profiling working surface plow body.

Prerequisites

Passed exams in 7 semesters (defined curriculum study program/ module) and passed items 1.1.5, 1.2.5 of the module IBS

Learning resources

1.Veljić M.: Technological processes of mechanized agriculture, MF, Belgrade, 1997.
2. Laboratory installation for profiling working surface plow body, instructions.
3. Veljić M., Written lectures, Belgrade, 2008.
4. Veljić, M.: Instructions for making assignments for the design of the working surface plow body.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	4
calculation tasks	6
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	10	project design	30
laboratory exercises	10	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 10

References

Gligoric R., Mechanisms of agricultural machinery with the settlement tasks, PF, Novi Sad, 2005.
Veljić M., Viewing construction of agricultural machinery, MF, Belgrade, 1992.
Urosevic M., Machinery and apparatus for the application of pesticides, PF, Belgrade, 2001.
Martinov M., Markovic D., Machinery and tools for soil cultivation, the first part, FTN, Novi Sad, 2002.

Design of plants and process and energy systems

ID: 1367
Responsible/Holder professor IVAN J. ZLATANOVIĆ
Teaching profesor(s): ZLATANOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: agricultural engineering

Goals

This course aims to provide students with the necessary knowledge and skills for designing and optimizing facilities and processes in the food production and processing industry. Throughout this course, students should familiarize themselves with various aspects of system design, including production technologies, energy management, quality control, and food safety. By the end of the course, students should be capable of applying the acquired knowledge to solving real-world problems in the field of food production and processing, thus contributing to the improvement and efficiency of these processes in the industry.

Learning outcomes

Upon successful completion of this course, students should be able to:
• Understand the basic principles of designing plants and process systems.
• Analyze and evaluate various energy systems in the context of their efficiency and economic viability.
• Prepare students to solve project tasks related to designing different plants and systems.
• Apply engineering standards and regulations in the process of designing.
• Develop teamwork skills through collaborative work on projects.
• Understand the impact of system design on the environment and sustainability.
• Apply mathematical methods and simulations in the design process.
• Develop critical thinking through the analysis of various design alternatives and their consequences.
• Improve communication skills through the expression and presentation of design solutions.
• Prepare students for a career in the field of design and engineering in energy.

Theoretical teaching

1. Basic principles of design;
2. Design of process systems of facilities with protected space: Initial data and project structure. Selection of calculation parameters of outdoor and indoor air. Description of the design object. Thermotechnical calculation and calculation and selection of basic equipment;
3. Design of process systems for livestock and poultry facilities;
4. Design of process systems for storage of materials and products in the food industry (fruits, vegetables, etc.) Structure of storage space. Heat balance and moisture transfer calculation in the warehouse. Ventilation system design;
5. Design of drying devices and plants;
6. Design of energy plants for the use of biogas and biomass;
7. Design of energy systems for the use of solar energy, wind energy, geothermal energy;

8. Design of process systems in the food industry.

Practical teaching

Practical classes: Seminar paper is given from some of the above theoretical units in order to acquaint students with existing solutions, their characteristics and monitoring achievements in the field covered by the course program. Laboratory exercise: Determining the hovering speed of different materials (depending on the type, shape, dimensions, humidity, etc.). Calculations are made in order to define and dimension the characteristic solutions from some of the theoretical units. A project is being prepared with a study depending on the selected theoretical unit, which is a continuation of the calculation tasks. Projects include the choice of plant concept and process and energy systems, the calculation and dimensioning of components and the corresponding drawings..

Prerequisites

Defined by the study program/module curriculum.

Learning resources

The Laboratory for Agricultural Machinery and Facilities possesses many physical models and prototypes used for educational purposes, as well as a computer center where various workstations are equipped with software for modeling processes and phenomena in agricultural and industrial facilities.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	25
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	20
laboratory exercises	20	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Топић, Р.: Пројектовање постројења и процесних и енергетских система, Машински факултет у Београду, 2013.
Roberts T.C.: Food plant engineering systems, CRC Press, 2002.
Stavros Yanniotis: Solving problems in food engineering, Springer, 2008.
Arun S. Mujumdar: Handbook of industrial drying, 3rd. ed., CRC Press, 2006.
Philip Richardson: Thermal technologies in food processing, CRC Press, 2001.

Drying process techniques and technologies

ID: 1413
Responsible/Holder professor IVAN J. ZLATANOVIĆ
Teaching profesor(s): ZLATANOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: agricultural engineering

Goals

This course provides an in-depth understanding of the various techniques and technologies involved in food drying processes. The course covers the principles and fundamentals of food drying, equipment and facilities for drying, drying methods and techniques, and the quality control of dried foods. The course also covers the application of drying in different food industries, including meat, fruits, vegetables, and grains.

Learning outcomes

Practical and theoretical knowledge of how to choose the appropriate method of drying agricultural and food materials.
Upon successful completion of this course, students should be able to:
• answers to technological requirements for drying agricultural and food materials,
• select the appropriate drying method,
• calculate the required capacities and sizes of importance for the selection of basic components of the dryer,
• independently design the dryer based on the given input parameters of the process.

Theoretical teaching

1. Drying theory (statics, kinetics, and dynamics of drying);
2. Methods of drying agricultural and food materials which imply the existence of the flow of hot agent through the material and the removal of water from its surface:
2.1. drying of a fixed layer of material (- chamber dryer, - conveyor dryer, - tunnel dryer.)
2.2. drying of the material in the moving bed (- shaft dryer, - rotary dryer, - fluidized bed dryer, - pneumatic dryer.)
3. Methods of drying slurry, puree, powder, and dehydrated flakes (- material spray dryer, - drum dryer.)
4. Drying methods that overcome the problems of structural damage and minimize the loss of taste and aroma (- lyophilization dryer, - dryer with osmotic dehydration.)
5. Drying methods used by modern technologies in order to achieve high quality of the dried product (- solar dryer, - dryer with integrated heat pump, - dryer with microwave and dielectric heating, - dryer with infrared heating, - jet dryer, - extrusion dryer, - ultrasonic vibration dryer, - Refractance Window dryer, - hybrid dryer.)

Practical teaching

Development of an independent dryer project based on the defined project task and technological requirements, calculation of heat and mass load and required capacities of

devices and equipment.

Prerequisites

Defined by the curriculum of the study program / module.

Learning resources

The Laboratory for Agricultural Machinery and Plants has a section specializing in measurements in the field of drying, as well as appropriate measuring equipment, models, models and exhibits. Also, the computer center of the laboratory has the resources necessary for data analysis and work on modeling processes and phenomena. Students are provided with an example of completed projects and seminar papers, various instructions, and standards.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	30
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	40
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Златановић И. Сушење у биотехничким системима, Машински факултет, 2022. (доступно у библиотеци Машинског факултета)
Топић, Р.: Специјалне технике и технологије процеса сушења, Машински факултет у Београду, 2013.
Лыков В. А., (1950), Теория сушки," Государственное энергетическое издательство", Москва - Ленинград.
Arun S. Mujumdar: Handbook of industrial drying, 3rd. ed., CRC Press, 2006.

Xiao Dong Chen, Arun S. Mujumdar: Drying Technologies in Food Processing, Blackwell publishing, 2008.

Geoinformation and remote control of biotechnic systems

ID: 1244
Responsible/Holder professor VOJISLAV D. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ VOJISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: agricultural engineering

Goals

1. Master the theoretical foundations of measurement and automation of agricultural machines and equipment; 2. Principles of measurement, sensors and methods of measurement non-electrical quantities on agricultural machines and equipment; 3. Automation of tractors and machines; 4. Automation combines: automatic control, regulation of technological devices, measurement and regulation of losses, monitoring, 5. Management in precision agriculture and food processing industry. 6. Monitoring of dinamic machines and proceses in real time

Learning outcomes

After successful completion of this course, studenty should be able to:
• Identify the different components of the automation system biotechnical,
• Define procedures for precision farming,
• Interpret hydraulic and pneumatic scheme of agricultural machinery,
• Projected guidance direction of agricultural machinery,
• Organize a complete cycle of precision farming,
• Communicate effectively in a multidisciplinary team.

Theoretical teaching

1. Introductory discussion of theoretical bases and methods of measurement and automation of agricultural machines and equipment: navigation leveling measurements, measuring distance (distance, measuring the number of revolutions and torque measuring yield loss measurement, the measurement of quantity and measurement of other parameters; 2 Principles of measurement, sensors , division, operating principles, static and dynamic characteristics, a method of measuring non-electrical quantities on agricultural machines and equipment, can bus system; third Automation tractors and machinery: automatic control of loading, automatic control of connection devices and machines on the tractor, the tractor can bus , automatic control and information systems; 4 combines automation: automatic control of the direction, regulation of the position Header, perform separation and other technological devices (automatic leveling), measurement and regulation of losses, monitoring of combine harvesters; fifth management in precision agriculture GPS and DGPS and automation systems and production lines in food processing industry.

Practical teaching

Laboratory exercises:
1. Measurements of the kinematic characteristics of agricultural machinery and equipment;

2. Measurement of energy parameters of agricultural machinery and equipment.
Seminar work at the choice of candidates in the field:
1. Automation of tractors and attachments of agricultural machinery and equipment;
2. Automation of universal self-propelled grain harvesters;
3. Automation of self-propelled combine harvesters for vegetables and industrial crops;
4. Automation of equipment and technological lines for food processing;
5. Application of GPS and DGPS in Precision Farming.

Prerequisites

Attended courses of previous years of study and all the conditions defined curriculum of study program / module

Learning resources

1. Markovic D.: Automation in agriculture, written lectures and lectures in electronic form, Belgrade, 2007.
2. Markovic D.: Transport in Agriculture, Belgrade, 1997.
3. Automation and measurement of agricultural machinery-handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	0
laboratory exercises	20	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 50

References

Martinov M., My tractor, Res trade, Novi Sad, 2007.
Zivanovic Z., N Janićijević., Automatic transmission vehicles, Belgrade, 2000.

Ribar Z., Control systems, MF in Belgrade, Belgrade 2008.
Bolton W., Instrumentation control systems, EUSEVIER SCIENCE & TEHNOLOGY BOOKS, 2004.
Popovic M., Sensors and measurements, Department of textbooks and teaching aids, Srpsko Sarajevo, 2004.

Microclimate management in agricultural and industrial facilities

ID: 1412
Responsible/Holder professor IVAN J. ZLATANOVIĆ
Teaching profesor(s): ZLATANOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: agricultural engineering

Goals

The aim of the subject "Microclimate Management in Agricultural and Industrial Facilities" in the Master's degree program at the Faculty of Mechanical Engineering is to provide students with a deep understanding of concepts and the application of methods for managing microclimates in various agricultural and industrial facilities. Through this subject, students are expected to acquire knowledge of methods for determining thermal and mass loads of objects, familiarity with measurement techniques and methods for monitoring environmental parameters, fundamentals of calculating required capacities of devices and systems to achieve desired microclimate parameters in agricultural facilities. By the end of the subject, students should be able to design, optimize, and manage microclimates in agricultural and industrial facilities in accordance with the latest standards and best

Learning outcomes

Practical and theoretical knowledge about the processes necessary for organizing and implementing environmental parameter control and the basis of device and control-regulatory systems. Upon successful completion of this course, students should be able to:
• Recognize and understand the key factors influencing microclimate, including temperature, humidity, lighting, and ventilation.
• Apply theoretical knowledge of microclimate management in specific agricultural and industrial facilities, aiming to optimize conditions for plants, animals, or workers.
• Identify potential risks associated with microclimatic conditions and develop strategies for managing them to minimize negative impacts on production, health, and safety.
• Utilize the latest technological innovations in microclimate management, such as automated systems for temperature and humidity control, air quality monitoring sensors, and other advanced tools.
• Apply principles of sustainable development in the planning and implementation of microclimate control systems.
• Effectively communicate and collaborate with various experts in agriculture, industry, engineering, and other relevant disciplines to achieve optimal results in microclimate management.

Theoretical teaching

1. Industrial and commercial production plants and premises (identification of heat and mass sources that significantly affect the ambient conditions, determination of their dissipation in the controlled area, devices and equipment for accepting targeted sources of contamination);
2. Storage of food materials (fruits, vegetables, etc.) and agricultural materials (biomass,

wood, etc.) and finished products (packaged food, wine cellars, etc.) (storage of materials and products in the food industry, storage space structure, heat balance and calculation of moisture and contaminant transfer in the warehouse);
3. Facilities with protected space (calculation and selection of basic equipment for microclimate control in protected space facilities);
4. Facilities in livestock and poultry (defining microclimatic and spatial conditions for animal husbandry, identification of contaminants, calculation of devices and equipment).

Practical teaching

1. Practical classes: Preparation of seminar papers from the above theoretical units in order to get acquainted with conventional and modern systems for achieving specific environmental conditions in different agricultural facilities;
2. Calculation tasks: Calculations of heat and mass loads, and required capacities of devices and equipment.

Prerequisites

Defined by the curriculum of the study program / module.

Learning resources

The Laboratory for Agricultural Machinery and Plants has a large number of physical models and mock-ups used for teaching purposes, as well as a computer center where software for modeling processes and phenomena in agricultural and industrial facilities can be used in several work positions. Also, measuring and regular equipment of the portable type is available, which is used to monitor the change of microclimatic parameters in the protected area.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	30
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	40
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Nils R. Grimm, Robert C. Rosaler. HVAC SYSTEMS AND COMPONENTS HANDBOOK. MCGRAW-HILL 1997.
Roberts T.C.: Food plant engineering systems, CRC Press, 2002.
Stavros Yanniotis: Solving problems in food engineering, Springer, 2008.
Walter T Grondzik. Air-Conditioning Systems Design Manual. Elsevier, 2007
Philip Richardson: Thermal technologies in food processing, CRC Press, 2001.

Plant design for food production and processing

ID: 1456
Responsible/Holder professor VOJISLAV D. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ VOJISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: agricultural engineering

Goals

1. Master the theoretical foundations of the design of machinery, equipment and technological lines for manufacturing and food processing; 2 Getting to know your limitations and the specific production lines and food processing; 3 Introduction to the principles of the design of machinery and equipment manufacturing and food processing; 4 Acquire practical skills in analyzing the set of engineering problems and its solving multidisciplinary approach.

Learning outcomes

After successful completion of this course, studenty should be able to:
• Define the project management plan,
• Describe the production technology and food processing,
• Select the appropriate machinery and equipment for the design of complete lines and factories for processing agricultural products,
• Design complete line and / or factory for the production, processing and storage of agricultural products,
• Estimates of the outcomes of the project in relation to the initial request,
• Estimates energy required for food processing,
• Be efficient in teamwork,
• Estimates of economic analysis,
• Preparing and exposing projects to potential investors.

Theoretical teaching

1) Engineering in food production and processing - the basic parameters, symbols and standards, machinery and equipment and their connection in the technological process, 2) materials for the food and biotechnology - classification, characteristics and behavior of materials, structures, materials, material selection, 3) Transportation systems and pipelines, support structure and joints, 4) Transport pathways in the house - people, raw materials, by-products, finished goods, packaging, waste, energy, transport vehicles, 5) Material - energy balances and 6) optimization of equipment and resources; 7) The requirements of food production - standards and regulations relating to machinery, equipment and facilities, and 8) Project documentation - conceptual design, machine design, other projects of interest, 9) The share of engineers in the lifetime of the building - from concept to commissioning plants in operation.

Practical teaching

Seminars
1. Analysis and calculation capacity lines for manufacturing and food processing: technological line for production and fruit processing, production lines for manufacturing and processing of vegetable preservation, technological lines for production and meat processing, dairy, grains and seeds,...). Defining the layout of machinery and equipment, analysis of the balance of materials, raw materials, fuels and fluids and transport routes.
Project
Development of conceptual design complete production lines for manufacturing and food processing by choosing from the topics listed in the essays.

Prerequisites

Attended courses of previous years of study and all the conditions defined curriculum of study program / module

Learning resources

1. CIGR-HANDBOOK Agricultural Engineering, Agro Processing Engineering, ASAE, USA, 1999.
2. Srivastava KA, Goering EC, Rohrbach PR: Engineering Principles of Agricultural Machines, ASAE, USA, 1993.
3. Markovic D.: Written lectures, Belgrade, 2007.
4. Example of a project.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	10
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	7
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	0	project design	50
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Zlatković B. . The technology of processing and storage of fruit., published by University of Belgrade, Faculty of Agriculture 2002nd
Moser E.:Verfahrenstechnik Intensivkulturen,Verlag Paul Parey,Univerzitet Hohenhein,2005.,Nemacka
Karel M., Lund D. B., Physical principles of food preservation, Marcel Dekker inc., New York, 2003.
Heldman D. R., Handbook of food engineering, Taylor & Franncis Group, New York, 2007.
M. Veres. Basics of food preservation, Belgrade, 2004.

Skill Praxis M - PPM

ID: 1530
Responsible/Holder professor VOJISLAV D. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ VOJISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: agricultural engineering

Goals

Practical experience and stay in the student environment in which the student will realize his professional career.
Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineering in such a business system.

Learning outcomes

Students get practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, in the context of his future professional competence. Establish the personal contacts and poznastva that will be able to use at school or entering into future employment.

Theoretical teaching

Selected topics through practical activities.

Practical teaching

Practical work podrazumva work in organizations that perform various activities in connection with mechanical engineering. Selection of thematic areas and commercial or research organizations carried out in consultation with the concerned teacher. Generally a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations engaged in mechanical equipment maintenance, and public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice may also be made abroad. During practice, students must keep a diary in which to enter a description of the tasks performed, the conclusions and observations. Following the practice must make a report to defend the subject teacher. The report is submitted in the form of the paper.

Prerequisites

Students of modul PPM

Learning resources

Laboratory and IT equipment

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	90

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	0	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Markovic D.: Transport in Agriculture, Belgrade, 1997.

Tractors and self-propelled agricultural machinery

ID: 1411
Responsible/Holder professor VOJISLAV D. SIMONOVIĆ
Teaching profesor(s): SIMONOVIĆ VOJISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: agricultural engineering

Goals

1. Mastering the theoretical foundations of propulsion machines - tractors and self-propelled agricultural machines - combines;
2. Concepts and constructions of agricultural tractors, motor cultivators and self-propelled chassis;
3. Transmission and connection systems for working machines and aggregates;
4. Concepts of simultaneous power transmission via drive wheels and PTO shafts, energy balance;
5. Theory of work, conception and construction of the combine, calculations of the movement of the moving part and technological devices of the combine.

Learning outcomes

1. Basic knowledge in the field of theory of work, conception and construction of driving machines - tractors, cultivators and self-propelled chassis and universal self-propelled combines;
2. Analysis of mechanical, hydrostatic and combined transmissions of agricultural tractors, self-propelled chassis and universal self-propelled combines;
3. Application of computers in calculations of plants and technological devices;
4. Connecting basic engineering knowledge and achieving a synergistic effect;
5. Acquisition of practical skills and application in practice.
Upon successful completion of this course, students should be able to:
• Manage the procurement of tractors with adequate characteristics according to the available agricultural machinery that the tractor aggregates,
• Organize and conduct operation and maintenance of tractors and self-propelled agricultural machines,
• Performs and applies solutions of various concepts of tractors and self-propelled chassis,
• Make plans for testing tractors,
• Determine, formulate and control the ergonomic conditions of the operator.

Theoretical teaching

1. Introductory considerations, theory of work, concepts and constructions of driving machines - agricultural tractors, motor cultivators and self-propelled chassis;
2. Concepts of transmissions and energy balance of simultaneous power transmission via drive wheels and PTO shafts;
3. Concepts, devices and systems for connection and formation of aggregates tractor - working agricultural machines;

4. Constructions and theories of operation of universal self-propelled combines;
5. Calculations of technological devices of combine harvesters;
6. Concepts of moving part drive, hydrostatic power transmission, selection of components and calculation of hydrostatic moving part drive and technological devices of the combine.

Practical teaching

1.Laboratory exercises:
1.1. Practical introduction to technical solutions of tractor, motor cultivator and self-propelled chassis assemblies;
1.2. Practical introduction to technical solutions of assemblies and technological devices of the combine.
2. Calculation tasks:
2.1. Development of computer tasks using computers and modern software packages in the field of tractors;
2.2. Creation of calculation tasks using computers and modern software packages in the field of universal self-propelled combines.
3. Project development:
3.1. Preliminary design in the field of tractors and self-propelled chassis;
3.2. Preliminary design in the field of universal self-propelled harvesters.

Prerequisites

Only for students IBS modul.

Learning resources

Lectures in electronic form, slides from lectures (handouts), instructions for laboratory exercises, assignments, instructions for drafting projects, laws, standards and regulations for tractors and self-propelled harvesters.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	10
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	20
laboratory exercises	20	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

Мартинов М., Мој трактор, Рес траде, Нови Сад 2007.
Живановић З., Јанићијевић Н., Аутоматске трансмисије моторних возила, Београд, 2000.

BIOMEDICAL ENGINEERING

Clinical Engineering

Early Diagnostics

Fractal mechanics

Information Technologies in Medicine

Introduction to nanotechnology

Nanomedical Engineering

Nanotechnology

Signal Processing

Skill Praxis M - BMI

Spectroscopy methods and techniques

Clinical Engineering

ID: 1283
Responsible/Holder professor LIDIJA R. MATIJA
Teaching profesor(s): MATIJA LIDIJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

To enable practical implementation, in real life clinical conditions, of theoretical knowledge and R&D results in the field of biomedical technology. To provide students with adequate medical knowledge to work in clinical environment. Enabling future clinical engineers to be a part of medical team and participate in every phase of clinical activities, such as: device initialization, adequate device application, device functions in vivo testing, monitoring of medical device or system performance, protection of patients and medical stuff from potential hazards in application of certain technologies, etc.
Introduction to design and maintenance of medical equipment (chirurgical tables, beds, chairs, etc.).
Give a history of medical devices and technologies development with respect to related branches of medicine. Getting to know medical reasons behind the development of certain devices. Overview of medical device classification based on the role they play in the hospitalization process. General introduction to medical device maintenance. Introduction to legislation regarding medical device design and maintenance. Basics of medical device design. Introduction to ARM microcontrollers for biomedical application. Making students capable to design medical devices based on STM 32, ARM, microcontrollers.

Learning outcomes

Upon successful completion of this course, students will be able to:

•Apply gamma camera, PET and ultrasound in medicine
•Perform surface electrical stimulation of small intensity and aactivation of afferent system - artificial perception (in the laboratory)
•Perform measurements of evoked potentials induced by transcranial magnetic stimulation and measurement of temperature distribution (in the laboratory).
•Prepare all necessary documents for obtaining ethical permission for clinical work
•Prepare all necessary documents for obtaining a license to use a new instrument in the clinic.
•Distinguish and define the basic principles of diagnostic devices (biochemical analyzer - ECG - Rò device)
•Develop applications for the STM32 microcontroller for adequately defined applications

Theoretical teaching

Good practices regarding work in clinical environment. Ethics, standards and IT. Concept and basic characteristics of medical device. Medical device vs medical equipment. History of medical devices development. Connection between advances in science and development of

biomedical apparatus. Medical device classification. Hospitalization and associated medical instrumentation.
Medical imaging – clinical applications (benefits, protection and potential hazards). DICOM standard. Electrical and magnetic stimulation - clinical applications; influence of electrical and magnetic field at a cellular level (benefits, protection and potential hazards). Clinical applications of laser.
Maintenance definition. Legislation regarding medical device and equipment maintenance. Maintenance organization and planning.Overview of different approaches to maintenance. Precautions regarding medical device maintenance. Adequate working environment and prerequisites for medical device maintenance. Maintenance of various devices and equipment.
Process and design stages of a medical device from an idea to a final product . Literature review: patent survey, marketing survey, setting up the requirements of the application, properties of the components of the device studied. Influence of regulatory aspects to medical device R&D chain. Setting up the schedule, work flow and budget for the project.
Introduction to microprocessors, microcontrollers and embedded systems. ARM microcontrollers architecture. Possible applications of microcontrollers in biomedical devices. Acquisition and processing of biomedical signals using microcontrollers and adequate peripherals. Microcontroller programming using C. Program debugging.

Practical teaching

Application of gamma camera and PET (at the Clinical Center of Serbia). Ultrasound applications in medicine (at the MMA). Low intensity surface electrical stimulation. Activation of afferent systems - artificial perception (in the laboratory). Measurement of evoked potentials induced by transcranial magnetic stimulation (of Neurology CCS). Measurement of temperature distribution (in the laboratory). Group exercises - projects:
1.Preparation of material for obtaining ethical permission for clinical work and
2.Preparation of material for obtaining a license to use a new clinical equipment/device.

Basics of operation and maintenance of a variety of devices at the Institute for Cardiovascular Diseases "Dedinje":
Diagnostic devices:
- Biochemical analyzer
- ECG
- Rồ aparatus
Medical intervention devices:
- An electro-scalpel
- Anesthesia machine
Devices for patient care:
- Respirator
- Monitor
- Syringe pump
Auxiliary devices, therapeutic devices and medical devices in general.
Application development for the STM32 microcontroller for the usage of triaxial accelerometer for acceleration monitoring of the individual body parts in various movements. Developing applications for the STM32 microcontroller for the usage of DS1820 temperature sensor for monitoring body temperature of a patient. Development of simple BAN (Body Area Network).

Prerequisites

Attending requirements are defined by the curriculum of the study program/module.

Learning resources

1. Written course material (handouts).
2. Printed manuals.
3. DAQ hardware.
4. Personal computers with installed data acquisition and processing software: LabView and MATLAB.
5. Four mikroACQ Kit 3 - STM32 ARM kits with adequate peripherals.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	10
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	3
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	45	project design	20
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Barbara L. ChristeI: Introduction to Biomedical Instrumentation. Cambridge University Press, 2009.
Bronzino, J.D. (Ed.): The Biomedical Engineering Handbook, 2. ed. CRC Press, 2000.
Myer Kutz (Ed.): Biomedical Engineering and Design Handbook, 2. ed. McGraw-Hill, 2009.
I. Hut, B. Jeftic: MATLAB i Microsoft Office za inženjere (autorizovane skripte), 2022.
E. White: Making Embedded Systems. O´REILLY MEDIA, 2011.

Early Diagnostics

ID: 1342
Responsible/Holder professor BRANISLAVA D. JEFTIĆ
Teaching profesor(s): JEFTIĆ BRANISLAVA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

The goal of this course is to introduce students to the molecular mechanisms of cancer development and existing methods for early diagnostics. Through critical approach to existing methods, and mastering the latest noninvasive or minimally invasive methods for early detection of cancer, student is enabled to take part in modern scientific research and development of new diagnostic methods, as well as application and improvement of existing methods in biomedical practice.

Learning outcomes

Upon successful completion of this course, students shall be able to:

•Understand principles of medical diagnostic devices
•Understand methods of medical image forming across various medical imaging modalities
•Perform measurements using Optomagnetic imaging spectroscopy in the early diagnostics of cancer
•Propose and define the appropriate hardware and software solutions for existing devices for early diagnostics in terms of improvement
•To write and present scientific work in accordance with the standards of professional quality

Theoretical teaching

Introduction to cancer research: risk factors, structural, energy and informational differences between normal and cancer cell. Genetics and biochemistry of cancer. Cell cycles: chromosomes and chromosome duplication. Spindle apparatus. Regulatory mechanisms. Cell cycles in healthy and cancer cells. Molecular basics of cancer: tumor markers, mechanism of action. Types and suitable choice of marker for diagnostic procedure. Demonstrating clinical value of a diagnostic test. Sensitivity and specificity. Existing methods, techniques, and tools for diagnostics. Methods of medical image forming across various medical imaging modalities: X-ray, Computerized Tomography, Magnetic Resonance Imaging, Medical Ultrasonography, Nuclear Medicine. Medical image processing for cancer diagnostics: traditional approach and artificial intelligence methods. Optomagnetic imaging spectroscopy application in early diagnostics of cancer (cervical cancer, colorectal cancer, oral cavity cancer and melanoma).

Practical teaching

1. Instructions for acquiring scientific literature, instructions on methodology for scientific research.

2. Image processing and analysis in MATLAB
3. Laboratory work: optomagnetic spectroscopy in early detection of cervical cancer (smear test). Comparison with PAP test.

Prerequisites

Defined by the curriculum of study module Biomedical Engineering.

Learning resources

1. Written course material (handouts)
2. MATLAB
3. Optomagnetic imaging spectroscopy device - instruments available in the laboratory of Biomedical Engineering department – Nanolab

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	18
laboratory exercises	6
calculation tasks	0
seminar works	0
project design	6
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	20
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

M. Papić-Obradović, Early diagnostics of epithelial cancer detection, Don Vas, Belgrade, 2012, , ISBN: 978-86-87471-24-5 (in Serbian)
L. Popović Maneski, B. Jeftić, N. Malešević, Signals and Systems in Rehabilitation, 2nd edition, Akademska Misao, Belgrade 2019, ISBN: 978-86-7466-794-1 (in Serbian)
Dj. Koruga, A. Tomić, System and Method for Analysis of Light-matter Interaction Based on

Spectral Convolution, US Patent Pub. No.: 2009/0245603, Pub. Date: Oct. 1, 2009
J. Mendelsohn, J.W. Gray, P.M. Howley, M.A. Israel, C.B. Thompson, The molecular basis of cancer, Elsevier, 2015, ISBN: 978-1-4557-4066-6
J.T. Bushberg, J.A. Seibert, E.M. Leidholdt, J.M. Boone, The Essential Physics of Medical Imaging, Lippincott Williams & Wilkins, USA, 2012, ISBN 978-0-7817-8057-5

Fractal mechanics

ID: 1278
Responsible/Holder professor LIDIJA R. MATIJA
Teaching profesor(s): MATIJA LIDIJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

The goal of this subject is to teach a student to apply fractal and multi-fractal system theory in a field of biomedical engineering; to learn to use mathematical apparatus of fractal analysis and modelling; to master fractal image processing and fractal signal analysis; to learn to define diagnostic parameters, algorithms and instruments for determining functional conditions of organs and organism (normal conditions and pathological conditions).

Learning outcomes

Upon successful completion of this course, students will be able to:

•Assess whether the objects have fractal properties and describe the fractal behavior of the systems by properly chosen method of fractal analysis
•Create fractal algorithms for image analysis and signal analysis
•Perform calculation of the fractal dimension using modern methods
•Define diagnostic parameters for determining the functional states of tissues, organs and organism based on fractal dimension

Theoretical teaching

Fundamentals of classic and quantum physics. Fundamentals of classical and quantum information. Cantor's diad-triad set. Laws of big numbers. Deterministic chaos. Mathematical basis of fractal and multifractal theory. Fractals and fractal dimensions. Fractal analysis of signals and images. Applications of fractal analysis in biomedical engineering. Applications of fractal analysis in cancer diagnostics. Applications of fractal analysis in mechanical engineering.

Practical teaching

Fractal dimension and lacunarity calculus for mathematically generated fractal object. Fractal dimension and lacunarity calculus applications for medical images of skin lesions.

Prerequisites

Defined by the study curriculum of Biomedical engineering module learning resources

Learning resources

Koruga,Dj., Matija, L., Munćan, J., Written course material (handouts)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	6
calculation tasks	2
seminar works	4
project design	2
discussion and workshop	2
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	6
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Коруга, Ђ.,Фрактална механика: Класично-квантни феномени у природи, биологији и инжењерству, DonVas, Београд, 2013
Brown, C., & Liebovitch, L. (2010). Fractal analysis (Vol. 165). Sage.
Manddelbrot, B.B., The Fractal geometry of nature, W.H.Freeman and Co., New York, 1983
Rangayyan, R. M. (2004). Biomedical image analysis. CRC press.
Nonnenmacher, T. F., Losa, G. A., & Weibel, E. R. (Eds.). (2013). Fractals in biology and medicine. Birkhäuser.

Information Technologies in Medicine

ID: 1344
Responsible/Holder professor BRANISLAVA D. JEFTIĆ
Teaching profesor(s): JEFTIĆ BRANISLAVA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

Introducing students with fundamental principles of applied information technologies in medicine, with a goal of examining the important characteristics of implementations of new technologies in medicine. Simulation of realistic problems and specific requirements for implementation of logical structures in hospitals, telediagnostics, national and global healthcare information systems.

Learning outcomes

Upon successful completion of this course, students shall be able to:
•Distinguish different branches of software engineering, as well as to differentiate which part of the Information System covers which branch of software engineering
•Define the specifics of medical information systems and ways of their design
•Apply the acquired knowledge to create models of simple and medium complexity of medical information systems
•Adequately analyze the requirements for the creation of an information system for a given problem
•Create a set of models that define a medical information system
•Create the necessary documentation and models for the development-construction of medical information systems

Theoretical teaching

Information systems, user-information system relation, information systems in medicine, structure of information systems in medicine. Information systems in hospitals, types, infrastructure, development. Clinical information system, definition, structure, problems in development of system modules and their coexistent functioning. Information systems in laboratories, definition, structure, requirements, modularity. Subsystems of information systems in medicine, support in main systems. Radiology information systems. Manager information systems, definitions, structures, requirements in medical institutions. Regional information systems, structure, data standardization and communication between medical institutions. Perspective of development of informational systems in medicine, trends, electronic health record. Telemedicine, software, hardware.

Practical teaching

Analysis of the existing documentation in health institutions (hospitals, clinics, health systems). Development of the new, improved medical system documentation in health institutions.

Prerequisites

None.

Learning resources

Written material from lectures (handouts)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	10
calculation tasks	0
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Y. Zhang, Health Information Science, Book Series, Springer, 2018-2022
B. Dixon, Health Information Exchange, 2nd ed., Elsevier, 2022
J. Bronzino, D. Peterson, The Biomedical Engineering Handbook, 4th ed, CRC Press, 2015

Introduction to nanotechnology

ID: 1399
Responsible/Holder professor IVANA M. STANKOVIĆ
Teaching profesor(s): STANKOVIĆ IVANA; VASIĆ-MILOVANOVIĆ ALEKSANDRA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: biomedical engineering

Goals

The objective of this course is to provide students with a fundamental understanding of the physics of nanostructures and nanotechnology. Through theoretical lectures and practical exercises, students will gain knowledge about the basic types and characteristics of nanomaterials and nanoparticles, methods and techniques for their synthesis and characterization, as well as the applications and implications of nanotechnology in various industries. Additionally, students will analyze the ethical, environmental, and societal aspects of nanotechnology, enabling them to critically consider the role of nanotechnology in modern society.

Learning outcomes

Upon successful completion of this course, students will be able to:

- Understand the basic concepts and principles of the physics of nanostructures and nanotechnology
- Establish the difference between physical and biological processes at the nano level, as well as micro and macro system
- Identify various types of nanomaterials and their specific properties
- Establish the difference and define the basic principles of devices used for the characterization of nanomaterials

Theoretical teaching

Introduction to the field of nanotechnology and its historical development. Fundamental principles governing nanoscale phenomena. Quantum effects and the unique properties of nanomaterials: size-dependent properties and their implications. Intermolecular forces, Van der Waals forces, hydrogen bonding and other intermolecular interactions at the nanoscale, and their influence on the behavior of nanostructures. Classification of nanomaterials (e.g., carbon-based, metal-based, dendrimers, and composites). Unique physical, chemical, and mechanical properties of nanoparticles. Inspiration from natural systems in designing nanoscale materials and devices. Examples of biomimetic nanotechnology in various applications.

Practical teaching

Introduction to techniques for characterization of nanomaterials. Principle of operation of the Scanning Probe microscope. Basic and additional modes of operation and modules.

Criteria for self-assembly and examples of molecular systems formed through self-assembly. Inorganic and organic systems, unspecific and non covalent interactions. Molecular recognition and biomimicry. Theoretical (physical and chemical) aspects of biological and technical nanosystems.

Prerequisites

Prerequisition for attending this course is that student is regulary attending MAS

Learning resources

1) Handouts from lectures
2) Nanolaboratory with Scanning Probe Microscope JEOL SPM 5200

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	8
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	40	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Bertino, Massimo F. Introduction to nanotechnology. 2022. ISBN-13: 978-9811231605
Binns, Chris. Introduction to nanoscience and nanotechnology. John Wiley & Sons, 2021. ISBN: 978-1-119-17223-9.
Hornyak, Gabor L., et al. Fundamentals of nanotechnology. CRC press, 2018., ISBN-13: 978-1420048032
Rogers, B., Pennathur, S., Adams, J., Nanotechnology: Understanding Small Systems, 3rd edition, 2014, ISBN-13: 978-1482211726.

Bhushan, B., Harald F.,, Sumio H., eds. Applied Scanning Probe Methods I. Springer Science & Business Media, 2014. ISBN: 9783642357923

Nanomedical Engineering

ID: 1400
Responsible/Holder professor IVANA M. STANKOVIĆ
Teaching profesor(s): STANKOVIĆ IVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

Student will get knowledge of nanoscience and nanotechnology applications in medicine together with good practical laboratory work in characterization of biomaterials with nanotechnological methods, techniques and instrumentation. Student will get knowledge of modern diagnostics and therapeutic nanotechnological methods in medicine and will learn how to prepare classical and biological samples and to characterize them with nanotechnological instrumentation.

Learning outcomes

Upon successful completion of this course, students will be able to:

•Distinguish principles of operation and the specific conditions of application of the devices in the field of nanotechnology in medicine
•Recognize the advantages of new medical devices in the field of nanotechnology as opposed to solutions in classical medical devices
•Give suggestions of modification of technical solutions in nanotechnologies with a review to their effective application in medicine
•Write and present scientific work in accordance with the standards of professional quality and in quality equal to the works published in professional journals

Theoretical teaching

Short history of medicine:From origins of menkind to Asclepius.From Asclepius to Hippocrates.From Hippocrates to healers.From healers to van Leeuwenhoek.From van Leeuwenhoek to DNA discovery.From DNA to quantum medicine.From quantum medicine to nanomedicine;Basics of molecular medicine:Classical medical approach to diseases. Resorption, distribution, metabolism and excretion of drugs.Interactions and undesirable effects of drugs.Molecular basics of diseases.Basics of molecular nanotechnology and its applications in medicine;Basics of nanomedicine:Nanoparticles and nanomaterials in medicine.Quantum dots based on semiconducting nanoparticles.Quantum dots based on nanomaterials (fullerenes).Adding of hydroxyl groups and other molecules to basic nanomaterials.Use of AFM for intermolecular bonding forces measurements in saline;Nanotechnology and nanobiomedicine:Comparison of classical and nanotechnological methods and techniques use in diagnostics and treatment.Advantages and risks of nanoparticles use in medicine;Nanosensors:Nanosensors for electrical,electro-chemical and optical measurements.Nanosensors for food and beverage analysis;Microtubules:Actine filaments.Intermedial fibers.Microtubules.Proteins added to microtubules.Molecular

motors.Myosin.Kinesin.Dynein.Cell division.Cytokinesis;Nanotechnology in pharmacy:Possibilities and range of nanopharmacy.Production of nanoparticles.Barriers in organism.Pharmaceutical nanosystems engineering.Intelligent systems for drug releasing;Nanotechnology in implantology:Nanotechnological implants in rehabilitation medicine.Nanoimplants in stomatology.Characterization of stomatological materials by AFM.Nanoimplants in dermatology;Nanotechnology and diabetes:Main sorts of diabetes.Insulin.Complications.Medical nanobots for diabetes control.Methods;Biocompatibility of nanomedical materials:Biocompatibility of coated diamond material.Biocompatibility of fullerenes and carbon nanotubes.Biocompatibility of fluoro-carbon polymers.

Practical teaching

UV-Vis-NIR,FTIR spectroscopy; Nanotechnological characterization:STM, AFM and MFM.Biocompatibility of nanomaterials:Analysis and characterization of nanomaterials surface with nanotechnological instrumentation.Toxicological tests of nanomaterials and nanoparticles; Nanoprobe measurements:Sample preparing techniques.Assessment of mechanical,electrical and magnetic characteristics of materials.

Prerequisites

Fractal Mechanics, Introduction to Nanotechnology , Signal processing, Nanotechnology

Learning resources

Written material for every lecture (Handouts), NanoLab: modern NanoProbe device with STM/AFM/MFM, Opto-magnetic spectroscopy device, Chemical Vapor Deposition for thin (nano) films, UV/VIS spectometer, NIR spectometer,microscope

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	5
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	25

test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Webster, Thomas J., ed. Nanomedicine: Technologies and applications. Woodhead Publishing, 2023.
Jain, K.K., The Handbook of Nanomedicine, Third Edition, Humana Press, New York, NY. 2017.
Wiesner, Mark R., Jean-Yves Bottero. Environmental nanotechnology: applications and impacts of nanomaterials. McGraw-Hill Education, 2017.
Bawa, Raj, Gerald F. Audette, Israel Rubinstein, eds. Handbook of clinical nanomedicine: nanoparticles, imaging, therapy, and clinical applications. Vol. 1. CRC Press, 2016.
Bawa, Raj, Gerald F. Audette, Israel Rubinstein, eds. Handbook of clinical nanomedicine: nanoparticles, imaging, therapy, and clinical applications. Vol. 1. CRC Press, 2016.

Nanotechnology

ID: 1282
Responsible/Holder professor LIDIJA R. MATIJA
Teaching profesor(s): MATIJA LIDIJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

Goal of this subject is for students to acquire knowledges of: electron tunnelling phenomena, molecular atractve and repulsive forces, nanomaterials, conversion and transport of energy on nanoscale level. Introduction of basic methodes, techniques and devices for characterisation of nanomaterials: Scanning NanoProbe microscopy and spectroscopy. Nano electrochemical cell. Characterisation of conductive, magnetic and non-conductive materials: inorganice as well as biological. Nano films: characterisation and modification of sample surfaces by STM/AFM/MFM methodes.

Learning outcomes

Upon successful completion of this course, students will be able to:

•Distinguish between the basic components and principles of electron tunneling as well as the basic components and principles of attraction-repulsion effects
•Apply basic theoretical and experimental knowledge to analyze nano system
•Work on devices for characterization of nanomaterials, STM and AFM
•Carry out appropriate preparation of various samples for the scanning probe microscopy
•Performs characterization of materials at the nano level
•Apply acquired knowledge of software analysis of graphical and analytical data obtained by scanning probe microscopy

Theoretical teaching

Conditions for beginning and development of nanotechnology. Basic terms from experimental and theoretical aspects of scanning tunnelling mycroscopy and spectroscopy. Schroedinger equation and electron tunnelling. Technologioes based on electron tunneling effect. Organization of processes of electrochemical interactions. Characterization of materials based on intermolecular forces. Alternative methodes and techniques for spectroscopy and scanning tunnelling microscopy methodes. Introduction to applied nanotechnologies. General areas of application of scanning tunnelling microscope and nanoprobe microscopy. Studying of solid and liquid materials on nanoscale. Solid state physics on the level of nanometers. Application of nanotechnologies in research of organic molecules, drugs and biomacro molecules(nucleic acids, proteins and membrane aggregates). Metrology and standards in nanotechnology. Material modifications on nano level. Integrational aspects of nanotechnology based on physics and chemistry. System aproach to nano-molecular sensores and devices engineering.

Practical teaching

Practical lessons: Demonstratory practice from nanotechnology instrumentation. Introduction to abilities and operations of scanning tunnelling microscope. Basic assemblies and principle of tunneling electron conrole. Practical work in sofrware for gathering data from sample analysis. Introduction with atomic force microscope. Comparing posibillities and results of STM and AFM. Basic assemblies and principle of attractional and repulsive forces controle. Nano consoles: characteristics, types, observing them by high magnification CCD camera. Nanomaterial images analysis. Introduction and operation with software tools for acquiring STM and AFM images. Difference between graphical and analytical data. Operation of nano-fluid cell and electrochemical cell.

Prerequisites

Enlisted in 2nd semester of Master studies. Recomended: Introduction to nanotechnology.

Learning resources

NanoLaboratory with Chemical vapor deposition device for making thin films, NanoProbe microscope with integrated STM/AFM/MFM, electrochemical cell and fluid cell.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	10
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	6
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	45	project design	0
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Л. Матија, Д.Којић, А. Васић, Б.Бојовић, Т.Јовановић, Ђ.Коруга,Увод у нанотехнологије, ДонВас, Београд, 2011

Тошић,Б. и сар., Примена диференцијалног рацуна у анализи наноструктура, ВАНУ,Нови Сад, 2005
Dj.Koruga, S.Hameroff, J.Withers, R. Loutfy, M.Sundareshan., Fullerene C60: History, physics,nanobiology, nanotechnology, North-Holland -Elsevier, Amsterdam, 1993
Hornyak,G.L. et. al, Introduction to nanoscience and nanotechnology, CRC Press, Boca Raton, 2009
Hanson,G.W., Fundamentals of nanoelectronics, Prentice Hall, New Jersey, 2008

Signal Processing

ID: 1343
Responsible/Holder professor BRANISLAVA D. JEFTIĆ
Teaching profesor(s): JEFTIĆ BRANISLAVA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

Introduction to basic concepts and knowledge related to continuous-time and discrete-time signals, deterministic and stochastic signals, signal processing and analysis in time and frequency domain, digital filter design. Introduction to the specific nature of the biomedical signals, mainly electhophysiological signals, and various approaches to biomedical signal processing and analysis. Mastering digital signal processing methods and its application using MATLAB.

Learning outcomes

Upon successful completion of this course, students shall be able to:
•Apply MATLAB software for the analysis and processing of the major electrophysiological time series
•Form and implement program for signal acquisition and properly choose acquisition system parameters depending on the type of biomedical signal
•Master the application and the characteristics of Fourier transform and Z-transform
•Distinguish characteristics of different biomedical signals (EEG, ECG, EMG) in time and frequency domain
•Select and apply different filtering methods depending on the characteristics of the signal being processed and the types of further applications of such signals
•Form a user interface for signal processing and displaying, adequately present time series and signal processing results in the time, frequency and time-frequency domain.

Theoretical teaching

Deterministic and stochastic signals. Biomedical signals. Electrophysiological signals - ENG, EMG, ECG, EEG. Signal analysis in time domain: averaging, correlation. Discrete signal analysis in frequency domain: Fourier transform, FTDS, DFT, FFT. Z-transform. Sampling theorem. Spectrogram. Digital processing of continuous signals: continuous signal discretization, systems for signal discretization and reconstruction (A/D, D/A conversion). IIR filters. FIR filters. Discrete stochastic signals.

Practical teaching

Introduction to MATLAB for digital signal processing. Import of various biomedical signals from PhysioBank data bank. Signal processing in time domain. Signal spectral analysis. EMG, ECG and EEG signal processing and analysis. Detection of characteristic signal parameters. Digital filter design. Biological systems modelling.

Prerequisites

None.

Learning resources

Auditory room equipped with computer, video beam, internet connection and accompanied inventory. Computer room with computers with needed software installed. [1] Handouts - lectures. [2] Handouts - Auditory exercises.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	0
calculation tasks	16
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	20	project design	0
laboratory exercises	0	final exam	35
calculation tasks	40		

Requirements to take the exam (number of points) 30

References

L. Popović Maneski, B. Jeftić, N. Malešević, Signals and Systems in Rehabilitation, 2nd Edition, Akademska Misao, Belgrade, 2019, ISBN: 978-86-7466-794-1
J. Semmlow, Circuits, Signals and Systems for Bioengineers, Elsevier Inc, 2018
K.J. Blinowska, J. Zygierewicz, Practical Biomedical Signal Analysis Using MATLAB, CRC Press, USA, 2022
R. Rangayyan, Biomedical signal analysis, Vol. 33. John Wiley & Sons, 2015
L. Popović-Maneski, I. Hut, B. Jeftić, I. Jovanov, Introduction to LabView i MATLAB, Akademska misao, Belgrade, 2015, ISBN: 978-86-7466-565-7 (in Serbian)

Skill Praxis M - BMI

ID: 1345
Responsible/Holder professor BRANISLAVA D. JEFTIĆ
Teaching profesor(s): JEFTIĆ BRANISLAVA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: biomedical engineering

Goals

Introducing students to operation and maintenance principles of instruments, apparatus and devices used in different medical fields, especially in clinics and medical centers. Upgrading theoretical knowledge and developing practical skills through practical experience in the environment where students shall develop their future professional career.

Learning outcomes

With mastering the course program, students get familiar with: 1. clinic's organizational processes and problems 2. functioning and maintenance of instruments for measurements, apparatus, and devices for diagnostics and therapy 3. instrumentation, apparatus, and device maintenance.

Theoretical teaching

Introducing students to the practice plan and schedule, procedures, rules, documents related to the protection on work.

Practical teaching

Visits to medical institutions, hospitals, and health centers. Getting familiar with work conditions in our country, and establishment of communication system with doctors (adoption of medical terminology). Apparatus and devices management for early diagnostics of cancer and melanoma, ophthalmic procedures for the constitution of sight. Interpretation of obtained results from the aspect of sensitivity and specificity. Analysis of functioning of ECG, EEG, CT, MRI, ultrasound, etc. Recording and analysis of information pathways, making the data base in clinics, introduction to the medical documentation.

Prerequisites

Attending praxis in the institution.

Learning resources

Biomedical lab 2 at the Faculty of Mechanical Engineering.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING		OTHER	
active teaching (theoretical)	0	knowledge checks	90

lectures	0	assessment of calculation tasks	0
elaboration and examples (revision)	0	check and assessment of lab reports	0
active teaching (practical)	**0**	check and assessment of seminar works	90
auditory exercises	0	check and assessment of projects	0
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	0
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

L. Popović Maneski, B. Jeftić, N. Malešević, Signal and Systems in Rehabilitation, 2nd Edition, Akademska Misao, Belgrade 2019, ISBN: 978-86-7466-794-1 (in Serbian)
L. Matija, B. Jeftić, I. Stanković, A. DInić, Introduction to Biomedical Engineering, University of Belgrade - Faculty of Mechanical Engineering, Belgrade, 2024, ISBN: 978-86-6060-186-7 (in Serbian)
L. Matija, M. Miloš, Z. Bjelica, Introduction to Medical Device Maintenance, NO QRIOT, Belgrade, 2018 (in Serbian)
M. Milos, Mašinsko inženjerstvo u praksi, elektronska knjiga, Mašinski fakultet, 2016

Spectroscopy methods and techniques

ID: 1398
Responsible/Holder professor IVANA M. STANKOVIĆ
Teaching profesor(s): STANKOVIĆ IVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: biomedical engineering

Goals

Introducing students to fundamentals of spectroscopic methods and techniques. Through theoretical lectures and practical work student masters the understanding of light-matter interaction and how this interaction can be used to acquire information about structure of the matter. Through practical work on in the laboratory and analysis of spectral data student learns to apply acquired knowledge about structure of the matter in order to control quality of various products (in food industry, pharmacy and other industrial branches) as well as perform characterization of new materials, biomaterials and biological samples with the purpose of applications in biomedical engineering for early detection of bio-markers, pathological changes and diseases.

Learning outcomes

Upon successful completion of this course, students will be able to:

•Use different measurement instruments and methods of UV-Vis / NIR and FTIR spectroscopy
•Work in the laboratory and perform characterization of materials using appropriately selected spectroscopic methods
•Determine composition, as well as the chemical and physical properties of the tested materials
•Perform multivariate spectral analysis using computer software packages

Theoretical teaching

Introduction to Spectroscopic methods and techniques. Classification of spectroscopy methods. Dual nature of light. Electromagnetic radiation. Light – matter interaction. Ultraviolet and visible spectroscopy. UV/VIS spectral interpretation, examples. Infrared spectroscopy: classification, types of spectrometers, accessorizes, sample preparation and acquisition modes. IR spectra interpretation. FTIR spectromicroscopy: transmittance, transflectance, attenuated total reflectance. Quantitative and qualitative analysis of FTIR hyperspectral images.Near infrared spectroscopy. Preprocessing of NIR spectra. Multivariate analysis: principal component analysis, soft independent modeling of class analogies, partial least squares regression, calibration and validation of models. Multivariate analysis applications on real spectral data. Raman spectroscopy. Applications of Raman spectroscopy.

Practical teaching

1. Practical work using UV/Vis/NIR spectrometer Lambda 950:

1.1. Preparation of artificial food dyes solutions in water and determination of dye color on the basis of absorption peaks in visible region
1.2. Determination of protection factor of sunglasses on the basis of glass absorption in UV region

2. Practical work using FTIR imaging system Spotlight 400 (Perkin Elmer) using ATR mode:
2.1. Preparation of samples of 2 unknown pharmacological substances and spectral acquisition with the purpose of their identification. Identification of unknown substances using spectral database.
2.2. Preparation of aqueous glucose solutions with varying concentrations; acquisition of spectra and determination of the presence of glucose based on its absorption peaks in fingerprint region. Preparation of sodium chloride aqueous solutions, spectral acquisition and comparison with the spectra of aqueous glucose solutions.

3. Practical work using FTIR Spotlight 400 imaging system – imaging mode
Demonstration of microspectroscopic analysis of cervical cytological smears belonging to different PAP groups. Acquisitions of hyperspectral images and identification of healthy and cancer cells based on their spectra.

Prerequisites

Prerequisition for attending this course is that student is regulary attending MAS.

Learning resources

1. Written course material (handout)
2. Scientific articles (KOBSON) - University network is available on laboratory computers (Nanolab) and cabinet 300
3. MATLAB, The Unscrambler, Pirouette, SPSS, Origin - sofwares available in full or trial version
4. FT-IR imaging system-microscope and spectrometer (Perkin Elmer)-Nanolab
5. UV/Vis/NIR spectrometer Lambda 950 (Perkin Elmer, USA) - Nanolab

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	6
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	45	project design	0
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Vitha, Mark F. Spectroscopy: Principles and instrumentation. John Wiley & Sons, ISBN: 978-1-119-43660-7, 2018.
Skoog, Douglas A., F. James Holler, and Stanley R. Crouch. Principles of instrumental analysis. Cengage learning, ISBN: 9781337468039, 2017.
Pavia, Donald L., et al. Introduction to spectroscopy. Cengage learning, ISBN: 9781305177826, 2014.
Jue, T. & Masuda, K., Application of near infrared spectroscopy in biomedicine. Berlin: Springer, ISBN: 978-1-4614-6251-4, 2013
Michael J. K. Thomas, David J. Ando, Ultraviolet and visible spectroscopy: Analytical Chemistry by Open Learning, 2nd Ed., John Wiley&Sons., ISBN: 978-0099449270, 2008.

CONTROL ENGINEERING

Automatic Control

Computer control

Dynamic systems modelling, identification and simulation

Fuzzy Control Systems

Industrial Automation

Industrial process control

Intelligent Buildings

Intelligent Control Systems

Nonlinear Systems 1

Nonlinear Systems 2

Skill Praxis M - SAU

Synthesis of linear systems

Automatic Control

ID: 0286
Responsible/Holder professor DRAGAN V. LAZIĆ
Teaching profesor(s): LAZIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: control engineering

Goals

• to provide theoretical basis, proofs of theorems and more detailed definitions than in the basic course (Introduction of Automatic Control) to get students familiar with the area and therefore fully understand the essence of matter.
• to include all the issues which usually listens worldwide at a course of control
• to enable students to follow the following subjects in this Department

Learning outcomes

• The acquisition of wider knowledge of the automatic control, as a technical field that requires a modern engineer
• identify and use the methods needed for analysis and synthesis of controllers in the control systems, and the entire control systems
• the implementation of computers and MATLAB and address the underlying problems of the automatic control, as well as other engineering problems
• the analytical and / or experimental investigation of the basic dynamic and static characteristics of the systems

Theoretical teaching

The concept of state space. Linear and nonlinear systems, time invariant and time varying systems. Definition of mathematical models in total coordinates and the coordinates of the absolute deviations. Defining the mathematical model in state space, relationship with differential equation and the transfer matrix of the system. Algorithms for the transition from one form of mathematical model to another. Lyapunov's concept of stability. Different properties of stability of the zero steady state: stability, attraction, asymptotic stability. Different characteristics of system stability: stability, border of stability and unstability. The concept of controllability and observability. Logarithmic frequency response and Bode diagrams. Algebraic stability criteria and frequency stability criteria: Hurwitz, Nyquist, Bode, Cipkin, Mihailov.

Practical teaching

Practical training shall include the computational tasks which illustrates the exposed material given by the definitions or by any theorem. Connecting different types of mathematical models of linear systems: differential equations, equations of the state and the output equations, transfer functions and block diagram of the system - the transition from one form to another model. Simulation results for the illustration the above definitions and theorems are done on personal computers using MATLAB. In this subject much more tools,

commands, scripts, ... from MATLAB will be used, as compared to those obtained in the subject Introduction of Automatic Control.

Prerequisites

Passed course Introduction of Automatic Control and nothing more

Learning resources

- Script on https://classroom.google.com/c/MTc5NTQ3MzI4OTgw?cjc=dqauglb
- Licensed Software in the possession of the Faculties.
- Freeware software.
- PCs.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	18
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	5	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 30

References

Dragan Lazic, "AUTOMATIC CONTROL", Script, Faculty of Mechanical Eng., 2007

Computer control

ID: 1554
Responsible/Holder professor VLADIMIR R. ZARIĆ
Teaching profesor(s): ZARIĆ VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: control engineering

Goals

Introducing of: nature of computer control systems (CCS) related to types of signal transfer; real CCS as mainly presented in the practice; choice of physical model of CCS; mathematical modeling of CCS. Mastering of: methods of determining of static and dynamic characteristics of CCS; real time computer control by discrete algorithms. "Offline" use of MATLAB as software standard of automatic control.

Learning outcomes

Exact but not approximate treatment of CCS according to their discrete nature. Scientific and engineering treatment of CCS as dominantly represented in practice. Applying the methods of analysis and synthesis of a controller in CCS, as well of whole CCS. Solving problems of calculation nature by means of computer and MATLAB in the "offline" mode, related to the analysis or synthesis of CCS. Determining of dynamic and static characteristics of CCS.

Theoretical teaching

Introduction in Computer Control (CC): specific nature of CCS, importance and examples. Samplers, quantization and coding: real and ideal samplers, mathematical description, technical realization, description of quantization and coding. Complex and frequency images of ideal sampler output: determination, Shannon's theorem. CCS transfer characteristics: definition in the frequency and s-domain. Systems for signal duration extension: definition, analysis and transfer characteristics. Z-transform: definition, transfer characteristics in z-domain. Block diagrams of CCS: algebra of s and z block diagrams. Modeling and analysis of CCS: classical mathematical modeling, static characteristics and types of action. State concept of CCS: modern mathematical modeling, properties and solving. Dynamic properties of CCS: definitions, determining, criteria.

Practical teaching

PA: Graphical determination of the signal in the receiver. Analytical calculation of time discrete signal x*(t). Quantization and coding of signals. All three forms of the discrete complex X*(s) and frequency image X*(jω) of the output signal of the ideal sampler. Application of Shannon's theorem. Characteristics of the zero order hold. Z transformation. Analysis of z-images. Application of z-block algebra. Discretization of the differential equation of behavior. Determination of the discrete (difference) equation of state and output and their solutions. Examples of testing the controllability, observability and stability of the system. PL: Work in MATLAB: simulation of types of signal transmission, determination of X*(s), X*(jω), frequency spectrum of input and output signal of ideal sampler and low-pass

filter, determination of z-images. Simulation of discrete mathematical models in Simulink. Determination of dynamic properties. Computer control of a physical object in real time. PZ: Manipulation with mathematical models, examination of static and dynamic characteristics of discrete systems. Manipulation with mathematical models, examination of the characteristics of discrete systems in transient and stationary regime.

Prerequisites

Basic knowledge of automatic control. Basic computer knowledge based on use of PC. Basic knowledge of undergraduate mathematics.

Learning resources

Script for Computer control (in Serbian). Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software. Power source, function generator, oscilloscope, PCs. Siemens Simatic PLC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	16
laboratory exercises	7
calculation tasks	0
seminar works	0
project design	7
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	60	project design	5
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

Lj. Grujić, Discrete Systems (in Serbian), ISBN: 86-7083-180-5, Faculty of Mechanical Engineering, Belgrade 1991.
K. J. Astrom, B. Wittenmark, Computer-Controlled Systems: Theory and Design, ISBN: 7-302-05008-2, Prentice Hall, Hoboken, 1997.

C. L. Phillips, H. T. Nagle, A. Chakrabortty, Digital Control System Analysis and Design, ISBN: 1-292-06122-7, Pearson, Edinburgh Gate, 2015.
C. H. Houpis, G. B. Lamont, Digital control systems, ISBN: 0-07-030500-5, McGraw-Hill, New York, 1992.

Dynamic systems modelling, identification and simulation

ID: 1555
Responsible/Holder professor VLADIMIR R. ZARIĆ
Teaching profesor(s): ZARIĆ VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: control engineering

Goals

For the student to learn the basic principles and stages of mathematical modeling and identification of dynamic systems of various natures. For the student to master working with the Matlab, Simulink, Simscape simulation packages.

Learning outcomes

Getting to know, accept and master the basic principles of mathematical modeling in the sphere of electrical, mechanical, electromechanical, fluid and thermal processes. Acquiring knowledge for verification of mathematical models of dynamic systems experimentally and identification of parameters of mathematical models by working on a computer using the Matlab and Simulink packages.

Theoretical teaching

Mathematical modeling of objects and processes in the form of differential equation of behavior (IO) and state space model (ISO). Dynamics of electrical systems. Dynamics of mechanical systems. Dynamics of electromechanical systems. System level dynamics. Dynamics of current-thermal processes. Linearization of nonlinear mathematical models. Simulation of dynamic systems using software packages Matlab, Simulink, Simscape. Identification of dynamic systems. Basic methods for identifying mathematical models of objects with the help of Matlab and Simulink software packages.

Practical teaching

Application of Matlab, Simulink, Simscape. Determination of mathematical models in the form of differential equation (IO) and state space model (ISO) of dynamic systems on examples of electrical, mechanical, electromechanical (DC motor), system level dynamics (system of coupled tanks) and current-thermal processes. Identification of mathematical models of various objects based on experimentally recorded data on real objects. Simulation of continuous and discrete automatic control systems. Simulation of hybrid automatic control systems.

Prerequisites

Defined by the curriculum of the study program/module.

Learning resources

Script for Dynamic systems modelling, identification and simulation. Modular educational real time control system with various control plants (DC servo motor, inverted pendulum,

double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software. Power source, function generator, oscilloscope, PCs. Siemens Simatic PLC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	16
laboratory exercises	7
calculation tasks	7
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	45	project design	0
laboratory exercises	5	final exam	45
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

D.Lj. Debeljković, A.M. Sićović, G.V. Simeunović, V.S. Mulić, Mathematical models of objects and processes in automatic control systems, Part II (in Serbian), ISBN: 86-7083-543-6, Belgrade, 2006.
D. Lj. Debeljković, Process Identification (in Serbian), ISBN: 978-86-7083-823-9, Faculty of Mechanical Engineering, Belgrade, 2014.
R. C. Dorf, R. Bishop, Modern Control Systems, ISBN: 0-13-440762-8, Pearson, Upper Saddle River, 2017.
K. Ogata, Modern Control Engineering, ISBN: 0-13-615673-8, Pearson, Upper Saddle River, 2010.
L. Ljung, System Identification, ISBN: 0-13-656695-2, Prentice Hall PTR, Upper Saddle River, 1999.

Fuzzy Control Systems

ID: 0642
Responsible/Holder professor RADIŠA Ž. JOVANOVIĆ
Teaching profesor(s): JOVANOVIĆ RADIŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: control engineering

Goals

• Understanding of fuzzy approach to modeling phenomenon, process and systems.
• Introduction to basic of fuzzy set theory and fuzzy control theory.
• Introduce students to the fundamental principles of artificial neural networks.
• Analysis, design, simulation and practical realization of fuzzy control systems using Matlab/Simulink programming software.

Learning outcomes

On successful completion of the course the students should be able to:
• Understand fuzzy set, fuzzy logic and fuzzy control theory.
• Design of fuzzy controllers and fuzzy systems.
• Realize of various fuzzy control algorithms.
• Perform simulation and practically implement various fuzzy control systems using PC and programing software Matlab/Simulink.

Theoretical teaching

Fuzzy set theory. Fuzzy relations, operations on fuzzy sets. Fuzzy logic: linguistic variables, fuzzy rules, approximate reasoning. Fuzzy systems: fuzzy rule base, fuzzy inference engine, fuzzifier, defuzzifier, mathematical representations of fuzzy systems. Fuzzy control: theoretical and practical approach. Design and analysis of fuzzy controllers, fuzzy PID controllers. Mamdani and Takagi-Sugeno fuzzy systems. Fuzzy systems as universal approximators. Fuzzy tuning of classical conventional controllers. Nonconventional fuzzy control algorithms. Application of fuzzy control.

Practical teaching

PA:
Practical work includes computational exercises that follow the content of course.

PL:
Practice and experiments: simulation and experimental application of fuzzy algorithms as well as their practical realization using Matlab/Simulink for control different plants within a modular educational real-time control system (inverted pendulum, , heat flow experiment, DC servo motor).

Prerequisites

Defined by curriculum of the study programme.

Learning resources

• Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software.
• PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers,
• Installation for control system testing and acquisition of electrical variables,
• Intelligent Control Systems Laboratory, Control Systems Laboratory.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	5	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

D. Driankov, H. Hellendoorn and M. Reinfrank, "An Introduction to Fuzzy Control" , Springer Verlag, 1996.
K. M. Passino, S. Yurkovich, "Fuzzy Control", Addison-Wesley, 1998
Radiša Jovanović, Fuzzy logic, modelling and control, Faculty of Mechanical Engineering, Belgrade, ISBN 978-86-6060-059-4, 2020 (in Serbian).
Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, ISBN 978-86-7083-896-3, 2021 (in Serbian).

Industrial Automation

ID: 0599
Responsible/Holder professor MILAN R. RISTANOVIĆ
Teaching profesor(s): RISTANOVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: control engineering

Goals

To introduce students to the contemporary industrial control systems, design and technology of their realization, component selection and practical implementation of simple solutions, as well as the role of Industrial Automation in Industry 4.0.

Learning outcomes

The acquired knowledge is used in engineering practice. The student is competent to understand modern control systems in the industry, component selection and practical implementation of simple solutions.
Student is able to implement simple solutions of electric, pneumatic and electropneumatic control.
Student is able to create project with Simatic S7-1200 PLC in programming language STEP 7 according to the standard IEC 61131-3. Student is trained to solve problem of sequential and real time control.
Student is able to create HMI project with operators panel.

Theoretical teaching

Overview of the development of automation in the industry. Definition of industrial automation. Piramide of industrial automation. Electrical control. Components of electrical contact control (push buttons, proximity switches, contactors and relays, time relays, switches, relays, pulse relays, solid-state relays, residual current device, safety shutdown, bouncing contacts, high voltage electrical discharge). IP protection rating. Displaying electrical contact control. Basic coupling with electric contact control. Control of three-phase induction motors. Pneumatic control. Perform pneumatic installation. Compaction systems and air preparation. Pneumatic cylinders. Pneumatic valves. Electro-pneumatic control. Programmable controllers. Characteristics of programmable controllers. CPU structure. Users program. Input/output modules. Programming the controller according IEC61131-3. Programming languages. Writing programs. Basic functions. Timers. Counters. Sekvential control. Analog value processing. Interrupts. Real time control. Communication between the controllers (Profibus, Profinet, ...). Human-machine interface. Distributed control and SCADA systems. Industrial automation and Industry 4.0

Practical teaching

Examples of implemented systems. Practical aspects of election management system components. Realization of simple solution in electrical, pneumatic and electro-pneumatic technology. PLC controllers programming. Development of SCADA system.

Prerequisites

Attended courses in Automatic control, Computer control and Digital systems.

Learning resources

M. Ristanovic, Industrial Automation, printed lectures
Laboratory for Industrial Automation
Siemens SIMATIC S7-1200
Siemens SIMATIC KTP-600PN
Siemens SIMATIC TP 700
TIA PORTAL - licensed software

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	8
colloquium, with assessment	5
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	10
laboratory exercises	5	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

M.Ristanovic, "Industrial Automation", in Serbian, University of Belgrade - Faculty of Mechanical Engineering, 2020., ISBN 978-86-6060-040-2
Schmiedt, Dietmar et. al, "Steuern und Regeln für Maschnienbau und Mecha- tronik", Verlag Europa-Lehrmittel, Haan-Gruiten, 2010.
Berger, Hans, "Automating with STEP 7 in LAD and FBD", Publicis Corporate Publishing, Erlangen, 2005.
Tapken, Herbert, "SPS Theorie und Praxis", Verlag Europa-Lehrmittel, Haan-Gruiten, 2011.
Stenerson J., Industrial automation and process control, Prentice Hall, 2003

Industrial process control

ID: 1380
Responsible/Holder professor MILAN R. RISTANOVIĆ
Teaching profesor(s): RISTANOVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: control engineering

Goals

To introduce students to methods of design and realization of control systems and real time control.

Learning outcomes

The acquired knowledge is used in engineering practice. The student is competent to understand
electrohydraulic and electromechanical servosystems and implementation of simple solutions.
The student is able to implement and tune control algorithms in real time. The student is able to commission servo drive and frequency controller.

Theoretical teaching

Electrohydraulic actuation systems. Working fluids. Selection of actuation system structure. Electrohydraulic systems control structure selection. Integration of electrohydraulic actuation systems. Basic actuation systems structure. Static and dynamic calculations. Numerical simulations of mathematical models. Electromechanical servosystems. Control of asynchronous and servo motors. Basic control structure's. Networking of servo drives and frequency controllers. Implementation of real time control. Realization of human-mashine interface.

Practical teaching

Demonstration of electrohydraulic servosystem for thrust vector control.
Commissioning and tune of PID controller.
Commissioning of frequency controller.
Commissioning of servo drives.

Prerequisites

None

Learning resources

Laboratory for industrial automation.
Laboratory for integrated technical systems.
Siemens SIMATIC S7-1200
Siemens SIMATIC KTP-600PN
Siemens SIMATIC TP 700

Siemens SIMATIC 1500-T
Siemens SINAMICS V90
Siemens SINAMICS G120
TIA PORTAL - licensed software

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	13
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	60
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Astrom K., Wittenmark J., Computer-Controlled Systems: Theory and Design, 2011
Astrom K., Wittenmark J., PID Controllers: Theory, Design, and Tuning, 1995
M.Ristanovic, Control of Industrial Processes, written lecturers, 2022

Intelligent Buildings

ID: 0656
Responsible/Holder professor MILAN R. RISTANOVIĆ
Teaching profesor(s): RISTANOVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: control engineering

Goals

To introduce students to the concept of intelligent buildings, technical systems in modern buildings and control systems technology and their integration.

Learning outcomes

The acquired knowledge is used in engineering practice. The student is competent to understand the technical sub-systems in modern buildings, their configuration and mutual integration of electrical and mechanical systems and management concepts.
Student is able to create ETS project and program KNX components.
Student is able to make application schematics of HVAC system, to define signal list and define quote of sensors, actuators and controllers.

Theoretical teaching

The definition of intelligent buildings. Technological systems in intelligent buildings. Introduction to digital control systems: analog / digital input / output values, sensors, actuators, digital controllers. Control valves. Basic communication standards and their characteristics. Control algorithms and tuning.
Management of central heating systems. Control of boilers. Control of substations. Outdoor temperature compensation. Central and zone control. Control in the solar system. Managing in the air conditioning. Typical control schemes of air conditioning. Cascade control. Secvential control. Regulation of air humidification. Control of air handling unit with variable flow. Lighting control systems. Lighting control system components, analog / digital control and lighting control strategies. Protection systems and solar radiation and control strategies. Measuring energy consumption. Fire protection systems. Access control systems. Building management systems. Application of Internet technology in control.

Practical teaching

Understanding the physical implementation of sensors, digital controllers and drivers. Understanding the physical implementation of control systems in buildings. Programming and networking of digital controllers.
Realization of simple solutions.

Prerequisites

Basic automatic control knowledge and digital systems.

Learning resources

M. Ristanovic, Intellingeng Buildings, printed lectures
Laboratory
KNX/EIB Trainings Kit
ETS3 - licensed software

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	10
calculation tasks	0
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	10
laboratory exercises	5	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Тодоровић, Ристановић М, Ефикасно коришћење енергије у зградама, Универзитет у Београду, 2015, ISBN 978-86-7083-875-8
Shengwei Wang, Intelligent Buildings and Building Automation, Spon Press, New York, 2010
H. Merz, T. Hansemann, C. Huebner, Building Automation, Springer-Verlag, Berlin Heidelberg, 2009
C.F. Mueller, Regelungs- und Steuerungstechnik in der Versorgungstechnik, 2002

Intelligent Control Systems

ID: 0657
Responsible/Holder professor RADIŠA Ž. JOVANOVIĆ
Teaching profesor(s): JOVANOVIĆ RADIŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: control engineering

Goals

• Introduction to methods for the analysis and design of intelligent control systems.
• Gaining practical knowledge of several of the main techniques of intelligent control and an introduction to some promising research directions.
• Use of the computer for simulation and evaluation intelligent control systems.

Learning outcomes

On successful completion of the course the students should be able to:
• Understand of the functional operation of a variety of intelligent control techniques.
• Understand of control-theoretic foundations.
• Carry out synthesiis and analysis of intelligent control systems based on combinations of various theories: simulation, neural networks, fuzzy systems, genetic algorithms, biologically inspired algorithms, etc.
• Use of the computer for simulation and evaluation intelligent control systems through Matlab/Simulink software, as and practical realization of control algorithms on various control plants using programming software Matlab.

Theoretical teaching

Introduction of intelligent control. Conventional and intelligent control. Fundamentals of artificial neural networks: architecture, classification, basic properties. Neural network learning rules: principles, Hebbian learning law, Widrow-Hoff learning, delta rule. Single layer feedforward neural networks, perceptron, linear network. Multilayer feedforward networks with backpropagation error. Radial basis function neural networks. Support vector machines. Dynamical neural networks. Neural networks for nonlinear dynamic system modelling and identification. Neural networks for control: direct control and indirect control, direct inverse control,model predictive control. Deep learning and convolutional neural network. Biologically-inspired and evolutive algorithms.

Practical teaching

PA:
Practical work includes computational exercises that follow the content of course.

PL:
Practice and experiments: computer applications in simulation and evaluation of intelligent control systems, as well as their practical realization using Matlab/Simulink for control different plants within a modular educational real-time control system (double inverted

pendulum, coupled tanks experiment, DC servo motor, heat flow exepriment).

Prerequisites

Defined by curriculum of the study programme.

Learning resources

• Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software.
• PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers.
• Installation for control system testing and acquisition of electrical variables.
• Intelligent Control Systems Laboratory, Control Systems Laboratory.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	10
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	6
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	5	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Radiša Jovanović, Introduction to Neural Networks and Fuzzy Systems, Lecture notes, Faculty of Mechanical Engineering, 2023.
Simon Haykin, Neural Networks and Learning Machines, Vol. 3. Upper Saddle River, NJ, USA:: Pearson, 2009.
Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, ISBN 978-86-7083-896-3, 2021 (in Serbian).

Nonlinear Systems 1

ID: 0628
Responsible/Holder professor RADIŠA Ž. JOVANOVIĆ
Teaching profesor(s): JOVANOVIĆ RADIŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: control engineering

Goals

• Introduction to nonlinearities in the plants and processes.
• Introduction to basic concepts of analysis of nonlinear systems.
• Understanding and using the basic tools for testing the stability of nonlinear systems.
• Analysis of nonlinear systems using Matlab/Simulink programming software.

Learning outcomes

On successful completion of the course the students should be able to:
Knowledge and understanding of:
• Recognize and understand nonlinear problems and phenomena in the processes and plants.
• Determine mathematical models of nonlinear systems.
• Apply basic methods for analyzing nonlinear systems in time domain and state space.
• Perform simulations, analysis and control of nonlinear systems using software package Matlab/Simulink.

Theoretical teaching

Introduction to nonlinear systems and control. Typical nonlinear problems and phenomena. Types of nonlinearity.Types of nonlinear systems. State space. Solution of nonlinear diferential equations, existence and uniqueness of solutions, Lipschitz function, comparison principle. Equilibrium points. Phase-plane analysis: phase portrait, limit cycles, stability domain, classification of singular points. Poincaré-Bendixson criterion. Lyapunov stability concepts. Lyapunov stability and instability theorems of equilibrium points. LaSalle's theorem, invariance principle and Chetaev's theorem. Lyapunov's direct and indirect methods. Krasovski's criterion.

Practical teaching

PA:
Nonlinear mathematical models of dynamic systems. Determination of equilibrium points. Phase-plane analysis: phase portrait, limit cycles, stability domain, stability and attraction of equilibrium points. Determining the system stability by applying indirect and direct method of Lyapunov.

PL:
Practice and experiments: verification of non-linear mathematical models of different objects using a PC; experimental determination of nonlinear static characteristics and analysis of the dynamic behavior of different objects of automatic control (DC servo motor, heat flow

experiment, coupled tanks experiment) using the programming software Matlab/Simulink.

Prerequisites

Defined by curriculum of the study programme.

Learning resources

- Lj.Grujić, D.Lazić, Nonlinear Systems, Lecture notes in electronic form.
- Radiša Jovanović, Nonlinear Systems 1, Lecture notes.
- Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software.
- PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers.
- Installation for control system testing and acquisition of electrical variables.
- Intelligent Control Systems Laboratory, Control Systems Laboratory.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	10
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	5	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Hassan K. Khalil, Nonlinear Systems, 3rd Edition, Prentice-Hall, 2002.
Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Englewood Cliffs, NJ: Prentice-Hall, 1991.
Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical

Engineering, Belgrade, ISBN 978-86-7083-896-3,2021.

Nonlinear Systems 2

ID: 0609
Responsible/Holder professor RADIŠA Ž. JOVANOVIĆ
Teaching profesor(s): JOVANOVIĆ RADIŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: control engineering

Goals

• Building the foundations of nonlinear control design and analysis.
• Introducing commonly used nonlinear control tools.
• Analysis and control of nonlinear systems using Matlab/Simulink programming software.

Learning outcomes

On successful completion of the course the students should be able to:
• Perform basis of dynamical analysis of certain classes of nonlinear systems.
• Apply various methods for testing the system stability by Lyapunov techniques and input-output analysis.
• Understand and use diferent control techniques of nonlinear systems.
• Perform simulations, analysis and control of nonlinear systems using software package Matlab/Simulink.

Theoretical teaching

Lurie's direct and indirect control systems. Linear and Aizerman Conjecture. Absolute stability. Popov's and Circle criteria. Tsypkin's trasnformation. Exact (feedback) linearization. Input-state linearization. input-output linearization. Zero dynamics and input-to-state stability. L2 gain and small gain theorem. Sliding mode control. Backstepping. Gain scheduling. Approximate methods. Describing function analysis. Modified Nyqiust criteria.

Practical teaching

PA:
Practical work includes computational exercises that follow the content of course: stability of Lurie direct and indirect systems; дерermination stability of nonlinear systems using linear and Aizerman conjecture; Popov's and circle criteria; exact (feedback) linearization: input-state linearization, input-output linearization; zero dynamics and input-to-state stability; sliding mode control: backstepping:gain scheduling; describing function analysis; modified Nyqiust criteria.

PL:
Application programming languages C and Matlab in the analysis, simulation and control of nonlinear systems.

Practice and experiments: analysis, design and simulation of nonlinear systems; experimental application of nonlinear control algorithms using the PC and the software Matlab/Simulink on different control plants (DC servo motor, inverted pendulum, coupled tanks experiment, heat flow system).

Prerequisites

Defined by curriculum of the study programme.

Learning resources

- Lj.Grujić, D. Lazić, Nonlinear systems, Lecture notes in electronic form.
- Radiša Jovanović, Nonlinear systems 2, Lecture notes.
- Modular educational real time control system with various control plants (DC servo motor, inverted pendulum, double inverted pendulum, heat flow experiment, coupled water tanks experiment), with acquisition hardware and software.
- PC and PC Embedded controllers, Siemens Simatic PLC, National Instruments controllers.
- Installation for control system testing and acquisition of electrical variables.
- Intelligent Control Systems Laboratory, Control Systems Laboratory.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	5
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	5	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Hassan K. Khalil, Nonlinear Systems, 3rd Edition, Prentice-Hall, 2002.
Jean-Jacques E. Slotine, Weiping Li, Applied Nonlinear Control, Englewood Cliffs, NJ: Prentice-Hall, 1991.
Radiša Jovanović, Matlab and Simulink in Automatic Control, Faculty of Mechanical Engineering, Belgrade, ISBN 978-86-7083-896-3, 2021 (in Serbian).

Skill Praxis M - SAU

ID: 1557
Responsible/Holder professor DRAGAN V. LAZIĆ
Teaching profesor(s): LAZIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: control engineering

Goals

Practical experience and students stay in the environment in which the student will realize his professional career.
Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineering in such a business system.

Learning outcomes

Students obtain practical experience on how the organization and functioning of the environment in which they will apply their knowledge in their future professional career.
Student identifies models of communication with colleagues and business information flows.
Student identifies the core processes in the design, manufacture, maintenance, in the context of his future professional competence. Establish the personal contacts and relationships that will be able to use at school or entering into future employment.

Theoretical teaching

Teaching is a practical.

Practical teaching

Practical work embrace all the activities in the organizations where are done different activities connected with mechanical engineering.
Choosing the thematic unit and organization is done in consultation with professor.
Student may do practical work in: manufacturing organizations, constructional and consulting organizations, organizations which are dealing with maintenance of machine equipment, and public utility companies and in some of the laboratories at Faculty of Mechanical Engineering.
The practice may also be made abroad.
During practice, students must keep a diary in which they write descriptions of the performed tasks, the conclusions and observations.
After finished practice students must make a report which they will justify to the subject teacher. The report is submitted in the form of the paper.

Prerequisites

None

Learning resources

Initial resources are laboratories that belong to the Mechanical faculty.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Skill Praxis M - SAU, PDF publication, Faculty of Mechanical Engineering, 2021.

Synthesis of linear systems

ID: 1556
Responsible/Holder professor MILAN R. RISTANOVIĆ
Teaching profesor(s): RISTANOVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: control engineering

Goals

For the student to know the basic requirements when designing an automatic control system, first of all in the form of knowing the basic indicators of the system's operation, both in a stationary state and in transient operating modes. For the participant to get to know a wide range of modern methods for designing realistic automatic control systems.

Learning outcomes

To get to know, accept and master some of the offered methods for designing automatic control systems and to be trained to implement them on each specific example from the class of studied systems. What is more expected is the application of automatic control system design methods that take place in real time on objects and processes and for classes of linear systems with feedback.

Theoretical teaching

System analysis in a complex domain. Effect of zeros and poles on system response. Evaluation of the quality of system behavior. Root locus. System stability and performance. Stability reserve. Loop shaping. Lag controller, PI controller. Lead controller, PD and PID controllers. A controller with two degrees of freedom. Synthesis in state space. Optimal control in the state space. Observer synthesis. Introduction to system robustness.

Practical teaching

System analysis in Matlab. Minimal realization of transfer functions. Assessment of system behavior quality indicators in Matlab. Synthesis of regulators using the root locus method. Synthesis of the phase leg controller. Synthesis of the phase lead controller. Synthesis of regulators in state space. Synthesis of LQ regulators. Synthesis of observers.

Prerequisites

Passed exam in Automatic control.

Learning resources

Computer classroom.
Matlab.
Simulink.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	2
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	40	project design	20
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Milan Ristanovic, "Synthesis of linear systems", written lectures, 2024
Sigurd Skogestad, Ian Postlethwaite: Multivariable Feedback Control: Analysis and Design, 2nd Edition, 2005. ISBN: 978-0-470-01168-3
John Doyle, Bruce Francis, Allen Tannenbaum: Feedback Control Therory

ENGINEERING MATERIALS AND WELDING, TRIBOLOGY, FUELS AND COMBUSTION

- Biofuels in combustion processes
- Biomaterials in Medicine and Dentistry
- Combustion and sustainable development M
- Combustion appliances
- Combustion M
- Design of Welded Structures
- Ecology of combustion
- Engineering materials 3
- Fracture mechanics and structural integrity
- Fuel, Lubricants and Industrial Water 2
- Quality assurance and quality control of welded joints
- Service Properties of Welded Joints
- Skill praxis M - ZZK
- Tribological systems
- Tribology
- Welding metallurgy
- Welding processes M
- Welding technology

Biofuels in combustion processes

ID: 0894
Responsible/Holder professor NEBOJŠA G. MANIĆ
Teaching profesor(s): MANIĆ NEBOJŠA; STOJILJKOVIĆ DRAGOSLAVA; JOVANOVIĆ VLADIMIR

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The objective of the course is for the student to:
acquire basic knowledge about biomass as fuel and biomass as energy storage; perceive the biomass types and classification; perceive the characteristics of biomass important for application (characterization of biomass - ultimate, proximate and chemical analysis); understand the modern procedures of analysis and characterization; understand the importance of biofuel standardization; perceive solid, liquid and gaseous biofuels (fuels obtained from biomass); perceive the characterization of biofuels; understand processes of thermochemical conversion of biomass (torrefaction, liquefaction, pyrolysis, gasification, combustion), chemical conversion and anaerobic digestion; perceive the advantages and disadvantages of the biomass conversion process; understand the possibilities of using biofuels for energy purposes; perceive the importance of biofuels from the environmental aspect, understand the production path of biofuels; understand sustainability criteria for biomass and biofuels and verification of sustainability criteria; understand the basics of calculating the combustion process and the emission of polluting substances; review the phases of the combustion process and the basics of modeling; understand modern biofuel combustion systems; acquire knowledge about the possibilities of using mixtures of biofuels and fossil fuels in combustion processes; perceive the strategies of using biofuels for energy purposes and the development of technologies in accordance with world and European policies and regulations.

Learning outcomes

After successfully passing the exam in this course, the student will be able to:
prepare reviews of directives and regulations for the promotion of the use of biomass as a renewable energy source; define the ways of determining and determine the potential of biofuels in the Republic of Serbia; define resources, potentials and characteristics of raw materials for biofuel production; perform comparisons of different types of biofuels; define the most important characteristics of biomass for application; evaluate the potential of different biofuels and their application for different energy technologies; use advanced knowledge on the production of different types of biofuels; perform technical, economic and environmental comparisons of different energy systems that use biofuels; make a comparative analysis of biofuels and fossil fuels; know how to make a critical assessment of logistical issues related to the possibilities of using biofuels in energy systems; make an analysis of the production path of biofuels and determine the most important stages; know how to apply sustainability criteria for different energy systems and evaluate the results of

such analysis; make calculations of biofuel combustion and apply appropriate models; perform an analysis, as the next generation of energy users, to predict the consequences of the choice of energy systems.

Theoretical teaching

Defining the term of biomass and biofuel in a broader sense. Biomass classification. Characteristics of biomass important for application. Biofuels in a broader sense: firewood, pellets, briquettes, wood chips, bioethanol, biodiesel, biogas, etc. Basic characteristics of biofuels. Specificities of biofuels in relation to fossil fuels. Biomass thermochemical conversion processes - torrefaction, liquefaction, pyrolysis, gasification, combustion: raw materials, process characteristics and obtained products. Chemical conversions and anaerobic digestion: raw materials, process characteristics and obtained products. Advantages and disadvantages of thermochemical conversion, chemical conversion and anaerobic digestion processes. Possibilities of using biofuels for obtaining electricity and heat and fuel for traffic. Modern systems for biofuels combustion. The influence of biofuel characteristics on the choice of the best combustion technology. Calculation of the combustion process and phases of biofuel combustion. Modeling of the biofuel combustion process. Biofuels and the environment: fuel production path, sustainability criteria for biomass and biofuels. Emissions of polluting substances during the combustion of biofuels. Strategies for using biofuels for energy purposes.

Practical teaching

Basics of biofuel characterization and specificities in relation to fossil fuels. Characterization of solid biofuels. Conversion of composition from one basis to another for solid biofuels. Characterization of liquid biofuels. Characterization of gaseous biofuels. Calculation and experimental determination of the heating value of biofuels. Elements of stoichiometry and determination of emissions of pollutants from the combustion process. Determination of physical and chemical characteristics of liquid biofuels. Basics of modeling the biofuel combustion process. Basics of measurement in modern biofuel combustion systems.

Prerequisites

No special requirements.

Learning resources

Laboratory equipment: bomb calorimeter, high temperature furnace, dryer, analytical balance, simultanous thermal analyser (TG+DTG), mass spectrometer, equipment for flash point determination, viscometer, aerometer.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	3
check and assessment of seminar works	0

auditory exercises	8	check and assessment of projects	0
laboratory exercises	18	colloquium, with assessment	1
calculation tasks	4	test, with assessment	5
seminar works	0	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	10	final exam	40
calculation tasks	5		

Requirements to take the exam (number of points) 30

References

Nebojsa Manic, Bojan Jankovic, Dragoslava Stojiljkovic, Milos Radojevic, Basics of biomass thermochemical conversion, pp. 225, ISBN: 978-86-6060-124-9, Faculty of Mecahnical Engineering Belgrade, 2022
Wim van Swaaij, Sascha Kersten, Wolfgang Palz, BIOMASS POWER for the World, pp. 727 , ISBN 978-981-4613-89-7, Taylor & Francis, 2015.
Rutz D., Janssen: BioFuel Technology Handbook, Intelligent Energy Europe, 2007.
Loo S., Koppejna J.: The Handbook of Biomass Combustion & Co-firing, Earthscan, 2007

Biomaterials in Medicine and Dentistry

ID: 1337
Responsible/Holder professor RADICA M. PROKIĆ-CVETKOVIĆ
Teaching profesor(s): SEDMAK ALEKSANDAR; PROKIĆ-CVETKOVIĆ RADICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

Introducing students to the application of different biomaterials, previously discussed during Foundations of Biomaterials course, in order to understand and study functional behaviour of biomaterials in the human body. Analysis of the connections between the biomaterial and the body system, in order to ensure reliable implant operation. The potential co-operation with experts in the field of materials science, dentistry and medicine is allowed, which provides the ability to work in specialized laboratories and clinical facilities.

Learning outcomes

By attending this course the student will master the application of biomaterials in medicine and dentistry, using modern scientific methods. Theoretical considerations, laboratory experimental work and the application of numerical analysis using the licensed software for finite element method, enables the synergy of the previously acquired knowledge in physics, materials science, mathematics and mechanics, in order to implement them in engineering practice.

Theoretical teaching

Application of biomaterials in medicine and dentistry. Fundamentals of making implants in the human body. Compounding biomaterials and achieving biocompatibility. Problems of contact surfaces in designing the structure of biomaterials in the human body. The problems of various physical, chemical and mechanical properties of combined materials. Damage of biomaterials during the exploitation: wear, corrosion and fatigue of biomaterials, corrosion under stress, cracking. Biocomposite materials; achieving a gradual change in material properties in the compound (functionally graded materials FGM). Thin coatings and nanostructured biomaterials. New alloys in biomedical applications. Testing of biomaterials. Lifetime and structural integrity assurance of biomaterials: analytical, numerical and experimental methods. Prevention of failure of the biomaterials structure (case studies).

Practical teaching

Examples of applications of biomaterials in the design, development and exploitation of structures used in medicine and dentistry. Examples and solutions of implants that are made from biomaterials. Experimental Methods In Vitro and In Vivo. Application of analytical and numerical models in the structural integrity assurance of biomaterials. Development of a model using the finite element method. Calculation examples considering problems in designing connecting surfaces in biomaterial structures. Application of configuration forces method to prevent failure of the biomaterials structures.

Prerequisites

required: Biomaterials Basics; desirable: Basics of biomedical engineering and Biophysics

Learning resources

[1] Written lessons from lectures (handouts)
[2] A. Sedmak, M. Rakin, Biomaterials - compounds and problems of the connecting surfaces, Belgrade 2011 (script in preparation)
[3] T. Nenadovic, Stainless Materials, BIGZ, Belgrade, 2001
[4] ABAQUS User's Manuals, Hibbit, Karlsson & Sorensen, Abaqus Inc., Version 6.5 and upgrades 2005-2007

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	8
calculation tasks	5
seminar works	0
project design	4
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	2
test, with assessment	1
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

J.B. Park and R.S. Lakes. Biomaterials An Introduction. Plenum Press, New York, 1992.
I.Milne, R.O. Ritcie, B. Karihaloo. Comprehensive Structural Integrity, Vol. 9: Bioengineering. Elsevier Ltd, Oxford, 2003.
D. M. Brunette, P. Tengvall, M. Textor, P. Thomsen, Titanium in Medicine, Springer, Berlin, 2001.
T.L. Anderson, Fracture Mechanics: Fundamentals and Applications 3rd ed. CRC Press, London, 2005.
M. Kojić, N. Filopović, B. Stojanović, N. Kojić, Computer Modeling in Bioengineering. John

Wiley and Sons, Ltd (2008)

Combustion and sustainable development M

ID: 1145
Responsible/Holder professor ALEKSANDAR M. MILIVOJEVIĆ
Teaching profesor(s): MILIVOJEVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

In the light of the fact that currently over 90% of world energy demand is produced by combustion processes, and that in the coming decades is expected that combustion will be the predominant technology for energy production, with a share of over 65%, this course is designed, keeping in mind that the main goal is to prepare students to work in the area of sustainable development and energy, to provide better understanding, accept the findings and enable students to competently participate in solving the problems of sustainable development.

Learning outcomes

After successful completion of this course, students should be able to:
- analyze the challenges posed by the new scenario of the problem of energy and sustainable development,
- master the obtained knowledge to an extent that would allow them to apply combustion technology in both existing and future energy systems and technologies,
- apply the acquired knowledge in this field in the industry and energy sectors,
- work in research and development organizations.

Theoretical teaching

The problem of energy. Energy sources.
Fossil fuels, renewable energy sources, industrial and municipal waste.
Environmental aspects - pollution of air, water and land.
Basics of the combustion process.
Material and energy balances.
Specifics of burning different types of fuel.
The impact on the environment.
The concept of sustainable development.
Complex systems.
Sustainable development in terms of the developed countries.
Specifics for developing countries.
Energy processes and devices based on combustion.
New technologies.

Practical teaching

Practical training shall include practical exercises, laboratory exercises, computational tasks and seminars.

Within auditory exercises will be done more examples of material and energy balance of the combustion process and pollutants, as well as the explanation of the principle of measuring emissions of combustion products. Laboratory classes will include measurements of emissions of polluting components from the combustion process. In the framework of the computational task, students will do an individual task in connection with the material and energy balance of a combustion fuel. Seminar will cover the analysis of the introduction of alternative energy sources, more favorable from the standpoint of sustainable development in a particular energy device or process.

Prerequisites

None.

Learning resources

Handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	3
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	3
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	30	project design	0
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

A. Milivojevic, Subject handouts 2010.
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE 1986.

Combustion appliances

ID: 1147
Responsible/Holder professor ALEKSANDAR M. MILIVOJEVIĆ
Teaching profesor(s): MILIVOJEVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The objective of this course is to provide students with general appliances that use combustion methods.

Learning outcomes

To teach and enable students to understand general combustion appliances and use the knowledge in industrial and energy sectors.

Theoretical teaching

The combustion appliances include burners, burner systems, combustors, furnaces and control systems. Different types of burners including diffusion, atmospheric, premixed with natural and force aerated, porous and thermal radiation types. Mixture preparation for liquid, gaseous and solid fuel types, flame stabilization methods, standards, safety systems.

Practical teaching

Displaying techniques for controlling the operation of various combustion devices.

Prerequisites

No preconditions for attendance

Learning resources

Subject Handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	5

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	2
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	3

seminar works	5	final exam	3
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

A. Milivojevic, Subject handouts 2010.
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE 1986.
Warnatz J., Mass U., Dibble R. Combustion, 2006.

Combustion M

ID: 0971
Responsible/Holder professor DRAGOSLAVA D. STOJILJKOVIĆ
Teaching profesor(s): STOJILJKOVIĆ DRAGOSLAVA; JOVANOVIĆ VLADIMIR; MANIĆ NEBOJŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The objective of the course is for the student to:
acquire basic knowledge about the importance of the combustion process; understand the different definitions of the combustion process; understand the physical and chemical processes that take place during combustion; perceive the most important laws that apply to combustion processes; perceive the thermodynamic basics of the combustion process; understand the material and energy balance of the combustion process; understand the basics of chemical statics and kinetics of thermal processes; perceive the types of chemical reactions that occur in combustion processes; understand the rate of chemical reaction and the influencing parameters; understand the occurrence of chemical equilibrium, its importance in the analysis of the development of chemical reactions and influential parameters; understand the thermal effects of chemical reactions; perceive the thermochemical laws; perceive the physical and physical-chemical phenomena in the combustion process (fuel and oxidizer mixing mechanisms, adsorption and absorption, diffusion); acquire basic knowledge about modeling the combustion process; perceive the classification of the combustion process according to different criteria; understand the processes of ignition, flame propagation and stabilization of the flame front; understand the phenomena and specifics of combustion of gaseous, liquid and solid fuels; review technologies and devices for combustion of gaseous, liquid and solid fuels; understand the formation of toxic components during the combustion process and ways to reduce air pollution.

Learning outcomes

After successfully passing the exam in this course, the student will be able to:
calculate the material and heat balance of the combustion process; determine the types of chemical reactions important for the combustion process; define the most important kinetic parameters for the considered chemical reactions; determine the thermal effect of chemical reactions; perform an analysis of influencing parameters on the development of chemical reactions and kinetic parameters; perceive the methods of fuel ignition and the spread of the flame front; application of available flame stabilization techniques; master flame testing techniques; perform an analysis of the efficiency of the combustion process; make a choice of technology and devices for combustion with the aim of meeting the energy and environmental characteristics; know how to apply available combustion process models; perform a comparison and analysis of the combustion process based on experimental results and modeling results; carry out the determination of toxic components produced during

combustion; choose the best technology for reducing the emission of toxic components; perform an analysis of the impact of the combustion process on the environment.

Theoretical teaching

Thermodynamics basics of the combustion process, general terms, material and energy balance of the process. Basics of chemical statics and kinetics of thermal processes. Rate of chemical reactions. Types of chemical reactions. Chemical equilibrium. Physical and physical-chemical phenomena in the combustion process (adsorption and absorption, diffusion). Laws for transfer phenomena and analogy. Ignition and self-ignition phenomena. Flame front and detonation wave. Flame front speed and stable combustion. Specificities of burning solid, liquid and gaseous fuels. Devices for burning different types of fuel. Basics of modeling the combustion of solid, liquid and gaseous fuels. Environmental aspects of combustion. Causes, mechanisms of formation of toxic components (sulfur oxides, nitrogen oxides, carbon monoxide, solid particles, etc.) and possibilities of prevention. Measures and procedures for reducing the emission of toxic components (primary and secondary procedures).

Practical teaching

Chemical kinetics, solving problems of the rate of chemical reactions and chemical equilibrium in the field of combustion. Heat of formation. Dissociation of combustion products, calculation of amount and composition of combustion products and combustion temperature for different types of fuel. Incomplete combustion, determination of the amount and composition of combustion products and combustion temperature. Laminar flame length, influential parameters, experimental determination. Flame stability limits, definitions and experimental determination. Flammability limits, definitions and experimental determination. Flame front speed, definitions and experimental determination. Devices for measuring the emission of toxic components, classification and operation principles. Measurement of the emission of toxic components from the combustion process and conversion in accordance with the requirements of the standard.

Prerequisites

No special requirements.

Learning resources

Experimental equipment for measuring flammability limits, flame velocity, etc., and laminar and turbulent flame characterization.
Experimental installation for investigation of energy efficiency and pollutants emission from different heating appliances (experimental installation comprised test stove/boiler, flue gas exhaust system, digital weighing scale, and data acquisition system).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	8

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	0

laboratory exercises	20	colloquium, with assessment	0
calculation tasks	2	test, with assessment	5
seminar works	0	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	10	final exam	40
calculation tasks	5		

Requirements to take the exam (number of points) 30

References

Dusan Draskovic, Milan Radovanovic, Miroljub Adzic, Combustion, pp. 278, ISBN: 86-7083-022-1, Faculty of Mechanical Engineering, Belgrade, 1986.
Milan Radovanovic, Handbook for experimental exercises in Combustion, pp. 79, ISBN: 86-7083-023-X, Faculty of Mechanical Engineering, Belgrade, 1986.
Vladimir Jovanovic: Handboolk for experimental exercises in Fuel, Industrial Water and Lubricants, pp.197, ISBN: 978-86-6060-095-2, Faculty of Mechanical Engineering, Belgrade, 2021.
Irvin Glassman, Richard A. Yetter, Nick G. Glumac: Combustion, Elsevier, 5th Edition, 2014, Hardback ISBN: 9780124079137, eBook ISBN: 9780124115552

Design of Welded Structures

ID: 0898
Responsible/Holder professor ZORAN J. RADAKOVIĆ
Teaching profesor(s): RADAKOVIĆ ZORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

After having completed the course, along with the theory and practical classes (through problems and calculation exersizes, seminars etc.), the student acquires the proper academic knowledge and skills in the field of weld design, and stress state analysis of the welded structure. The welded structures of interest are made of steel and aluminium alloys. In addition to the static calculation and design of welded structures, other fields of design include cases of fatigue loading, as well as dynamic loads. Particular design cases also include modern methods in evaluating the residual stresses and strains. Candidates shall be familiar with, and be able to apply their knowledge to real welded structures in exploitation. They should be familiar with modern scientific papers in the field, and are able to fully understand and keep track of scientific articles.

Learning outcomes

Upon the successful completion of the course, the students are able to:
• Identify the loading types of welded structures
• Analyze the stress state of the welded structure (also with the presence of complex loads)
• Solve specific problems of calculating welded structures with both fillet and butt welded joints
• Solve complex stress states, that evolve from a combination of different loading types (tension, bending, shear, torsion, restrained torsion) in both static and dynamic conditions
• Solve problems in the calculation of fatigue loaded welded structures
• Solve problems in the calculation of dynamically loaded (impact) welded structures
• Solve problems in the calculation of welded structures with characteristic member sections – light-weight structures with thin cross sections, both open- and closed profile contour sections
• Solve the implications that may arise in cases of poor design, or as a result of material structural damage
• Connect the acquired knowledge from this field to the knowledge from other fields: engineering materials, mechanics, strength of materials, structural resistance, metal structures, welding technology, with applications in practice

Theoretical teaching

Introduction. Theoretical basis of welded structures. Strength of materials basics. The basics of weld and structural design. Behaviour of welded structures at various types of loading. Design of welded structures in static loading conditions. Design of welded structures in dynamic (fatigue) loading conditions. Stress and strain states. Modern methods for

measuring i determining the residual stress and strain state in the welded structure.

Practical teaching

Static calculation and design of welded structures. Dynamic calculation and design of welded structures. Problem solving, examples, exercises. Application of standard codes for evaluating stress states at various loading types. Calculation of stress and strain states. Deformation and stress measurements. Tensometry and its application to welded structures. Examples of tensometric applications on welded structures with a retrospective view on some existing problems in practice.

Prerequisites

Attended lectures and exercises: Strength of Materials, Mechanics, Resistance of Structures, Basics of Welding, and Engineering Materials 1 and 2.

Learning resources

1. Z. Petkovic, D. Ostric, Metallic Structures in the Machine Building Industry 1, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 1996 (or later). (in Serbian)
2. Z. Perovic, Welded Structures, University of Montenegro, Faculty of Mechanical Engineering, Podgorica, 2002 (or later) (in Serbian)
3. D. Ruzic, Strength of Structures, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
4. Strength of Materials - Tables, Chair/Cabinet of the Theory of Structures, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2000. (in Serbian)
5. Scripts/handouts from class lectures and exercises, and presentations in electronic format.
6. Internet resources.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	15
seminar works	10
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	2
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10

test/colloquium	30	project design	0
laboratory exercises	0	final exam	40
calculation tasks	15		

Requirements to take the exam (number of points) 40

References

Z. Petković, D. Ostrić, Metalne konstrukcije u mašinogradnji 1, izd. Univerzitet u Beogradu, Mašinski fakultet, Beograd, 1996.
Z. Perović, Zavarene konstrukcije, izd. Univerzitet Crne Gore, Mašinski fakultet, Podgorica, 2002
O.W. Blodgett, Design of Welded Structures, Publ. The James F. Lincoln Arc Welding Foundation, 1966.
T. Lassen, N. Récho, Fatigue Life Analyses of Welded Structures, ISTE Ltd, 2006.
Recommandations concernant les structures soudées en aluminium et alliages Al-Mg: doc. IIS/IIW-398-72 - révisé, Institut international de la soudure, Ed. 2, Publications de la Soudure Autogène (1980)

Ecology of combustion

ID: 1146
Responsible/Holder professor ALEKSANDAR M. MILIVOJEVIĆ
Teaching profesor(s): MILIVOJEVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

More than 90% of the world's energy consumption is produced by combustion. It is expected that combustion will still be a prevailing method for energy production in the coming decades. On the other hand, having in mind that combustion is by far the biggest source of pollution, the goal of subject is to enable better understanding of the topic, train and qualify students to become competent experts in this field of international key importance.

Learning outcomes

After successful finishing the course students should be able to:
- recognize and use modern technologies of the combustion processes,
- use techniques for reduction of emission of harmful and polluting combustion products,
- apply the acquired knowledge in combustion in the industry and energy sectors,
- work in research and development organizations.

Theoretical teaching

Combustion basics.Conservation of mass and enery.
Specific topics on combustion of different fuels.
Combustion facilities and their performance.
Biofules.
Co-combustion.
Emissions of polluting and harmful contaminants.
Role of CO2.
Technics to reduce emission of NOx.
Technics to reduce emission of SO2.
Technics to reduce emission of CO and HC.
Technics to reduce emission of particulates.
Technics to reduce emission of heavy metals
Technics to reduce emission of CO2.
CO2 trading.
New technologies. Fuel cells. Hydrogen.

Practical teaching

Practical tuition includes analysis and examples of conservation of mass and enery laws regardding combustion and emissions. Examples of technics to reduce emissions of NOx and SO2 will be treated in particular. Measurements of flue gas emission components will be performed in a purpose built test stand. The effect of influencing parameters on emission

performance of a purposely built burner will be experimentally performed and analyzed. A student will theoretically and numerically solve a problem of mass and energy balance of one of pollution reduction techniques.

Prerequisites

No conditions

Learning resources

Subject Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	3
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	10	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

A. Milivojevic, Subject handouts 2010.
Principles of Combustion (Принципи сагоревања), Kenneth K. Kuo, BARNES & NOBLE 1986.

Engineering materials 3

ID: 0892
Responsible/Holder professor GORDANA M. BAKIĆ
Teaching profesor(s): BAKIĆ GORDANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written+oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The aim of this course is to introduce students to different types of engineering materials and their properties with the goal of understanding and studying the possibility of their application for manufacturing of different elements and constructions. Special attention is devoted to studying the influence of composition, thermical proccesing and processing by plastic deformation on the structure and properties of the material. This course enables possible collabortions with institutes, companies and factories that make and construct engineering materials and deal with their application.

Learning outcomes

Upon the successful completion of the course, students are able to:
- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;
- determine the potential causes of damage;
- perceive the eventual possibilities for preventing the occurrence of damage;
- define the testing programme for detecting damages in mechanical structures;
- prescribe maintenance measures for preventing damage in mechanical structures;
- relate the acquired knowledge to other fields, with practical applications.

Theoretical teaching

Advanced course of Engineering materials. Ferrous and non-ferrous engineering materials and their clasification. Carbon steels, modern steel making processes, ingot casting, casting microstructure, hot and cold working of carbon steels, classification of plane carbon steel, heat treatment, microstructure and properties. Microalloyed steels, precipitation mechanisms, strengthening. Dual-phase steels. Effects of alloying elements on microstructure and properties of alloy steels. Hardenability. Classification of alloy steels. Temper embrittlement in low-alloy steel. Maraging steels. Classification of stainless steels according microstructure, ferritic, martensitic, austenitic, precipitation-hardening stainless steels and duplex stainless steels. Tool steels, classification and properties. High-speed tool steels. Nickel, applications, microstructure, properties. Nickel-based alloys, composition, applications, microstructure, properties.

Practical teaching

Aluminium and its alloys. Classification of aluminium alloys, chemical composition, applications, microstructure, properties. Water-hardening tool steels. Hot-work tool steels. Secondary hardening of tool steels. Heat treatment of high-speed tool steels. Powdered alloy,

sintering. Superalloys. Casting of superalloys. Problems and tasks: calculation of microstructural phase fractions, engineering designing with alloy steels and aluminium steels properties. Titanium and its alloys, applications, microstructure, properties. Magnesium and zinc alloys. Copper alloys.

Prerequisites

Necessary conditions: Engineering materials 1 and 2.
Desired condition: Physics and Strength of material.

Learning resources

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	15
elaboration and examples (revision)	3
active teaching (practical)	**18**
auditory exercises	1
laboratory exercises	2
calculation tasks	7
seminar works	8
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	1
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	25	project design	0
laboratory exercises	0	final exam	30
calculation tasks	15		

Requirements to take the exam (number of points) 35

References

Mechanical materials 2, Radica Prokić Cvetković, Olivera Popović, Gordana Bakić, Miloš Đukić, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2021
Metallography, Hermann Schumann, University of Belgrade, Faculty of Technology and Metallurgy, Belgrade, 1989
W.D.Callister: Materials Science and Engineering, An Introduction, 2000, John Wiley, NewYork
W.Smith: Structure and Properties of Engineering Alloys, 1993, McGrow-Hill,Inc
/

Fracture mechanics and structural integrity

ID: 1446
Responsible/Holder professor NENAD Z. MILOŠEVIĆ
Teaching profesor(s): MILOŠEVIĆ NENAD; SEDMAK ALEKSANDAR; RADAKOVIĆ ZORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The objectives of the course are that students, after completing theoretical classes in fracture mechanics, as well as maximum engagement in practical classes (through laboratory exercises, calculation tasks, seminar papers, etc.), become competent in the field of structural integrity and acquire appropriate academic skills. they also develop creative abilities and master the specific practical skills needed to practice the profession.

Learning outcomes

By mastering the study program, provided by the curriculum, the student is able to solve specific problems of structural integrity, as well as to see the possible consequences that may occur in case of poor solutions. The student is also able to connect the acquired knowledge in this field with other areas and apply them in practice.

Theoretical teaching

Theoretical classes: Introduction. Fundamentals of fracture mechanics. Stresses and strains in the body with a crack. Linear elastic and elasto-plastic fracture mechanics. Fracture mechanics parameters. Stress intensity factor, crack tip opening, J integral. Application of fracture mechanics to structural integrity assessment. Welded joint as a crack site. Integrity of welded structures. Estimates in the domain of elasticity and elasto-plasticity. Crack growth force with respect to material resistance curves.

Practical teaching

Practical classes: Determining the parameters of fracture mechanics in the elastic and elasto-plastic areas. Experimental, numerical and analytical methods. Standard procedures for measuring fracture mechanics parameters, such as material properties. Fracture analysis diagram and its application to welded joints and structures. Assessment of the integrity of a given construction using all acquired knowledge.

Prerequisites

necessary: Mechanical materials 1 and 2, Material resistance, Mechanics, Fundamentals of structural resistance

Learning resources

[1] Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	4
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	35
calculation tasks	30		

Requirements to take the exam (number of points) 30

References

A. Sedmak, Application of fracture mechanics to the assessment of structural integrity, 2003 monograph, Faculty of Mechanical Engineering, Belgrade, language: Serbian
N. Milošević, Handouts from lectures, 2022. electronic version, Faculty of Mechanical Engineering, Belgrade, language: Serbian

Fuel, Lubricants and Industrial Water 2

ID: 0893
Responsible/Holder professor VLADIMIR V. JOVANOVIĆ
Teaching profesor(s): JOVANOVIĆ VLADIMIR; STOJILJKOVIĆ DRAGOSLAVA; MANIĆ NEBOJŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

Fuel types. Stoichiometric combustion equations. Combustion temperature. Characterization of solid fuels, technical and fundamental analysis. Solid fuel origins, derivation, applications. Liquid fuels, origins, derivation, applications. Gaseous fuels, origins, derivation, applications. Lubricants, types and main characteristics, applications. Industrial water, types and properties. Essential characteristics of the water for industrial purposes. Problems in the use of natural waters. Water treatment for industrial applications.

Learning outcomes

Upon completion of this course students should be able to:
1 Define the concept of fuel, the criteria for the characterization of fuel and fuel types according to the adopted criteria, calculate the amount and composition of the combustion products and combustion temperature.
2 Define basic characteristics of solid fuels: moisture content, mineral content, the volatile content, carbon residue content, heating value.
3 Define basic characteristics of liquid fuel: behavior at elevated temperatures, behavior of low temperatures, density, water content and mechanical impurities, volatility, viscosity, resistance to detonation and inflammability.
4 Define the role of lubricants in engineering and basic characteristics of them
5 Define the role of water for industrial applications and the most important characteristic: hardness and acidity.

Theoretical teaching

The concept of fuel. Fundamentals of combustion, the stoichiometric equations. Calculation of the quantity and composition of combustion products. The combustion temperature, types and methods of calculation. Solid fuels, origins, procedures for derivation and application. Liquid fuels, origins, procedures for derivation and application. Gaseous fuels, origins, procedures for derivation and application. Lubricants: lubricants types, main characteristics relevant for application, the application of lubricants. Industrial water: water types and basic characteristics. Preparation of water for industrial applications, methods.

Practical teaching

The conversion from one to another mass of solid fuel. Calculation of heating value of the fuel. Elements of stoichiometry. Combustion temperature . Determination the characteristics of proximate analysis of solid fuels. Determination of heating value of solid and liquid fuels

with a bomb calorimeter and the determination of heating value of gaseous and liquid fuels with Junkers calorimeter. Determination of the distillation curve. The significance of the main temperature on distillation curve. Characteristics of fuels at elevated and reduced temperatures. Quality control. Determination of the viscosity of liquid fuels and lubricants (dynamic, kinematic viscosity and relative). Determination of the basic characteristics of grease. Determination of water hardness and acidity.

Prerequisites

No special requirements.

Learning resources

Laboratory equipment for the characterization of solid and liquid fuels:
Calorimeter IKA C200,
Device for determining the ignition temperature of liquid fuels according to the Pensky-Martens method,
Analytical scales for mass measurement,
Dryers,
Muffle furnace

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	7
elaboration and examples (revision)	5
active teaching (practical)	**12**
auditory exercises	3
laboratory exercises	9
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	1
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	1
test, with assessment	1
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	10	final exam	40
calculation tasks	5		

Requirements to take the exam (number of points) 20

References

Milan Radovanović: Fuels, Faculty of Mechanical Engineering, University of Belgrade, 1986 , ISBN-86-7083-246-1
Milan Radovanović: Industrial Water, Faculty of Mechanical Engineering, University of Belgrade, 1996, ISBN-86-7083-278-X
Aleksandar Rac: Lubricants and machine lubrication, Academic Mind, 2007, ISBN-978-86-7083-595-5
Vladimir Jovanović: Handbook for laboratory exercises in Fuel, Lubricants and Industrial Water, Faculty of Mechanical Engineering, University of Belgrade, 2021 , ISBN-978-86-6060-095-2

Quality assurance and quality control of welded joints

ID: 0720
Responsible/Holder professor MILOŠ Z. ĐUKIĆ
Teaching profesor(s): ĐUKIĆ MILOŠ; BAKIĆ GORDANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The aim of this course is for students to become competent in the area of quality assurance and quality control of welded joints and welded structures. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing.

Learning outcomes

After fulfilling all the course requirements, as prescribed by the course plan, the student is capable of applying the acquired knowledge to:

•Explain the importance of quality assurance (QA) and quality management (QM) of welded structures.
• Describes and to distinguish between different types of welded joint defects/imperfections/cracks.
• Defines possible causes for certain types of welded joint defects/imperfection/cracks.
• Defines the quality control plan for welding joints and welded structures.
• Apply quality control plan, QA and QM in the case of different welded structures.
• Defines specification and qualification of welding procedures for metallic materials.
• Connect the acquired knowledge in this field with other areas and applies them in practice.

Theoretical teaching

The concept and importance of the quality of welded construction. Quality assurance (QA) and quality management (QM) of welding construction. Quality requirements for fusion welding of metallic materials. Welded joint defects/imperfection. Causes of defects. Clasification of defects and analysis of different types of defects. Fusion welding and allied processes - classification of geometric imperfections in metallic materials. Typical forms and causes of certain types of welded joint defect. Quality assurance and inspection of welds and welded construction. Welding coordination - tasks and responsibilities. Welding quality control plan. Qualification test of welders - fusion welding. The procedure for design of welded construction. Specification and qualification of welding procedures for metallic materials. Weld cracking, classification, main causes. The methodological approach to the analysis of weld cracking. Hot Cracks. Cold cracks. Lamellar tearing. Weld post weld heat treatment cracks. Fusion welding – quality level for imperfection. Levels of quality assurance. Nondestructive Evaluation of welded joint and quality control.

Practical teaching

Recapitulation - welded joints basic types, elements, forms of and marking. Clasification of welded joint defects. Practical examples of welded joint defects. Analysis of macro and microstructure of welded joints. Preparation of Welder qualificitaion certificate. Preparation of welding procedure specification (WPS). Preparation of welding procedure qualification record (WPQR). Fusion welding – quality level for imperfection (practical exercises). Exercises in welding shop – welded joint defects analysis. Characterization of welded joints. Fusion welding - quality level for imperfection. Assessment of imperfections. Acceptance criteria for welds and examination methods for evaluating weld. Influence of welding shape defects, lack of fusion and other defects onto appearance of damage of welded joints. Office hours.

Prerequisites

Necessary conditions for a student to attend this course are: attended course lectures and finished exercises of Engineering materials 2.

Learning resources

1. Mechanical materials 1, R.P. Cvetkovic, O. Popovic, University of Belgrade, Mechanical Faculty, Belgrade, 2012
2. Mechanical materials 2, Radica Prokić Cvetković, Olivera Popović, Gordana Bakić, Miloš Đukić, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2021.
3. Welding procedures, O. Popović, R.P. Cvetković, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2016
4. Basic mechanisms of mechanical structures damages, Gordana Bakić, Miloš Đukić, Vera Šijački Žeravčić, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2021

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	8
calculation tasks	7
seminar works	10
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	1
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15

test/colloquium	35	project design	0
laboratory exercises	10	final exam	30
calculation tasks	5		

Requirements to take the exam (number of points) 40

References

ASM Metals HandBook Volume 06 - Welding Brazing and Soldering v1, 1993
ASM Metals HandBook Volume 17 - Nondestructive Evaluation And Quality Control v3, 1998
ASM Metals HandBook Vol 08 - Mechanical Testing and Evaluation, 2000

Service Properties of Welded Joints

ID: 0719
Responsible/Holder professor GORDANA M. BAKIĆ
Teaching profesor(s): BAKIĆ GORDANA; ĐUKIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The aim of this course is for students to become competent in the area of the analysis the current state of metal during service as well as failure and fracture of welded joints. They should also develop appropriate academic skills and creativity and master practical skills needed for the profession. This course is designed to provide information through theoretical lectures but also through laboratory type (practical) exercises, computational classes and seminar papers students are responsible for writing.

Learning outcomes

Upon the successful completion of the course, students are able to:
- solve specific problems in the fields of detecting and recognizing damages in metallic structures and welded joints in particular;
- determine the potential causes of damage;
- perceive the eventual possibilities for preventing the occurrence of damage;
- define the testing programme for detecting damages in mechanical structures;
- prescribe maintenance measures for preventing damage in mechanical structures;
- relate the acquired knowledge to other fields, with practical applications.

Theoretical teaching

Introduction.Fractures. Service properties of welded joints. Mechanical properties. Microstructural properties. Long term exploitation. Stress state. Mechanisms and causes of damage. Types of damage. Dissimilar joints. Corrosion. Damage caused by working conditions and combination of different sources. Damage and defects. Creep. Fatigue. Combination of creep and fatigue. Erosion and abrasion. Analytical diagnostic. Modern maintenance concepts and metal damage monitoring during service.

Practical teaching

Fracture. Characterization of welded joints. Mechanical properties. Microstructural properties.Metallography. Types of damage generaly as well as of welded joints. Corrosion. Examples of corrosion damage. Damage caused by environment and combination of different sources. Creep. Creep damage. Microstructural degradation. Deformation and fracture maps. Fatigue. Combination of creep and fatigue. Erosion and abrasion. Criteria for replacements and reparation of welded joints. Technical regulations. New steels for high temperatures.

Dissimilar joints. Analytical diagnostic. Reports. Modern maintenance concepts and metal damage monitoring during service.

Prerequisites

Necessary conditions for a student to attend this course are: attended course lectures and finished exercises of Engineering materials 2.

Learning resources

Structural Engineering HandBook - Fatigue & Fracture, 1999
ASM Metals HandBook Volume Special - Heat-Resistant Material
ASM Metals HandBook Vol 13 - Corrosion, 1987

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	10
calculation tasks	5
seminar works	10
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	40	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Basic mechanisms of mechanical structures damages, Gordana Bakić, Miloš Đukić, Vera Šijački Žeravčić, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2021
ASM Metals HandBook Vol 11 - Failure analysis and preventions, 1986
ASM Metals HandBook Vol 08 - Mechanical Testing and Evaluation, 2000
ASM Metals HandBook Vol 09 - Metallography And Microstructures, 1985
ASM Metals HandBook Vol 10 - Materials Characterization, 1986

Skill praxis M - ZZK

ID: 1447
Responsible/Holder professor NENAD Z. MILOŠEVIĆ
Teaching profesor(s): RADAKOVIĆ ZORAN; PROKIĆ-CVETKOVIĆ RADICA; POPOVIĆ OLIVERA; BAKIĆ GORDANA; ĐUKIĆ MILOŠ; SEDMAK ALEKSANDAR; MILOŠEVIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The goals of the course are that students, after completing theoretical classes, are maximally engaged in conducting practical professional classes. The goal is for students to become competent in the field of welding and acquire appropriate academic skills, as well as develop creative abilities and master the specific practical skills needed to perform the profession.

Learning outcomes

By mastering the study program, provided by the curriculum, the student is able to solve specific problems from practice, as well as to see the possible consequences that may occur in case of poor practical solutions. The student is also able to connect the acquired knowledge from different fields and apply them in practice.

Theoretical teaching

Introducing students to problems in practice.

Practical teaching

Performing professional practice, individually in the selected company. Writing a report after completing an internship.

Prerequisites

Attended lectures and exercises in the subject Mechanical Materials 1 and 2, Welding Procedures B (M), Welding Metallurgy, Welding Technologies

Learning resources

[1] Handouts [2] Excerpts from the standard

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0

active teaching (practical)	**0**	check and assessment of seminar works	70
auditory exercises	0	check and assessment of projects	0
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	20
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

N. Milošević, Skill praxis M, 2022. electronic edition, Faculty of Mechanical Engineering, Belgrade, language: Serbian
Плавшић Н., Шијачки-Жеравчић В., Стаменић З.: Таблице машинских материјала, профила, лимова и жица, Машински факултет, Београд, 2004;

Tribological systems

ID: 0537
Responsible/Holder professor ALEKSANDAR A. VENCL
Teaching profesor(s): VENCL ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The student attending this course should:
• Comprehend the issue and the importance of tribological processes in the most important machine elements (slide bearings, roller bearing, gear pairs, guides, seals, etc.);
• Master the calculation methods for tribological elements using the modern lubrication theories;
• Make decisions on selection of the type of lubrication and lubricants for lubrication of the major mechanical elements.

Learning outcomes

Based on the mastered knowledge the student is qualified to:
• Recognize the basic parameters that impact the tribological properties of some system, as well as to explain their impact;
• Exterminates the basic mechanical systems from the tribological point of view by analyzing the structure of tribological systems;
• Propose the solutions for problems originate from the friction and wear process;
• Recognize the dominant type of wear in plain and roller bearings, gears, cam mechanisms, elements with linear reciprocating motion and dynamic seals;
• Applies methods for the calculation of working and tribological characteristics of considered tribological system;
• Select materials, lubricants and lubrication mode for the considered tribological systems.

Theoretical teaching

• Definition of the tribological systems; Tribological characteristics of the mechanical systems.
• Bearings – purpose and types; Preliminary selection of bearing types; Reynolds equation.
• Sliding bearings (hydrodynamic, hydrostatic, sintered and self-lubricated); Calculation of: friction, minimum lubricant film thickness, lubricant flow, bearing load and oil or surface temperature; Selection of lubricants and lubrication procedures.
• Roller bearings; Calculation of: friction, minimum lubricant film thickness and oil temperature; Selection of lubricants and lubrication procedures.
• Gear pairs tribology – the influence of lubrication on the reliability and efficiency; Calculation of: friction, minimum lubricant film thickness, oil temperature, etc.; Selection of lubricants and lubrication procedures.
• Cam mechanisms tribology – materials and tribological characteristics; Selection of lubricants and lubrication procedures.

• Elements with reciprocating linear motion (piston-piston ring-cylinder system, slide ways and guides) – materials and tribological characteristics; Selection of lubricants and lubrication procedures.
• Dynamic seals – type, purpose and materials; Calculation of the tribological characteristics; Selection of lubricants and lubrication procedures.

Practical teaching

• Lubricants – role, type, classification and basic properties; Rheology of lubricants; Forms and types of lubrication.
• Examples for sliding bearings (hydrodynamic, hydrostatic, sintered and self-lubricated) tribological characteristics calculation.
• Examples for rolling bearings tribological characteristics calculation.
• Examples for gear pairs and cam mechanisms tribological characteristics calculation.

Prerequisites

No special requirements.

Learning resources

1. --, Handouts for each lecture.
2. A. Rac, Fundamentals of Tribology, Faculty of Mechanical Engineering, Belgrade, 1991, (in Serbian).
3. A. Rac, Lubricants and Machine Lubrications, Faculty of Mechanical Engineering, Belgrade, 2007, (in Serbian).
4. A. Rac, A. Vencl, Sliding Bearing Metallic Materials – Mechanical and Tribological Properties, Faculty of Mechanical Engineering, Belgrade, 2004, (in Serbian).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	17
discussion and workshop	13
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0

test/colloquium	40	project design	25
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

D. Dowson, G.R. Higginson, Elasto-hydrodynamic lubrication, Pergamon Press, Oxford, 1977.
T.A. Harris, Rolling Bearing Analysis, John Wiley & Sons, New York, 1984.
R.J. Welsh, Plain Bearing Design Handbook, Butterworths, London, 1983.
W.B. Rowe, Hydrostatic and Hybrid Bering Design, Butterworths, London, 1983.
W.A. Gross (Ed.), Fluid film lubrication, John Wiley & Sons, New York, 1980.

Tribology

ID: 0519
Responsible/Holder professor ALEKSANDAR A. VENCL
Teaching profesor(s): VENCL ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The student attending this course should:
• Comprehend the significance of friction, wear and lubrication (tribology keywords) and the problems connected with it, the field of construction and maintenance of mechanical parts and systems;
• Master the fundamental knowledge in these areas of tribology in order to decide the merits of the choice of materials and lubricants for the construction and tribological components;
• Solve problems related to the prevention of wear and competently decide on techniques to improve tribological properties of materials and lubrication technologies.

Learning outcomes

Based on the mastered knowledge the student is qualified to:
• Identifies and critically analyze the basic causes of energy and material dissipation in some mechanical system;
• Recognize the dominant type of wear in some mechanical system and to propose appropriate measures for its reduction;
• Choose the appropriate type of material for the basic tribological elements (plain bearings, roller bearings and gears);
• Describes and distinguishes the most common surface modification and coating deposition methods;
• Explain the influences of temperature and pressure on the value of the viscosity (lubricants rheology);
• Describes and distinguishes the basic types and methods of lubrication with their characteristics.

Theoretical teaching

• Tribology as a science and technical disciplines and techno-economical importance of tribology.
• Properties of surfaces and the nature of contact of two bodies.
• Friction – the basic causes and principles; Friction of metals and non-metals.
• Wear – mechanisms and types; Wear calculation and measuring methods; Wear prevention.
• Tribological materials (types and application in tribology); Characteristics and selection of materials for tribological components.
• Technologies for improving the tribological properties of materials (surface modifications and coatings).
• Lubricants – role, type, classification and basic properties; Rheology of lubricants.

• Forms and types of lubrication; Hydrostatic, hydrodynamic, elastohydrodynamic and boundary lubrication.
• Lubrication systems (tasks and roles; procedures and classification; elements definition) and lubricants selection.
• Lubrication services organization and lubricants ecology.

Practical teaching

• Tribological losses in the industry and transportation; Tribological improvements studies.
• Characterization of the tribological surfaces; Methods and apparatus for surface roughness measuring; Surface roughness standards; Influence of material processing and machining on the surface roughness; Properties of surface layers.
• Presentation of worn surfaces and machine parts failure due to wear, and wear products (debris).
• Examples of different solutions for improving the tribological properties of materials.
• Laboratory practice: "Experimental evaluation of roughness, friction and wear"; Measuring of roughness and coefficient of friction and wear values for different materials and test conditions.
• Classifications and specifications of lubricants; Methods for lubricants testing.
• Laboratory practice: "Experimental investigation of the rheological properties of lubricants"; Determination of the rheological properties of lubricating oils (viscosity, viscosity-temperature dependence, viscosity index) and greases (shear stress and shear rate gradient, apparent viscosity).
• Essay writing.

Prerequisites

No special requirements.

Learning resources

1. --, Handouts for each lecture.
2. A. Rac, Fundamentals of Tribology, Faculty of Mechanical Engineering, Belgrade, 1991, (in Serbian).
3. A. Rac, Lubricants and Machine Lubrications, Faculty of Mechanical Engineering, Belgrade, 2007, (in Serbian).
4. A. Rac, A. Vencl, Sliding Bearing Metallic Materials – Mechanical and Tribological Properties, Faculty of Mechanical Engineering, Belgrade, 2004, (in Serbian).
5. Pin-on disc tribometer; Block-on-ring disk tribometer; Four Ball machine.
6. Viscometer for liquid lubricants; Pressure grease viscometer.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING		**OTHER**	
active teaching (theoretical)	**30**	**knowledge checks**	**15**
lectures	20	assessment of calculation tasks	0
elaboration and examples (revision)	10	check and assessment of lab reports	2
active teaching (practical)	**30**	check and assessment of seminar works	4
auditory exercises	0	check and assessment of projects	0
laboratory exercises	12	colloquium, with assessment	0

calculation tasks	0	test, with assessment	4
seminar works	5	final exam	5
project design	0		
discussion and workshop	13		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10
test/colloquium	45	project design	0
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

B. Ivković, A. Rac, Tribology, Yugoslav Tribology Society, Kragujevac, 1995 (in Serbian).
J. Halling, Principles of Tribology, The MacMillan Press Ltd., London, 1975.
D.F. Moore, Principles and Applications of Tribology, Pergamon Press, Oxford, 1975.
B. Bhushan, Principles and Applications of Tribology, John Wiley & Sons, New York, 1999.
A.R. Lansdown, Lubrication – A Practical Guide to Lubricant Selection, Pergamon Press, Oxford, 1982.

Welding metallurgy

ID: 0901
Responsible/Holder professor RADICA M. PROKIĆ-CVETKOVIĆ
Teaching profesor(s): PROKIĆ-CVETKOVIĆ RADICA; POPOVIĆ OLIVERA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The aim of this course is for students to become competent in the areas of materials and welding and also to develop appropriate academic skills needed for the future profession. This course is designed to provide informations through theoretical lectures, computational classes, seminar papers and through welding workshop practice.

Learning outcomes

Upon the successful completion of the course, the students are able to:
•Understand the distribution of temperature in the material during welding, and the influence of heat input on metal solidification
•Name all possible types of cracking (hot-, cold-, lamellar-, and reheat cracking) that may appear in the welding process, and to be able to differentiate between them
•Understand the metallurgical aspects of various steel classes (carbon-, low alloyed, high alloyed, stainless), and select the proper welding technique and appropriate welding consumables
•Understand the metallurgical aspects of weldability of different types of non-ferrous metals and alloys (Al and Al alloys; Cu and Cu alloys; Ni and Ni alloys; Ti, Zr, Mg and their alloys)
•Understand the metallurgical aspects of the weldability of heterogeneous metals
•Apply the concept of predicting crack appearance in the welded joint depending on the type of material and welding technology, in the goal to avoid the occurrence of damage and failure

Theoretical teaching

Introduction. Physical basics of welding. Chemical reactions during welding. Welding thermal processes. Cracking phenomena in welded joints. Heat treatments of welded joints and CCT diagrams. Introduction to welding metallurgy of steels. The weldability of unalloyed and high strength steels. Welding of creep resistant steels and steels for cryogenic and low temperature services. Welding of stainless and heat resistant steels. Welding of nonferous materials.

Practical teaching

Residual stresses and distortions of welds. Structural changes in welded joints. Application of CCT diagrams. Heat treatment of welded joints. The weldability of different grade steels - Carbon equivalent (CE), Cr and Ni equivalents. Welding discontinuities and defects. Testing of welded joints. Joining of dissimilar materials. Welding of nonferous materials: Al, Cu, Ni, Ti,

Mg, Zr, Ta and their alloys. Welding of cast irons and steels. Processes of joining nonmetalic materials (plastics, ceramics and composites). Practice in welding workshop.

Prerequisites

Passed exams in Engineering materials 1 and Engineering materials 2. Attended course - Welding processes.

Learning resources

1. A Sedmak, V. Sijacki Zeravcic, A. Milosavljevic, V. Djordjevic, M. Vukicevic, Engineering materials, second part, Faculty of Mechanical Engineering, Belgrade, 2000.
2. V. Sijacki Zeravcic, A. Milosavljevic, A Sedmak, Manual for Engineering materials – Welding, Brazing and Casting, Faculty of Mechanical Engineering, Belgrade, 1996.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	22
elaboration and examples (revision)	8
active teaching (practical)	**30**
auditory exercises	2
laboratory exercises	9
calculation tasks	4
seminar works	15
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10
test/colloquium	50	project design	0
laboratory exercises	5	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

B. Sabo at all, Weldability stainless steels, N. Sad, 1995.
i. Hrivmjak, Weldability steels, Gradjevinska knjiga, Belgrade, 1982.
S. Kou, Welding Metallurgy, second edition, 2003.

Welding processes M

ID: 0899
Responsible/Holder professor OLIVERA D. POPOVIĆ
Teaching profesor(s): POPOVIĆ OLIVERA; PROKIĆ-CVETKOVIĆ RADICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

The aim of this course is for students to become competent in the area of welding. This course is designed to provide information through theoretical lectures, computational classes and seminar papers, but also through welding workshop practice. They should also develop appropriate academic skills needed for the profession and become informed with the specificity of each welding process and appropriate equipment.

Learning outcomes

Upon the successful completion of the course, the students are able to:
-Detail the differences between welding processes according to their characteristics
-Detail the rang of application, appropriate joint preparations and potential problems to be overcome
-Understand fully the fundamental physics of an electric arc, including the main parameters influencing arc stability
-Explain fully the principles of welding processes including transfer modes and their applications
-Explain the purpose and working principle of each component of the equipment
-Identify the influence of welding parameters on weld quality
-Choose appropriate welding process, power source, parameters and filler material for particular applications and materials
-Predict potential hazards and define methods for safe handling of welding equipment

Theoretical teaching

Introduction. Classification of welding processes. Basic terms in welding. Gas welding. Characteristics of fuel gases. Basics of electricity and electronics. Magnetism in welding. Theory of electric arc. Welding power sources characteristics. Manual metal arc welding. Introduction to gas shielded arc welding. Gas metal arc welding (MIG/MAG). High efficiency MIG/MAG processes. Flux cored arc welding. Gas tungsten arc welding (TIG). Special techniques of TIG (spot welding, key-hole, hot-wire, orbital welding). Submerged arc welding. Resistance welding processes. Special welding processes (laser, electron beam, plasma). Survey of other welding processes:electro-slag, friction, friction stir, ultrasonic, explosive, diffusion, aluminothermic, cold-pressure, magnetic pulse, high-frequency welding. Cutting processes. Mechanical cutting. Gas cutting. Other cutting processes:arc-air, carbon and metal-arc, oxy-arc, plasma, electron beam, laser cutting, water jet. Surfacing. Spraying.Brazing and soldering. Bonding.

Practical teaching

Symbolic representation of joints. Classification and designation of MMA electrodes. Calculation of consumption of electrodes for manual metal arc welding. Estimation of parameters for MIG/MAG process. Practice in the welding workshop. Equipment for arc welding processes. Equipment for resistance welding, gas welding and cutting. Fully mechanised welding processes. Robotics. Risks, hazards and methods of safe handling and working. Project papers in the field of contemporary trends and special procedures of welding, soldering and bonding. Workshop.

Prerequisites

Attended course lectures and finished exercises of Engineering materials 1 and Engineering materials 2.

Learning resources

1. O.Popović, R.Prokić Cvetković, Welding processes, Faculty of Mechanical Engineering, Belgrade, 2016.
2.A.Sedmak, V.Šijački-Žeravčić, A.Milosavljević, V.Đorđević, M.Vukićević, Engineering materials, Second part, Faculty of Mechanical Engineering, Belgrade, 2000.
3. R.Prokić-Cvetković, O.Popović, Welding and related processes, Serbian state publisher of textbooks, Belgrade, 2011
4.V.Šijački-Žeravčić, A.Milosavljević, A.Sedmak, Manual for engineering materials-welding, brazing and casting, Faculty of Mechanical Engineering, Belgrade,1996.
5. Lectures

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	15
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10
test/colloquium	45	project design	0
laboratory exercises	10	final exam	30

calculation tasks	0

Requirements to take the exam (number of points) 35

References

W. Galvery, F.Marlow, Welding Essentials: Questions and answers, Industrial Press, Inc., New York, 2007
S.Kou, Welding metallurgy, John Wiley&Sons, 2nd.ed., New Jersey, 2003
S.Kalpakjian, S.R.Schmid, Manufacturing engineering and technology, Pearson Education, 2006.
K.Weman, Welding processes handbook, Woodhead Publishing Ltd, 2003.
D. Geary, Welding, McGraw-Hill, 2000

Welding technology

ID: 1445
Responsible/Holder professor NENAD Z. MILOŠEVIĆ
Teaching profesor(s): MILOŠEVIĆ NENAD; SEDMAK ALEKSANDAR; PROKIĆ-CVETKOVIĆ RADICA; BAKIĆ GORDANA; POPOVIĆ OLIVERA

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: engineering materials and welding, tribology, fuels and combustion

Goals

Understanding the basic principles of welding technology development as a prescribed flow of activities to be followed when making each welded joint in the structure. Introducing students to the techniques of material selection, preparation, thermal cycle of welding, methods of ensuring and controlling the quality of welding and possible subsequent activities, subsequent heat treatment. Understanding and making examples of welding technology. Development of independent work by making and presenting selected seminar papers.

Learning outcomes

By attending the course, the student masters the basic skills and principles for the development of welding technology for a specific case. Theoretical considerations, as well as computational examples allow the student to master all the necessary principles of welding technology needed to make different types of welded joints. Introducing students to the existing modern standards and recommendations in the field and developing a critical way of thinking about them.

Theoretical teaching

Introduction to the basic principles of welding technology. Defining the previous welding procedure specification (pWPS). Qualification of previous welding procedure specification (WPQR). Welding procedure specification (WPS) - analysis of documents defined by the standard and necessary to contain data on the manufacturer, base material, welding procedure and position, joint preparation, groove and groove edges, welding technique, additional material, all welding parameters, preheating temperature and interlayer temperature ... Heat treatment after welding. Welding sequence. Qualification of welders - analysis of standard EN 287-1 which includes the principles on which the test of professional competence of welders for fusion welding of steels is based ...

Practical teaching

Classroom exercises with examples of tasks from welding technology. Preparation of preliminary specification of welding technology - examples include different types and thicknesses of base material, welding procedure and position. Development of tasks from the qualification of welding technology - examples include different types and thicknesses of basic material, welding procedures and positions, as well as the method of qualification. Presentation and defense of selected seminar papers.

Prerequisites

necessary: Mechanical materials 1,2,3; Basics of welding B (M); Welding metallurgy

Learning resources

[1] Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	5
seminar works	10
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	3
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	55
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 30

References

Radaković, Z., Kalaba, D., Sedmak A., 2016. Welding technology: practicum, Faculty of Mechanical Engineering, Belgrade, language: Serbian
Prokić Cvetković R., Popović, O., 2019. Welding metallurgy, Faculty of Mechanical Engineering Belgrade, language: Serbian
Popović, O., Prokić Cvetković, R., 2020. Welding procedures, Faculty of Mechanical Engineering Belgrade, language: Serbian
Milošević N., Excerpts from lectures, 2022. electronic edition, Faculty of Mechanical Engineering, Belgrade, language: Serbian

FLUID MECHANICS

Computational Fluid Dynamics (CFD)

Computational Fluid Mechanics

Fluid Mechanics 1

Fluid Mechanics M

Gas Dynamics

Microfluidics and Nanofluidics

Multiphase flow

Multiphase flow M

Transport of fluid through pipes

Computational Fluid Dynamics (CFD)

ID: 1559
Responsible/Holder professor ALEKSANDAR S. ĆOĆIĆ
Teaching profesor(s): ĆOĆIĆ ALEKSANDAR; RADENKOVIĆ DARKO; RAKOVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: fluid mechanics

Goals

Student should gain basic theoretical knowledge and principles of computational fluid dynamics (CFD), to be able to perform basic numerical calculations by using CFD methods, and to learn to use open-source CFD software OpenFOAM.

Learning outcomes

Upon successful completion of the course, students will be able to:
- explain the general principles of numerical solution of governing equations for fluid flow
- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow
- explain and apply principles of numerical grid generation
- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)
- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in various domains
- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow

Theoretical teaching

Basic ideas and principles in CFD. Analysis of various forms of fundamental equations of fluid motion. Types of partial differential equations (PDE). Boundary conditions for PDEs. Finite difference method. Approximation of PDEs by finite differences. Explicit and implicit methods of discretization. Stability of explicit and implicit methods. Methods for solving systems of linear algebraic equations. Finite volume method (FVM). Disretization of fundamental equations of fluid motion in FVM. Domain discretization - grid generation. Structured, block-structured and unstructured grid. Criteria for determination the grid quality. Numerical solution of Navier-Stokes equation. Basic principles of modelling and solution of turbulent flow. Basics of CFD based on finite element method.

Practical teaching

GNU/Linux operating system. Work in terminal (shell) and BASH environment. Python programming language. Numerical solution of Coutte flow using finite difference method (FDM), with explicit and implicit methods of discretization. Implementation in Python code.

Numerical solution of hyperbolic PDE by methods of characteristics - water hammer problem. Implementation in Python code. Advanced software for postprocessing - paraview. Numerical solution of two-dimensional Laplace equation using FDM. Implementation in Python code. Finite volume method (FVM). Numerical solution of steady diffusion and convection-diffusion problems by FVM. Methods of convective term discretization: upwind, central and hybrid scheme. Implementation in Python code. Structure and code of OpenFOAM. Mesh generation in OpenFOAM: blockMesh, snappyHexMesh and cfMesh. Solution of diffusion problems in various domains with OpenFOAM. Solution of incompressible viscous fluid flow with OpenFOAM.

Prerequisites

Passed exam Fluid Mechanics M.

Learning resources

https://wiki.openfoam.com/Main_Page

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	0	final exam	50
calculation tasks	20		

Requirements to take the exam (number of points) 0

References

Anderson J. Computation Fluid Dynamics, The Basics With Applications, McGraw Hill Series in Aeronautical and Aerospace Engineering
Versteeg H., Malalasekera, An Introduction to Computational Fluid Dynamics - The Finite Volume Method, Pearson Prentice Hall

Computational Fluid Mechanics

ID: 0939
Responsible/Holder professor ALEKSANDAR S. ĆOĆIĆ
Teaching profesor(s): ĆOĆIĆ ALEKSANDAR; RADENKOVIĆ DARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: fluid mechanics

Goals

Student should gain basic theoretical knowledge and principles of computational fluid dynamics (CFD), to be able to perform basic numerical calculations by using CFD methods, and to learn to use open-source CFD software OpenFOAM

Learning outcomes

Upon successful completion of the course, students will be able to:
- explain the general principles of numerical solution of governing equations for fluid flow
- explain and apply finite difference and finite volume methods for discretization of governing equations for fluid flow
- explain and apply principles of numerical grid generation
- use Python programming language for solution of modeled equation of fluid mechanics (1D and 2D heat equation, 1D wave equation, Burgers equation)
- use OpenFOAM solvers for determining the solution of 3D Laplace and convection-diffusion equation, and laminar incompressible flow in various domains
- explain general principles in turbulence modeling and apply turbulence models in OpenFOAM on specified cases of turbulent flow

Theoretical teaching

Basic ideas and principles in CFD. Analysis of various forms of fundamental equations of fluid motion. Types of partial differential equations (PDE). Boundary conditions for PDEs. Finite difference method. Approximation of PDEs by finite differences. Explicit and implicit methods of discretization. Stability of explicit and implicit methods. Methods for solving systems of linear algebraic equations. Finite volume method (FVM). Disretization of fundamental equations of fluid motion in FVM. Domain discretization - grid generation. Structured, block-structured and unstructured grid. Criteria for determination the grid quality. Numerical solution of Navier-Stokes equation. Basic principles of modelling and solution of turbulent flow. Basics of CFD based on finite element method.

Practical teaching

GNU/Linux operating system. Work in terminal (shell) and BASH environment. Python programming language. Numerical solution of Coutte flow using finite difference method (FDM), with explicit and implicit methods of discretization. Implementation in Python code.

Numerical solution of hyperbolic PDE by methods of characteristics - water hammer problem. Implementation in Python code. Advanced software for postprocessing - paraview. Numerical solution of two-dimensional Laplace equation using FDM. Implementation in Python code. Finite volume method (FVM). Numerical solution of steady diffusion and convection-diffusion problems by FVM. Methods of convective term discretization: upwind, central and hybrid scheme. Implementation in Python code. Structure and code of OpenFOAM. Mesh generation in OpenFOAM: blockMesh, snappyHexMesh and cfMesh. Solution of diffusion problems in various domains with OpenFOAM. Solution of incompressible viscous fluid flow with OpenFOAM.

Prerequisites

Passed exams: Fluid Mechanics B and Numerical Methods, and Fluid Mechanics M (not obligatory, but it's will be easier to follow the lectures).

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	10
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	10	project design	50
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Anderson J. Computation Fluid Dynamics, The Basics With Applications, McGraw Hill Series in Aeronautical and Aerospace Engineering, 1995
Versteeg H., Malalasekera, An Introduction to Computational Fluid Dynamics - The Finite

Volume Method, Pearson Prentice Hall, 2011
Petrović Z., Stupar S. Projektovanje računarom, Mašinski fakultet Beograd, 1992

Fluid Mechanics 1

ID: 0829
Responsible/Holder professor NEVENA D. STEVANOVIĆ
Teaching profesor(s): MILIĆEV SNEŽANA; STEVANOVIĆ NEVENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: fluid mechanics

Goals

Aims of the course is to introduce students to basic principles and laws in fluid mechanics. Deeper understanding of basic equations of fluid mechanics allows the student to successfully apply them in process of finding the solution to specific engineering problems, and also improves his scientific and practical development.

Learning outcomes

Students are trained to:
- apply the basic equations of fluid mechanics ie. equations of continuity, momentum and energy to describe the one-dimensional compressible fluid flow, two-dimensional potential incompressible fluid flow and fluid flow in the boundary layer;
- calculate one-dimensional subsonic and supersonic compressible fluid flow, such as: isentropic flow, adiabatic and isothermal flow with friction, inviscid gas flow with heat transfer, shock wave as well as the gas flow through the convergent and Laval nozzle;
- determine the velocity and pressure field for potential incompressible fluid flow which enables them to calculate forces which act on the contour in inviscid fluid stream. Also, based on acquired knowledge, by applying complex potentials, they can form complex flows which enable obtaining the desired contour shape and force which act on it;
- solve the boundary layer equations for flow over a flat plate and calculate friction shear stress at the plate surface, and therefore the drag force.
- modeling the turbulent flow by using the theory of turbulent flow and turbulent stresses models.

Theoretical teaching

Physical and mathematical models, principles and phenomena of fluid mechanics. Physical and mathematical foundations of fluid mechanics. Forces, the general state of stress and stress models in fluids. General equations in fluid mechanics. Laws of conservation. Conservation of mass, momentum and energy.

Dynamics of inviscid fluid. Two-dimensional potential flow of inviscid fluid. Application of hydrodynamic singularities and theory of analytical functions of complex variable. Basic and complex potential flows. Combined straight line flow and sink, doublet. Flow past a cylinder. Kutta-Joukowski`s low.

Dynamics of viscous flow. Navier-Stokes equation. Steady, laminar flow of Newtonian incompressible fluid. Exact analytical solutions of the Navier-Stokes equation. Hydrodynamic

lubrication theory.

Turbulent flows of incompressible fluid. Reynolds equation. Turbulent stress models. Turbulent flow in a hydraulically smooth and hydraulically rough pipe.

Application of momentum equation: turbo-reactive jet engine, Euler`s equation for turbo-machines, Pelton turbines.

Boundary layer theory. Prandtl theory. Boundary layer over a flat plate. Application of integral methods to boundary layer calculation.

One-dimensional model of fluid flow. Basic equations of one-dimensional flow. One-dimensional flow of incompressible fluid. One-dimensional flow of compressible fluid. Mach number. Adiabatic and isothermal compressible flow with friction. Shock waves. Inviscid gas flow with heat exchange. Gas flow in the convergent, divergent and Laval nozzle.

Practical teaching

One-dimensional viscous incompressible flow. Methods of calculation of complex pipe networks. Hydraulic jump. Cavitations in turbo-machines and pipes.

One-dimensional invisced and viscous compressible flow through pipes and jets. Adiabatic and isothermal compressible flow with friction. Shock waves.

Dimensional analysis and similarity theory. Drag and lift forces.
Two-dimensional ideal flow. Stream function, velocity potential. Applications of Cauchy-Riemman equations. Basic and complex potential flows. Joukovsky function.

Exact solutions of Navier-Stokes equations. Basic theory of hydrodynamic lubrication. Turbulent flows modelling. Fully developed turbulent flow in hydraulically smooth and rough pipes.

Prandtl equations of boundary layer. Integral methods application to boundary layer calculation.

Prerequisites

Passed exams in following subjects: Fluid Mechanics B.

Learning resources

Books of professors from the department, laboratory equipment; printed and hand-written materials (handouts).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING		**OTHER**	
active teaching (theoretical)	**30**	**knowledge checks**	**15**
lectures	20	assessment of calculation tasks	0
elaboration and examples (revision)	10	check and assessment of lab reports	2

active teaching (practical)	**30**	check and assessment of seminar works	0
auditory exercises	28	check and assessment of projects	0
laboratory exercises	2	colloquium, with assessment	5
calculation tasks	0	test, with assessment	3
seminar works	0	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	45	project design	0
laboratory exercises	10	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

Чантрак С., Хидродинамика, Машински факултет, 2012.
Ђорђевић В., (2000): Динамика једнодимензијских струјања флуида, Машински факултет, Београд.
Црнојевић Ц., (1998): Класична и ульна хидраулика. Машински факултет, Београд.
С., Бенишек М., Павловић М., Марјановић П., Црнојевић Ц.: Механика флуида, теорија и пракса, Машински факултет, Београд, 2005.

Fluid Mechanics M

ID: 1290
Responsible/Holder professor ALEKSANDAR S. ĆOĆIĆ
Teaching profesor(s): LEČIĆ MILAN; ĆOĆIĆ ALEKSANDAR; MILIĆEV SNEŽANA; STEVANOVIĆ NEVENA; RAKOVIĆ MILAN

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: fluid mechanics

Goals

Main goal is to learn student general principles of fluid mechanics and how to apply them in solving practical engineering problems. In that sense proper understanding of general laws and equations is necessary. This will also enable student to develop further in other topics based on fluid mechanics.

Learning outcomes

Student will gain knowledge on general principles in fluid mechanics and develop capabilities of analytical thinking. Firstly, knowledge on general laws and various forms of general equations (continuity, momentum and energy) and constitutive equations (rheology, Fourier law), and how and when the equations could be approximated. Upon successful completion of the course student should be able to: apply dimensional analysis and similarity theory and their application in fluid mechanics problems; apply the theory of potential flows; apply one-dimensional theory for solving engineering problems: incompressible and compressible flow in pipes and nozzles.

Theoretical teaching

Physical and mathematical aspects in fluid mechanics. Forces, state of stress and rheology. General equations of fluid mechanics. Conservation laws: mass, momentum and energy. Dynamics of inviscid flow. Potential flow: stream function and velocity potential and Cauchy-Riemann equations. Basic flows: source, sink, doublet, vortex and their superposition. Application of complex analysis in studying potential flows. Forces on the body in potential flow stream. Conformal mapping, airfoils, Kutta-Joukovski condition. Viscous flows. Some exact solutions of Navier-Stokes equations in cases of laminar flow. Turbulent flows of incompressible fluid. Reynolds equations and modeling. Turbulent flows is channels and pipes. Boundary layer theory. Prandtl equations of boundary layer. One-dimensional flows. Form of general equations for one-dimensional flows. Water hammer. One-dimensional gas flows. Speed of sound. Shock wave. Adiabatic and isothermal flows with friction. Quasi one-dimensional flows in nozzles: convergent and convergent-divergent nozzle. Basics of computational fluid mechanics (CFD).

Practical teaching

Application of integral form of general equations - control volume analysis. Exact solutions of Navier-Stokes equations. Dimensional analysis. Planar potential flows of incompressible fluid. Stream function, velocity potential. Application of complex analysis in solving problems

of potential flows. Conformal mapping. Integral analysis of boundary layer. Numerical calculation of water hammer. One-dimensional flow of compressible fluid - gas dynamics. Isothermal and adiabatic gas flow in pipes. Shock wave. Quasi one-dimensional flows in nozzles.

Prerequisites

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Learning resources

Library, computer classrooms

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	0	final exam	60
calculation tasks	0		

Requirements to take the exam (number of points) 15

References

Crnojevic C. (2014): Fluid Mechanics, Faculty of Mechanical Engineering, Belgrade (in Serbian)
Cantrak S (2014): Hydromechanics, Faculty of Mechanical Engineering, Belgrade (in Serbian)
Crnojevic C. (2014): Classical and Oil Hydraulics, Faculty of Mechanical Engineering, Belgrade (in Serbian)
Gerhart P.M., Gerhart A.L., Hochstein J.I. (2021): Munson, Young, Okiishi's Fundamentals of Fluid Mechanics, 9th Edition, Wiley

Gas Dynamics

ID: 1011
Responsible/Holder professor SNEŽANA S. MILIĆEV
Teaching profesor(s): MILIĆEV SNEŽANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: fluid mechanics

Goals

The student should:
1. acquire basic theoretical knowledge in the field of gas dynamics;
2. be trained to perform basic engineering calculations of compressible flows;
3. become familiar with the basic procedures for experimental research in gas dynamics.

Learning outcomes

Attendance and regular monitoring of the theoretical and practical training the student should master the basic knowledge in the field of gas dynamics. This will enable him, on the one hand, to solve specific engineering problems in the elementary problems of compressible flows, and, on the other hand, help him to better understand other courses based on this scientific area.

Theoretical teaching

Basic concepts. Basic equations. Continuity, momentum and energy equation. The concept of entropy. Disturbances of the final intensity. The normal shock wave. Oblique shock waves. Interaction and reflection of shock waves. Prantdl-Mayer expansion.
Flow through the nozzle. Equations for isentropic flow with varying cross-section. Convergent and de Laval nozzle - regimes of flow in the nozzle.
Non-isentropic flow. The influence of friction in the flows of gas in the pipes. Adiabatic and isothermal flow with friction. Flow with heat transfer.Characteristics of sonic flow over a body. Critical Mach number. Boundary layer. Interaction of shock waves and boundary layer. Experimental methods and devices. Methods for flow visualization. Various types of wind tunnels. Basic methods for measuring pressure and temperature. Anemometric methods.

Practical teaching

Application of the basic equations of gas flow. Speed of sound. Critical and total values of physical quantities. Assessing the impact of compressibility.
Isentropic gas flow. Calculation of normal shock wave. Conditions for the formation of oblique shock wave. Calculation of oblique shock wave. Calculation of gas flow through a sequence of shock waves. Interaction of shock waves in the flow field. Prandtl-Mayer expansion. Non-linearized airfoil theory. Calculation of the forces exerted by the fluid on airfoil in super-sonic flow.
Calculation of flow through the nozzle. Flow through convergent nozzle. Flow through de Laval nozzle. Supersonic diffuser. Determining the value of reactive force.
Non-isentropic flows. Calculation of adiabatic flows of viscous gas. Calculation of isothermal

flow of viscous gas. Calculation of inviscid flows with heat transfer.
Linearized airfoil theory.

Prerequisites

Passed exam in course Fluid Mechanics B

Learning resources

1.Handouts;

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	0	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 35

References

Handouts, 2023.
Tables for calculation of compressible flows with theoretical handouts, Snežana S. Milićev, Aleksandar S. Ćoćić, Faculty of Mechanical Engineering, 2017.
Compressible Fluid Flow, M. A. Saad, Pearson, 2020.
Modern Compressible Flow: With Historical Perspective, J. D. Anderson, McGraw Hill, 2002.

Microfluidics and Nanofluidics

ID: 0940
Responsible/Holder professor NEVENA D. STEVANOVIĆ
Teaching profesor(s): MILIĆEV SNEŽANA; STEVANOVIĆ NEVENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: fluid mechanics

Goals

The aim of this subject is getting academic knowledge about fluid dynamical processes in micro and nano flows and introducing with scientific methods for predicting, analyzing and studying gas and liquid flow in structures of micrometer and nanometer characteristic dimensions.

Learning outcomes

Students are trained to:
-apply the basic equations of fluid mechanics ie. equations of continuity, momentum and energy to describe the compressible and incompressible fluid flow in micro and nano channels;
-determine the velocity and pressure field for isothermal compressible and incompressible fluid flow in micro and nano channels, pipes and bearings for continuuma boundary conditions;
- calculate the velocity and pressure field for isothermal compressible gas flow in micro channels, pipes and bearings for the slip flow regime;
- calculate the velocity, pressure and temperature field for non-isothermal compressible gas flow in micro channels, for the slip flow regime;
-calculate the pressure and velocity field for electroosmotic flow in micro and nano channels and pipes;
- applie the law of diffusion equation and obtained analytical solutions which enables determination the change of a substance concentration in the micro channel with no fluid stream, as well as in the fluid stream;
-determine the equilibrium height in the capillaries and the time required for its achievement, as well as the change in the liquids position with time in the capillary pump.

Theoretical teaching

Theoretical lessons contains fundamental fluid mechanics equations applied on fluid flow modeling in the micro and nano structures, rarefaction effect, slip and temperature jump boundary conditions, the behavior, manipulation and control of fluids that are confined to structures of nano and micrometer characteristic dimensions, electric double layer and Debye length, electrokinetic effects such as electrophoresis and electroosmosis which are often present in the micro-and nanofluidics, basic diffusion equations and some exact analytical solutions for the substance concentration in the fluid, the ability to use the process of diffusion for mixing and separation in micro and nanosystems, capillary phenomena that are important for micro and nanosystems, micro-pumps.

Practical teaching

Practical lessons contains: application of the basic fluid mechanics equations, exact solutions for modeling fluid flow in the micro and nano structures which include different effects as rarefaction, slip and temperature jump at the wall,calculation of electro-osmotic flow for different channel geometries taking into account the presence of the double layer and Debye-Huckel approximation for the distribution of charge density in the electric double layer , calculation of electro-osmotic pumps of various structures, calculation of the propagation of the substance due to diffusion and advection for different conditions, calculation of capillary motion of fluids and capillary pump.

Prerequisites

Third semestar of Master study

Learning resources

[1]Stevanović N., Fundamentals of microfluidics and nanofluidike, Faculty of Mechanical Engineering, University of Belgrade, 2014.
[2] Karniadakis G., Beskok A., Aluru N., Microflows and Nanoflows Fundamental and Simulations, Springer, 2005.
[3] Kirby, B., Micro and Nanoscale Transport in Microfluid Devices, Cambridge University Press, 2010.
[4] Dongqing L., Encyclopedia of Microfluidics and Nanofluidics, Springer, 2008.
[5]Stevanović,N.,Fluid flows in microdevices, Faculty of Mechanical Engineering, Belgrede,2010.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	25
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30

calculation tasks	40

Requirements to take the exam (number of points) 30

References

Kirby, B., Micro and Nanoscale Fluid Mechanics Transport in Microfluid Devices, Cambridge University Press, 2010.
Dongqing L., Encyclopedia of Microfluidics and Nanofluidics, Springer, 2008.
Bruus H., Theoretical Microfluidics, Oxford University Press, 2008.
Tabeling P., Introduction to Microfluidics, Oxford University Press, 2005.

Multiphase flow

ID: 1382
Responsible/Holder professor MILAN R. LEČIĆ
Teaching profesor(s): LEČIĆ MILAN; RADENKOVIĆ DARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: fluid mechanics

Goals

The main objective of the course is to master the knowledge, calculation models and appropriate practical skills that treat the problems of one-dimensional flows of mixtures of fluids and solids in pipes and ducts. In the field of flow of homogeneous and non-homogeneous machinists, important engineering problems are particularly studied, such as: fluidization, pneumatic transport, hydraulic transport, pneumo-hydraulic elevators and problems of particle separation from fluid.

Learning outcomes

The student has knowledge of a special field of flow of mixtures of fluids and solids. He knows and knows that he uses: characteristic particle shapes, various forms of volume and mass concentration, physical properties of mixtures, deposition rate, critical fluid velocity, and characteristic current magnitudes of one-dimensional flows. The basic outcomes of the course are learning and mastering the calculation skills for different classes of fluid flow of mixtures of fluids and particulates, such as: application of appropriate calculation models that provide basic engineering current parameters:
pressure, flow rate, flow rate and pressure drop in pipes and ducts at specific flows: in fluidized beds, hydraulic and pneumatic transport and pneumo-hydraulic lift. An important part of learning outcomes is learning about different modes of transport, selecting and calculating separators.

Theoretical teaching

TRANSPORTATION OF MIXTURES. The concept and types of mixtures. Granulometry. Eulerian and Lagrangian approaches to studying the flow of mixtures. Particle acting forces. Resistance force and Stokes solution for spherical particle. Deposition rate: solitary particles, dilute mixtures and in non-Newtonian fluids. Porosity. Concentrations - volume and mass. Viscosity and density of mixtures. FLUIDIZATION. Fluidization application. Pressure drop in fluidized bed at incompressible fluid flow. Calculation of pressure change in isothermal compressible flow. The first and second critical fluidization velocities. PNEUMATIC TRANSPORT.Application, Advantages and Disadvantages, and Pneumatic Transport Systems. Horizontal pneumatic transport. Fluid lift. FLYING PNEUMATIC TRANSPORT. Isothermal compressible streams of the mixture. Critical Stream Speed. Changing the pipe diameter along the pipeline route. HYDRAULIC TRANSPORT. Suspension rheology. Laminar suspension flow. Hydraulic transport of inhomogeneous mixture in horizontal, vertical and oblique pipelines. Determination of pressure drop during hydraulic transport of mixtures. Application and calculation of pneumo-hydraulic lift.

SEPARATORS.EJECTORS.

Practical teaching

TRANSPORTATION OF MIXTURES. Particle shape. Form factor. Equivalent particle. The force of resistance. Resistance coefficient. Mass concentration measurement. FLUIDIZATION. The movement of a particle through a fluidized bed. Porosity of fluidized bed. PNEUMATIC TRANSPORT. Change in pressure in an incompressible and compressible fluidized bed as a function of supplementary resistance. FLYING PNEUMATIC TRANSPORT. Pneumatic transport systems. Vacuum cleaners. Dispensers. SEPARATION. Degree of separation. Selection criteria for separator type. Solid material separation chambers. Canvas and electrostatic filters. Cyclones. HYDRAULIC TRANSPORT.
Application, division, critical fluid velocity and viscosity of the homogeneous mixture. Hydraulic transport systems. EJECTORS. Application, ejector characteristics. Determination of optimal ejector parameters.

Prerequisites

Regular class attendance, completed and defended lab work. It is desirable that the course of Fluid Mechanics M be heard and explained.

Learning resources

Chair Book and Collection (in the library). Laboratory equipment and installations.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	26
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	35	project design	0
laboratory exercises	5	final exam	55
calculation tasks	0		

Requirements to take the exam (number of points) 10

References

Crnojević C., Transport of solid materials through pipes, Faculty of Mechanical Engineering, Belgrade, 2002. (in Serbian)
Šašić M., Transport of fluids and solid materials through pipes. Scientific book, Belgrade, 1990. (in Serbian)
Šašić M., Calculation of the transport of fluids and solid materials through pipes. Scientific book, Belgrade, 1985. (in Serbian)

Multiphase flow M

ID: 1381
Responsible/Holder professor MILAN R. LEČIĆ
Teaching profesor(s): LEČIĆ MILAN; RADENKOVIĆ DARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: fluid mechanics

Goals

In the field of multiphase flows, important engineering problems are particularly studied, such as: fluidization, pneumatic transport, hydraulic transport, pneumatic-hydraulic lifts, cavitation, evaporation, condensation and biphasic flows. skills that treat the problems of one-dimensional multiphase flows in pipes and ducts.

Learning outcomes

The student has knowledge in the field of multiphase flows - mixtures of fluids and solids, or mixtures of different fluids. He knows and knows that he uses: characteristic particle shapes, various forms of volume and mass concentration, physical properties of mixtures, deposition rate, critical fluid velocity, and characteristic current magnitudes of one-dimensional flows. The basic outcomes of the course are to learn and master calculation skills for different classes of incompressible and compressible multiphase flows that take place without or with heat exchange, such as:
application of appropriate design models that provide basic engineering current parameters: pressure, flow rate, flow rate and pressure drop in pipes and ducts at specific flows: in fluidized beds, hydraulic and pneumatic transport, and pneumo-hydraulic lift. Using the knowledge gained, the student is able to dimension the pipeline system for transporting mixtures. An important part of learning outcomes is learning about different modes of transport, selecting and calculating separators.

Theoretical teaching

The concept and types of mixtures and properties of mixtures.Basic equations for calculating the flow of mixtures. Laws of maintaining matter, quantities of motion and energy, equation of diffusion, equation of motion of particles. Eulerian and Lagrangian approaches to the study of multiphase flows. One-dimensional multiphase flow equations in pipes. Forces acting on gas bubble and solid particle, Stokes solution. Concentrations. MULTIPHASE FLUID AND SOLID PARTICLE FLOWS: Deposition velocities. Porosity.
Pressure drop in fluidized bed. Calculation of pressure change in isothermal compressible flow. The first and second critical fluidization velocities. PNEUMATIC TRANSPORT. Application, Advantages and Disadvantages, and Pneumatic Transport Systems. Horizontal pneumatic transport. Fluid lift. FLYING PNEUMATIC TRANSPORT. Isothermal compressible streams of the mixture. Critical Stream Speed. HYDRAULIC TRANSPORT. Suspension rheology. Laminar suspension flow. .Hydraulic transport of inhomogeneous mixture in horizontal, vertical and oblique pipelines. Application and calculation of pneumo-hydraulic lift. TWO-PHASE FLOW. Flow modes and maps in horizontal and vertical tubes.

Determination of pressure drop. Lockart-Martineli method. Hydraulic characteristic of the mixture. Two-phase streams with separation surface. Cavitation, evaporation, condensation. Two-phase flows in heat exchange tubes. Numerical methods for multiphase flow calculation.

Practical teaching

TRANSPORTATION OF MIXTURES. Particle shape. Form factor. Equivalent particle. The force of resistance. Resistance coefficient. Mass concentration measurement. FLUIDIZATION. The movement of a particle through a fluidized bed. Porosity of fluidized bed. PNEUMATIC TRANSPORT. Change in pressure in an incompressible and compressible fluidized bed as a function of supplementary resistance. FLYING PNEUMATIC TRANSPORT. Pneumatic transport systems. Vacuum cleaners. Dispensers. SEPARATION. Degree of separation. Selection criteria for separator type. Solid material separation chambers. Canvas and electrostatic filters. Cyclones. HYDRAULIC TRANSPORT.
Application, division, critical fluid velocity and viscosity of the homogeneous mixture. Hydraulic transport systems. EJECTORS. Application, ejector characteristics. Determination of optimal ejector parameters.

Prerequisites

Regular attendance. Preferably, the student has previously taken a course in Fluid Mechanics M.

Learning resources

Chair Book and Collection (in the library). Laboratory equipment and installations.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	26
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	8
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	35	project design	0
laboratory exercises	5	final exam	55

calculation tasks	0

Requirements to take the exam (number of points) 10

References

Crnojević C., Transport of solid materials through pipes, Faculty of Mechanical Engineering, Belgrade, 2002. (in Serbian)
Šašić M., Transport of fluids and solid materials through pipes. Scientific book, Belgrade, 1990. (in Serbian)
Šašić M., Calculation of the transport of fluids and solid materials through pipes. Scientific book, Belgrade, 1985. (in Serbian)

Transport of fluid through pipes

ID: 1558
Responsible/Holder professor DARKO R. RADENKOVIĆ
Teaching profesor(s): LEČIĆ MILAN; ĆOĆIĆ ALEKSANDAR; RADENKOVIĆ DARKO; RAKOVIĆ MILAN

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: fluid mechanics

Goals

The goal of studying the subject is to learn and study important engineering problems related to the pipeline transport of fluids, and especially to the calculation methods of water pipelines, oil pipelines, gas pipelines and steam pipelines. The goal is also to get acquainted with the problems of: water hammer, corrosion of pipelines, methods of pipe support and techno-economic analysis of pipeline transport.

Learning outcomes

As a result of studying the subject, mastering theoretical assumptions, physical laws, approximations and calculation methods of one-dimensional fluid flows through special purpose pipelines, such as: water pipelines, hot water pipelines, oil pipelines, gas pipelines and steam pipelines. As a result of the course, practical knowledge is obtained to solve technical problems: water hammer in pipelines, corrosion of pipelines, thermal expansion of pipelines and ways of supporting pipes.

Theoretical teaching

Physical properties of fluids, density and viscosity. Basic equations of one-dimensional flows in pipes. Flow losses. Friction coefficient, exact and approximate formulas, empirical methods, time effects on the change of friction coefficient. Calculation of branched and ring networks. Methods: Hardy-Cross, linearization and Newton-Raphson. Flow measurement in waterworks. TRANSIENT PROCESSES IN HYDROSYSTEMS. Water hammer.1D model of unsteady fluid flow. Speed of sound in elastic tubes, and in the presence of undissolved gases. The influence of pipeline geometry on the speed of sound. Methods of protection against water hammer. Method of characteristics. TRANSPORTATION OF HEATED LIQUIDS Oil pipelines and hot water pipelines. Fluid temperature change along the pipeline. Ways of determining the pressure drop. OIL PIPELINES Deposits and composition of oil. Rheological model. Isothermal stationary oil flow. Temperature change along the oil pipeline at different current and thermal parameters. Determining the pressure drop of non-isothermal oil flow.

Practical teaching

Energy flow losses. General form of Darcy's formula. Determination of the coefficient of friction. Transient processes in hydrosystems. Speed of sound in elastic tubes. The influence of the tube support method on the speed of sound. Determination of the speed of sound in a liquid in the presence of undissolved gases. OIL PIPELINES Deposits. Determination of pressure drop. GAS PIPELINES Gathering, main and measuring-regulating stations. 1D model

of isothermal and adiabatic flow with friction and inviscid flow with heat exchange.

Prerequisites

-

Learning resources

-

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	25
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	15

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 10

References

Marko Ivetic: Flow in pipes, Faculty of civil engineering, Belgrade, 1996 (in Serbian)
Mane Sasic: Pipeline transport, Faculty of Mechanical Engineering Belgrade 1992 (in Serbian)

GENERAL MACHINE DESIGN

High speed machine design

Innovative Design of Technical Systems

Machine Design and Construction M

Optimization and reliability of construcitons

Practicum in engineering design basics

Skill Praxis M - DUM

Software Tools in Design in Mechanical Engineering

Structure Modelling with Calculation

Technical regulations and standards

High speed machine design

ID: 1572
Responsible/Holder professor NENAD M. KOLAREVIĆ
Teaching profesor(s): KOLAREVIĆ NENAD; SEDAK MILOŠ; DIMIĆ ALEKSANDAR; GRBOVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: general machine design

Goals

The goal of the course is to introduce the students to the design of specific parts and assemblies of the high speed machines.

Learning outcomes

Upon successful completion of this course, students should be able to deal with the engineering design of specific parts and assemblies for high speed machine systems. The design methodology implies teaching student to calculate and correctly select bearings, couplings, seals, gears and other machine elements for operation at high speed revolutions. In addition students will have basic knowledge in the field of the design of housing, lubrication, balancing and testing of such systems.

Theoretical teaching

• Bearings : types, characteristics, operating temperature, misalignment compensation, rotation speed, axial/radial forces, bearing selection, lubrication, sealing, cage types, low friction, fixed/loose/floating bearing principle, bearing mounting, bearing life assessment.
• Seals: sealing principle, types, materials, non-contact seals.
• Couplings: types, advantages/disadvantages, misalignment compensation methods, rotation speed, shaft connections, gear joints, clamping devices, key connection, flange connection.
• Shafts: dimensioning, rotor dynamics, balancing.
• Finite element method: basics, structural calculations, modal analysis.
• Testing and mounting of high speed machine systems.
• Испитивање и склапање високо обртних система.
• Software : ANSYS, KISSsoft.

Practical teaching

Presentation of machine elements that are suitable for high speed opetaion. Visiting facilities for engineeritn design, production and testing,of high speed machines.

Prerequisites

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Learning resources

1. Book: Milos M., Grbovic A.: Software Tools in Design, University of Belgrade, Faculty of

Mechanical Engineering 2017th.
2. Examples with the solutions and the necessary data for the calculations that are given in the book.
3. Power-Point presentations, lectures available to students in the form of hand-out materials.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	40	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Book: Milos M., Grbovic A.: Software Tools in Design, University of Belgrade, Faculty of Mechanical Engineering 2017th.
Examples with the solutions and the necessary data for the calculations that are given in the book.
Power-Point presentations, lectures available to students in the form of hand-out materials.

Innovative Design of Technical Systems

ID: 1302
Responsible/Holder professor NENAD M. KOLAREVIĆ
Teaching profesor(s): KOLAREVIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: general machine design

Goals

Introduce the students with the role and importance of innovative development of technical systems for the development of economics and technology at the global level until to small enterprises and individuals. Review the levels of innovation and market implementation procedure. Introduce students to the process of searching for ideas and solutions. The aesthetics or ecological properties or the transformation of biological principles into technical solutions may also be incentives and challenges. Introducing into the procedure of synthesis (creation) of a fundamentally new technical system, from the idea to the project that is the basis for its production, exploitation and recycling, is another goal. The overriding goal is to develop creative skills for engineering design.

Learning outcomes

Upon successful completion of this course, students should be able to:
• Abstract thinking in the innovative creation (design) of a technical system.
• Manage the process of searching for ideas and design solutions.
• Create a conceptual structure (new operating principle) of a technical system based on the developed function structure.
• Raise the level of properties of technical systems in functional, aesthetic, ecological, market and other environmental conditions.
• Develop innovative technical solutions based on the transformation of biological systems, software and mental functions.

Theoretical teaching

1. Meaning, role and importance of technical innovation
2. Procedure and models for innovative development of technical systems.
3. Transformation of function into conception and conception into structure.
4. Robust and axiomatic design of technical systems.
5. Property based design of TS. Partial approach in the development of TS - DfX approach

6. Theory of TS abstraction as the basis of innovation.
7. Methods of searching for innovative ideas and solutions.
8. Biological systems as a basis for technical innovation.
9. Development of aesthetic properties of innovative technical systems.
10. Effects of eco-friendly and ergonomic TS design and innovation.

Practical teaching

In the course of semester the students working out seminar work which that allows them to understand the purport of the technical system functions. The starting point is existing design solution and the inverse procedure application leads the students to the abstract structure of the functions which is the basis for the development of innovative i.e. to the new design solutions. Auditory exercises also contains analysis and discussions of issues and practical examples covered by theoretical classes with the aim to introduce students to the phenomena that need to process in their seminar works and to prepare for the tests.

Prerequisites

Defined by the curriculum of the study program / module

Learning resources

1 Examples with the solutions and the necessary data for the calculations are given in the book referred to in the point 1.
2 Power-Point presentations, lectures available to students in the form of hand-out materials.
3 Laboratory for Design in Mechanical Engineering.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Ognjanovic M.: Innovative Development of Technical Systems (in Serbian), -University of Belgrade, Faculty of Mechanical Engineering, 2014.
Pahl G., Beitz W., Feldhusen J., Grote K.: Engineering Design - A systematic approach, -

Springer Verlag, 2007.
Hubka V., Eder E.: Theory of Technical Systems, - Springer - Verlag, 1984.
Hubka V., Eder E.: Design Science, - Springer - Verlag London Limited, 1996.
Haufe T: DESIGN, - DuMont Buchverlag, 2008.

Machine Design and Construction M

ID: 1441
Responsible/Holder professor ŽARKO Z. MIŠKOVIĆ
Teaching profesor(s): MITROVIĆ RADIVOJE; MIŠKOVIĆ ŽARKO; DIMIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: general machine design

Goals

Acquisition of basic knowledge of designing and constructing machinery elements and structures. Mastering the methods of construction and design process. Developing skills of teamwork and interconnecting knowledge and skills in various fields of Mechanical Engineering. Training for further study.

Learning outcomes

After the attended course, students gain knowledge about:
• Through the design stages they will be able to selects the optimum variant design from technological and economic point of view - Techno-economic analysis,
• Applying technical directives and regulations in the machine design and putting the product on the market,
• Evaluate the operational capacity of pressed joints,
• Resolves advanced problems with measuring chains,
• Check capacity of thin and thick-walled pressure vessels from strength point of view,
• Make a selection of welded joints in terms of mutual position of the parts to be joined,
• To form and do the technical documentation of given mechanical construction.

Theoretical teaching

Stages in the process of machine designing and constructing. Definition of executors for basic, partial and general functions. The formation of variant solutions and their evaluation - techno economic criteria. Selection of a compromise solution. The variant constructions. The product life cycle. Unification and typization. Measuring chains. The rules and regulations in the machine design process and constructing. Introduction to basic concepts and regulations related to construction processes in mechanical engineering. The necessity of compliance with regulations. Conformity Assessment. Harmonized standards. CE marking of products. Placing products on the market. Pressure vessels. Thick and thin walls pressure vessels. Operational stresses. Thermal strain. Critical stresses in static conditions. Selection of welded joints in terms of mutual position of parts to be joined. Types of edges and butt welds (shapes and dimensions) and their application domain. The behavior of structures in the area of low cycle fatigue. The behavior of structures in the area of high cycle fatigue. Design and construction of welded structures. Lightweight constructions. Technologibility in the process of constructing.

Practical teaching

Variant construction solutions. Construction of typizated parts. Executors of elementary and

partial functions. Forming and calculation of measuring chains. Application of rules and regulations in the machinery design process. Essay. Calculation problem training in the field of Pressure vessels. Example of constructing in the area of low fatigue load. Dimension calculation of elementary functions executors. Determination of service life. Calculation of light structures. The essay about dimension calculation of elementary and partial functions executors. Machine Design from fabrication and assembly point of view.

Prerequisites

Passed all fundamental subjects on B.Sc studies (dealing with the machine materials, material resistance, machine elements, mechanic etc.).

Learning resources

Laboratory for Machine design, University of Balgrade, Faculty of Mechanical Engineering. Handouts, Presentations, Wireless Internet connection and access to the course Web presentation provided with usefull links.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	25	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Ognjanović M.: Machine design, Faculty of Mechanical Engineering, Belgrade, 2000., in Serbian
Karl-Heinz Decker: Machinenelemente: Funktion, Gestaltung und Berechnung, Hanser Verlag, 2000.
Orlov P.: Fundamentals of Machine Design, MIR Publishers - Moscow, 1980.

S.Veriga: Machine elements 1, Faculty of Mechanical Engineering, Belgrade, 2000., in Serbian
Fundamentals of design - a collection of solved calculated problems, MFB, 1999, ZZD, bibl. FME, in sebian

Optimization and reliability of construcitons

ID: 1482
Responsible/Holder professor MILOŠ I. SEDAK
Teaching profesor(s): SEDAK MILOŠ; DIMIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: general machine design

Goals

Learning the fundamentals of numerical analysis and optimization. Learning the fundamentals of optimization. Students are taught how to formulate optimization problems and identify essential parts of the optimization process. Teaching students how to use optimization methods to optimize constructions. Basic understanding of the reliability of machine components and constructions. Understanding how to determine the reliability of basic and complicated systems. Improving teamwork abilities and linking information and ideas from many fields. Knowing the technical and economic significance of faliure, as well as possessing the knowledge to analyze faliure based on the established cause-manifestation categories.

Learning outcomes

The student will be able to: 1. Establish the optimization model of the machine system, identify the necessary variables, and describe the functional limitations and criteria for the appropriate optimization assignment after successfully completing the course.
2.Conduct an analysis and simulation of the sensitivity of the established functional constraints to parameter changes.
3. Suggest a procedure for decomposing large construction optimization models into less complex ones, and create a MATLAB application to do so.
4. Use one-dimensional and multidimensional numerical methods in the MATLAB software programme.
6. Use and create new optimization methods to identify the optimal sizes of complicated machine systems on your own or as part of a team.
7. Describe the fundamental markers of reliabilty indicators;
8. Use approximation approaches to calculate the basic reliability indicators of machine parts and structures.
9. Use analytical methodologies to determine the fundamental reliability indicators of machine parts and structures.
10. Determine the parameters of basic distributions using probability paper;
11. Examines the effect of working and critical stress distribution on the safety and reliability of machine parts and structures.
12. Assess the reliability of complicated systems with series, parallel, and combination element connections.
13. Constructs machine parts and assemblies on the reliability basis.

Theoretical teaching

Introduction to modeling and optimization. Optimization problem setting. General mathematical model for optimization. Graphical optimization procedure. Defining the fiesable area. Use of MATLAB program for graphical optimization procedure. Optimization problems without constraints. Optimization problems with constraints. Post optimal analysis: the physical meaning of Langrange multipliers. Engineering optimization examples in the MATLAB program. Non-linear programming. Constraints in the form of equality. Constraints in the form of inequalities. Numerical methods for unconstrained optimization. Numerical methods for optimization with constraints. Method of penalty functions. Optimization examples in MATLAB. The importance of reliability in the process of designing and constructing machine structures. Definition of reliability. Basic indicators of reliability. Estimated and theoretical reliability, confidence level. Reliability of elementary and partial function executors for different failure intensity functions: constant function, linearly increasing and exponentially increasing function. Operating and critical stress distributions. Comparative analysis of construction based on reliability and safety factor. Methodology for dimensioning elements and joints of mechanical construction based on the required reliability. Reliability of machine structures for different connections (structures) of elements: serial, parallel and combined. Statistical analysis of complex tolerances (tolerance chains). Correlation between reliability and safety factor for different ratios of standard deviations and mean values of operating and critical stress.

Practical teaching

Using the graphical method to determine the optimal solution to a linear programming issue. Development of suitable MATLAB programming codes and implementation of optimization methods within this package to address optimization challenges. The approximate determination of fundamental reliability indicators. Assessing reliability using analytic reliability functions. Distributions of operating and critical stress. Reliability-based dimensioning of machine construction elements. The reliability of structures with series-parallel and mixed element connection. Statistical analysis of complex tolerances. Corellation between reliabilty and safety factor.

Prerequisites

Defined within the module curriculum.

Learning resources

Computer usage: Students are required to use computers and MATLAB programming tools.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	20
calculation tasks	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3

seminar works	6	final exam	5
project design	2		
discussion and workshop	2		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	35	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Singiresu S. Rao "Engineering Optimization Theory and Practice" John Wiley and Sons, inc., 2019.

Practicum in engineering design basics

ID: 1483
Responsible/Holder professor TATJANA M. LAZOVIĆ KAPOR
Teaching profesor(s): LAZOVIĆ-KAPOR TATJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: general machine design

Goals

Introduction to the engineering design basics for typical machine parts, elements and assemblies. Application of basic previously acquired knowledge and skills for the design of machine parts, elements and assemblies (computer graphics, material technology, machine elements calculations, production technology). Preparation of technical documentation. Generating fundamentals for higher levels of complex machine systems design and product development.

Learning outcomes

At the end of this course, the student should be able to:
- recognise and explain the construction of machine parts, elements and assemblies (from the aspect of material technology, manufacturing and assembly technology, and application);
- to apply basic knowledge about the dominant influences on construction (static strength, dynamic durability, stiffness, load-bearing capacity, service life, reliability, technological aspects, economic aspects, user needs, market requirements) in the design of machine parts, elements and assemblies;
- to create construction documentation and instructions for installation, use and

Theoretical teaching

Recapitulation of the content of the subject Machine elements, Elaboration of the conceptual solution, Designing of gear and worm transmissions, belt and chain transmissions, Mounting of rotating parts on shafts and axles, Designing of bearing arrangements, shafts and axles, housings, screw pairs, systems for lubrication and sealing. Creation of construction documentation: assembly drawings, manufacturing drawings of typical machine elements, general view, 3D model, instructions for installation, use and maintenance, Presentation of the project.

Practical teaching

Examples of developing conceptual solutions, Examples of designing multiple variant solutions of typical machine elements and assemblies, Creating simple assembly drawings, manufacturing drawings of typical machine elements, and examples of showing a general view of the structure with instructions for installation, use and maintenance. Realization of practical tasks is done by applying acquired skills in using software packages for 2D drawing and 3D modelling chosen by the student.

Prerequisites

Prerequisites

No special requirements for attending classes.

Learning resources

Suggested literature includes the necessary material for lectures and individual students' work. Required additional material (handouts and design instructions) is given in the e-form. Lectures and exercises are carried out using a blackboard and/or video. Samples of machine elements and assemblies are available in the Laboratory of Machine Elements at the Faculty of Mechanical Engineering

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	12
colloquium, with assessment	0
test, with assessment	3
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	20	project design	50
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 70

References

Ognjanović, M.: Mašinski elementi, Univerzitet u Beogradu, Mašinski fakultet, Beograd, 2021
Mitrović, R., Ristivojević, M., Rosić, B.: Mašinski elementi 1, Univerzitet u Beogradu, Mašinski fakultet, Beograd, 2021
Ristivojević, M., Stamenić, Z., Mitrović, R.: Mašinski elementi 2, Univerzitet u Beogradu, Mašinski fakultet, Beograd, 2022
Handouts and presentations of the subject teacher, 2023.
Textbooks, Manuals, Catalogues in the subject teacher's office: hard copy and e-form

Skill Praxis M - DUM

ID: 1571
Responsible/Holder professor NENAD M. KOLAREVIĆ
Teaching profesor(s): KOLAREVIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: general machine design

Goals

Practical experience and stay student in an environment where will realize his professional career. Identifying the basic functions of the business system in the field of product development, production and use as well as the role and tasks of mechanical engineers in such a business system.

Learning outcomes

After completion of the Professional training - M - DUM, students should gain insight into the practical aspects of the innovative and creative work of engineers in the next.
- In recognition of the basic functions of the business system in the field of TS development, production and use of TS as well as the role and tasks of engineers in such a business system.
- The manner of organization and functioning of the environment in which it will apply the acquired knowledge in their future professional career or entrepreneurial work.
- The models of communication and flows in the development and implementation of product and market realization.
- In recognition of the basic processes in engineering design, manufacture and maintenance of TS.

Theoretical teaching

Introduction, aim, content activity.

Practical teaching

Practical work means work in organizations where they perform various activities in connection with mechanical engineering. The choice of thematic units and commercial and research organizations carried out in consultation with the subject teacher. In principle, the student can carry out the practice in manufacturing organizations, project and consulting organizations, organizations dealing with maintenance of mechanical equipment, public utility companies and one of the laboratories at the Faculty of Mechanical Engineering. The practice may also be made abroad. During the practice students have to keep a diary in which to enter a description of the tasks they perform, the conclusions and observations. After completed practice must make a report that will defend in front of the subject teacher. The report shall be submitted in the form of a seminar paper.

Prerequisites

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Learning resources

Organizations that includes life-cycle product development, production, use.
-Organizations engaged in product development.
-Industrial Companies whose business is making products in mechanical engineering.
-Industrial Companies whose business is based on the use of mechanical systems.
-The companies whose activity is distribution and maintenance of machines and components.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	50	seminar works	20
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

M. Milos: Mechanical Engineering Praxis, PDF book, Faculty of Mechanical Engineering, 2016.

Software Tools in Design in Mechanical Engineering

ID: 1570
Responsible/Holder professor NENAD M. KOLAREVIĆ
Teaching profesor(s): GRBOVIĆ ALEKSANDAR; KOLAREVIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: general machine design

Goals

The main objective of this course is to achieve basic competence in the process of generating of technical systems and innovation, as well as introduction of basic academic knowledge of the capabilities and use of specialized software applied in three stages in the product development (design, elaboration of technological processes and the production).

Learning outcomes

Students will acquire knowledge, tools and practical skills in the application of specialized software for the design and construction (engineering design) as well as programs that enable communication between various software for different purposes.

Theoretical teaching

Basic definitions provided in mechanical engineering design. The notion of a technical system. The concept of technical innovation. Creation of technical systems and innovation.
Basic capabilities of CATIA software (3D models and from them derived two-dimensional drawings and plans, linking them with additional modules for the kinematic calculations, FEM calculations and NC-programming).
Processing of 3D geometry imported into CATIA software from 3D scanners; translating from .stl format to .igs or .stp records suitable for improving the geometry and FEM analysis.
Basic design methods in the program SolidWorks.
Interface programs that enable communication between the software for different purposes, and their interconnection.
Linking programs CATIA and SolidWorks programs for the implementation of the finite element method Ansys and Abaqus; process optimization design.
Methods of computer analysis and optimization of the product; parametric optimization of three-dimensional structural elements (Goal Driven Optimization in Ansys) and structural optimization (using Altair HyperShape).
DELMIA software package; virtual planning, defining, monitoring and controlling production processes necessary to transform a computer model to a real mechanical products.

Practical teaching

Examples of the application of software tools in the processes of the designing products used in the motor vehicle industry, shipbuilding, mechanical engineering, machinery, aviation,...
Practical exercise on a 3D printer.
Demonstration exercise of the NC machine.

Prerequisites

-

Learning resources

Moodle (Modular Object-Oriented Dynamic Learning Environment, open-source PHP web application for producing modular internet-based courses that support a modern social constructionist pedagogy).
Lectures, power point presentations, room equipped with computers & software for design and simulations, 3D printer (Laboratory for Hybrid Technical Systems), NC machine, handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	15

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	45
test/colloquium	0	project design	0
laboratory exercises	15	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 45

References

M. Milos, A. Grbovic: Softverski alati u dizajnu, Mašinski fakultet, 2017.
N. Kolarevic, M. Stankovic, A. Grbovic, M. Milos: Softverski alati u dizajnu-zbirka zadataka-strukturalna analiza, Mašinski fakultet, 2022.
M. Milos, A. Grbovic: Software Tools in Design in Mechanical Engineering – professor's handouts - Faculty of Mechanical Engineering, 2014.
M. Ognjanovic: Innovative Development of Technical Systems - Faculty of Mechanical Engineering, 2014.
Users Manuals

Structure Modelling with Calculation

ID: 1098
Responsible/Holder professor ALEKSANDAR B. MARINKOVIĆ
Teaching profesor(s): MARINKOVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: general machine design

Goals

The aim is to introduce students to the understanding of space and geometric forms in 3D environment. Intention is also understanding the topology types of machine parts, such as methodology of forming a 3D model as a starting point for the development of forms of machine parts and assemblies.
Machine components shape and dimensions determination used to be conducted based on previous knowledge and overpowered skills from Machine elements 1 and 2 courses. Learning and exercising of procedures and tools developed for manipulating forms and dimensions with parameter changes. Aim od this modification is to get an optimum shape that allow us to achieve optimal solutions in machine design modeling.

Learning outcomes

Starting from basics in Machine elements, student used to define shape design of machine components concerning their dimensions and function. Taking into account other design criteria, student has skills to manage corresponding shapes of common machine components using CATIA software. It is completely trained to parametrically vary the shape and form parts, to optimize the form and combine them to compose the assembly. Student has acquired knowledge that the application of CATIA tool optimizes the shape and adjust the properties of this form. The student is also familiar with basics of using modules for simulation and structural analysis.

Theoretical teaching

Introduction, on the course and shape modeling (concept model, role models, use of models). Modeling tools, for software and their characteristics. Principles and method of modeling the form. Surface modeling, surface models. Modeling geometric body (Boolean operations). Additional tools for modeling shapes in CATIA V5.
Forming of machine components shape based on dimensions and their functional determination. Overview of calculation and shape design for shafts, sliding bearings, thread couples, springs and other important components of machine.
Parametric modeling, role and importance of parametric approach. Principles of modeling components. Modeling shape and production of technical documentation. Advanced tools and commands in the modeling using CATIA V5. Further application forms and components modeled in the simulation and analysis.

Practical teaching

Introductory class. Training Concept with calculations and projects, Importance of

dimensions calculation and function of machine components aime to define their proper shape. Calculation methods and determination of shafts and axles dimensions and shapes, Calculation methods in determination sliding bearing, thread pairs, springs and other important machine components dimensions and shapes. Application of calculation results in shape design of machine components using CATIA V5 software tool.
The concept of using CATIA V5 software. The content of the program and the general settings of CATIA V5. Drawing projection and profile (Sketch). Body Modeling (Part Design), the basic principles and advanced commands. Shape modeling (Shape Design), it advantages and disadvantages. Defining relationships between the parameters of the modeled shape. Fundamentals of modeling assemblies (Assembly Design). Modeling circuits of varying complexity (Assembly Design). Obtaining drawings and preparation of technical documentation (drafting). Advanced tools and commands, special modules in CATIA V5. Introduction to analysis and simulation of components and assemblies.

Prerequisites

Required: Attended and passed Engineering Graphics, Machine Elements 1 and Machine Elements 2
Preferred: Attended and passed Basics of Machine Design

Learning resources

other literature for CATIA V5 software;
hand-outs of lessons;
equipment available in room 455, 3D printer and computers;
CAD working station, CAD software tool CATIA V5.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	0
calculation tasks	6
seminar works	0
project design	12
discussion and workshop	6
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	1
test, with assessment	1
final exam	4

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20

laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 35

References

CATIA V5 documentation and tutorials for Shape Design and Structural Design modules
Ognjanovic M.: Innovative Development of Technical Systems (in Serbian), -University of Belgrade, Faculty of Mechanical Engineering, 2014.

Technical regulations and standards

ID: 1444
Responsible/Holder professor ŽARKO Z. MIŠKOVIĆ
Teaching profesor(s): MITROVIĆ RADIVOJE; MIŠKOVIĆ ŽARKO; STAMENIĆ ZORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: seminar works
Parent department: general machine design

Goals

Acquiring of the basic knowledge in the field of technical regulations and standards. Fully understanding the mutual correlation between international and national technical regulations. Full training for the project documentation making in terms of respect for the essential requirements relevant to technical regulations and standards.

Learning outcomes

After the attended course, students gain knowledge about:
• the content, significance and types of technical regulations and standards,
• technical legislation of EU directives,
• conformity assessment procedures, notified bodies,
• CE marking, market surveillance,
• machine safety,
• Risk assessment and national legislation on safety and health at work.

Theoretical teaching

The role, importance and types of technical regulations in mechanical engineering. The place and role in the process of technical regulations and machinery design. Standardization. Application scope. Lows about standardization. Low of Accreditation. Low of Metrology. Laws of Technical Directives. Directives and other regulatory legislation documents. EU technical legislation. EU directives. The meaning of new and global approach. Scope of application of the New Approach
Directives. Products and goods covered by directives. Compatibility to the Directives. Standard procedure for conformity assessment. Modules. Quality standards application. Notified bodies. Principles of Accreditation. The process of certification. Notified bodies and subcontracting. Coordination and cooperation of notified bodies. CE marking. The principles of the CE markings. Products which is marked with CE. Market surveillance. Principles of market surveillance. Machine safety. Reliability. Hazard. Risk. Functions of machinery safety. Safety protection. Manual Instruction. Strategy for selection of safety measures. Risk assessment. The evaluation of risk. Law on Safety and Health at work.

Practical teaching

Examples of application and use of various types of technical regulations and standards in the construction and design process. Examples of formation and complete technical documentation for obtaining the CE mark for the product. Examples of forming and completing the documentation for the accreditation of laboratories for product testing.

Examples and conformity assessment of products. Examples of designing technical solutions for machinery safety and protection. Example of making manual instructions for machinery, equipment or installations. Examples of risk assessment for machinery and mechanical systems. Examples of completing a documentation for the risk assessment. During course, students will visit the following institutions:
- Certified Laboratory for Machinery Elements and System Testing - LIMES, University of Belgrade, Faculty of Mechanical Engineering;
- Directorate of Measures and Precious Metals (DMDM)of the Republic of Serbia;
- The Intellectual Property Office of the Republic of Serbia;
- Institute for Standardization of the Republic of Serbia;
- Notified Body of Vinča Institute.

Prerequisites

There are no special requirements for attending the course.

Learning resources

- Teaching materials: Instructions for the application of directives based on new approach and global approach - Danish Technological Institute (translated version) 2006, EU Directive, EU Standards, Standards of Republic of Serbia, the Law on Standardization, the Law on Accreditation
Act, the Law on Metrology, Lawc on technical regulations. Required additional materials (handouts, Directives Of Republic of Serbia, etc..) are given at the web site or as a hard copy. Large-scale electronic materials can be made available to students in direct contact.
- Computer equipped classroom;
- Access to Internet;
- Laboratory for General Machine Design, University of Belgrade, Faculty of Mechanical Engineering;
- Certified Laboratory for Machinery Elements and System Testing - LIMES, University of Belgrade, Faculty of Mechanical Engineering;
- Certified Laboratory for Vehicle Testing - CIAH, University of Belgrade, Faculty of Mechanical Engineering.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	10

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	25
test/colloquium	25	project design	0
laboratory exercises	0	final exam	45
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Fundaments of Technical Regulatives, University of Belgrade - Faculty of Mechanical Engineering, Belgrade, 2015.
Directives and regulation books of Republic of Serbia
EU Directives (MD, LVD, EMC, HACCP, ATEX,...)
Websites of Institute for Standardisation of the Republic of Serbia and Directorate for Measures and Precious Metals
Patent base ESPACENET

HYDROPOWER ENGINEERING

CFD Modelling of Turbo-machinery

Design of Pumps, fans and turbo copmpresors

Fans and turbocompressors

Hydraulic power transmitters

Hydraulic turbines

Hydropower measurements

Hydropower plants and equipment

Mechanical engineering measurements and sensors

Pumps

Pumps and fans

Renewable energy resources - small hydropower plants

Skill Praxis M - HEN

Theory of Turbomachinery

Turbomachinery

CFD Modelling of Turbo-machinery

ID: 1425
Responsible/Holder professor NOVICA Z. JANKOVIĆ
Teaching profesor(s): JANKOVIĆ NOVICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: hydropower engineering

Goals

The knowledge of engineering numerical design of turbomachines. Ability to work in design and development offices in the turbomachinery industry. Ability to innovate design methods, as well as to acquire the basis for academic development in terms of the application of computational fluid mechanics.

Learning outcomes

Upon successful completion of this course, students will be able to:
1. apply different procedures for designing turbomachines,
2. compare geometric and energy characteristics of turbomachines obtained by applying different calculation approaches,
3. perform engineering calculations, using modern software for geometry construction (CAD) and flow calculation (CFD) in turbomachines,
4. have the skill to work in a computer environment,
5. analyze and present the obtained calculation results.

Theoretical teaching

CAD techniques in turbomachine design. Flow calculation by CFD technique.

Practical teaching

Numerical calculation of the flow of the selected turbomachine. Design geometry, mesh generation, solving equations and displaying results. Analysis and comparison with experimental data.

Prerequisites

Passed exams: Fluid Mechanics B, Fluid Mechanics M. Prerequisite knowledge of the subject Design of pumps, fans and turbo compresors.

Learning resources

Lecture handouts and exercises. Literature. Laboratory for Hydraulic machinery and energy systems.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	OTHER

active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	10
calculation tasks	5
seminar works	10
project design	5
discussion and workshop	0
research	**0**

knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	10
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0
test/colloquium	0
laboratory exercises	20
calculation tasks	10

seminar works	40
project design	0
final exam	30

Requirements to take the exam (number of points) 21

References

CFD One - Zlatko Petrovic and Slobodan Stupar, Belgrade 1996.
Ansys Workbench - Help

Design of Pumps, fans and turbo compresors

ID: 1424
Responsible/Holder professor NOVICA Z. JANKOVIĆ
Teaching profesor(s): JANKOVIĆ NOVICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: hydropower engineering

Goals

The knowledge of engineering design of pumps, fans and turbo compresors. Ability to work in design and development offices in the pump, fan and turbo compresor industry. Ability to innovate project methods.

Learning outcomes

Upon successful completion of this course, students will be able to:
1. design pumps, fans and turbocompresors according to various procedures,
2. analyze the consequences of different design approaches,
3. use and analyze hydraulic, numerical and experiential data used in design,
4. model the geometry of pumps, fans, turbo compresors.

Theoretical teaching

Calculation of the radial pump impeller. Meridian cross-section of the impeller and determination of the flow net. Horizontal projections of the imepller. Point-to-point method. Conformal mapping method. Model cross-sections. Volute design and calculation. Axial pump design. Selection of optimal Flow coefficient and Head coefficient. Application of blade cascade theory for the calculation of impeller and axial pump diffuser. Weinig-Eckert method. Determination of hydraulic, volumetric and mechanical losses of the pump. Axial and radial force: origin, calculation, balancing. Sealing: types and applications. Bearing and construction. Calculation of pump characteristics.

Practical teaching

Project examples: Calculation of the radial pump impeller. Shaping the meridian cross-section of the impeller and determining the flow net. Shaping the horizontal projection of the impeller. Point-to-point method. Conformal mapping method. Model cross-sections. Preliminary and diffuser design. Volute design and calculation. Weinig-Eckert method. Design of impeller and diffuser. Bearing and construction.

Prerequisites

Passed exams Pumps, Fluid Mechanics B. Knowledge of basic computer tools.

Learning resources

Lecture Handouts. Laboratory for Hydraulic Machinery and Energy Systems, test rigs, measuring equipment.

NUMBER OF HOURS

Total number of hours: 60

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	22
discussion and workshop	3
research	**15**

OTHER	
knowledge checks	**0**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	70	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

Lectures - prof. Protic - prof. Nedeljkovic, 2020.

Fans and turbocompressors

ID: 0809
Responsible/Holder professor ĐORĐE S. ČANTRAK
Teaching profesor(s): ČANTRAK ĐORĐE
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: hydropower engineering

Goals

Mastering knowledge of engineering applications of fans and turbocompressors as machines for raising of fluid energy. Capacity to work in practice on energy installations, as well as design of installations that include a fan or turbocompressor as built-in element with its function.

Learning outcomes

Upon successful completion of this course, students should be able to:
1. identify and describe the various types and constructions of the fans and turbocompressors, the principles of their work, as well as the standard way of their installation,
2. determine the duty points of the ventilation system and fan,
3. select the appropriate fan and the most energy efficient way of its regulation,
4. determine the duty point of the fan by using the dimensionless parameters (characteristic coefficients),
5. calculate the fan characteristics when working with other fluid density,
6. calculate the thermodynamic and energy parameters of the turbocompressor,
7. design and develop (with the help of CNC and 3D printers) the 3D model of multistage axial compressor, with special emphasis on the impeller blades and guide vanes.

Theoretical teaching

Task and constructions of fans. Examples of application. Similarity theory, dimensionless parameters and fans classification. The calculation of basic dimensions of the fan – type, impeller diameter, impeller outlet width, spiral casing. Matching and regulation of fans. Testings of fans. Specifics of fan and fan systems. In built characteristics of fans. Axial fans without stay vanes - a characteristic of the fan, its matching. Turbulent swirl flow phenomenon in pipes and jets. Air curtains, reversible fans, fans for fire conditions, ceiling and roof fans, fans in cooling systems. Fan selection. Fans in building energy certification. Building air leakage test ("blower door" test). Noise levels of a fan and fan installation. Thermal machines classification. Task and constructions of turbocompressors. Energy balance. Thermodynamic basis. Efficiency. Uncooled and cooled turbocompressors. The exchange of energy in the axial grid. Multistage compressors. Typical performance curves of axial turbocompressors and behavior in work (choke and surge limits). Determination of optimal characteristic coefficients of centrifugal compressors. Performance curves of centrifugal compressors and their behavior at work.

Practical teaching

1. Auditory exercises:
Calculation examples of lectured material: Matching and regulation of fans. Fan selection. Thermodynamic analysis. Efficiency determination for cooled and uncooled turbocompressors. Multistage turbocompressors.
2. Project design:
2.1. Presentation of the manual for multistage axial compressor design: from calculation of basic dimensions to 3D model.
2.2. Introduction to the application of the existing softwares for turbocompressor design.
3. Laboratory exercises:
3.1. Demonstration:
Laboratory for hydraulic machines - constructions of fans and turbocompressors and description.
3.2. Active laboratory exercises:
1.Testing of the fan performance curves.
2.Determination of sound power levels of noise sources (fan) using sound pressure.
3.Fan electrical motors and regulators wiring and starting the machines.

Prerequisites

Completed courses: Fluid Mechanics B and Thermodynamics B.

Learning resources

1. Textbooks listed in the references and list of literature provided for students.
2. Lectures and exercises handouts.
3. Manual for multistage axial turbocompressor design.
4. Laboratory for hydraulic machines - fans and turbocompressors, installations, measuring equipment.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	5
calculation tasks	5
seminar works	0
project design	8
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	50	project design	15
laboratory exercises	5	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

Genić S.,Stamenić M.,Živković B.,Čantrak Đ.,Nikolić A.,Brdarević Lj. (2017):Manual for energy managers' training in the industry energetics,Fac. of Mech. Eng.,University of Belgrade,Belgrade (in Serb)
Protić Z., Nedeljković M. (2021): Pumps and fans, Problems, solutions, theory, 7th edition, Faculty of Mechanical Engineering, Belgrade (in Serbian)
Obradović N. (1974): Turbocompressors, Faculty of Mechanical Engineering University of Belgrade, Belgrade. (in Serbian)
Ilić D. B., Čantrak Đ. S. (2017): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
Čantrak Đ.S.(2022):Investigation of the Turbulent Rankine Vortex in Pipe behind Axial Fan Impeller Using Optical (PIV and LDA) Measurement Methods and Visualization,NTI,Vol.59,No.1,MTI,Belgrade,(Serb)

Hydraulic power transmitters

ID: 1376
Responsible/Holder professor NOVICA Z. JANKOVIĆ
Teaching profesor(s): JANKOVIĆ NOVICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: hydropower engineering

Goals

Theory and practical skills about hydraulic power transmission, with focus on hydrodynamic power transmission. Selection and application of hydraulic transmission.

Learning outcomes

Upon successful completion of this course, students should be able to:
1. identify and describe the various types and constructions of the hydraulic power transmission systems (hydraulic torque converter, hydraulic coupling and brake), and the principles of their work,
2. select the appropriate hydraulic power transmission system,
3. examine the hydraulic power transmission system according to the valid international standard.

Theoretical teaching

Classification of the power transmitters. Classification of the devices for hydraulic power transmission. Development of the hydrodynamic power transmitters. Classification of the hydrodynamic power transmitters according to the standard VDI 2153. Working principles. Main elements and calculation. Hydrodynamic converter, coupling and break (retarder). Applications. Characteristic lines of coupling and converter. Similarity laws. Schematic symbols. Operating parameters, ratio of conversion, torques. Torque characteristics, adjustability, energy efficient exploitation. Hydrodynamic calculation of the coupling. Main relations in pump and turbine impellers. Operating process in the converter. Moments, velocity triangles and energy balance. Flow rate dependence of the working regime. Torque dependence of the conversion ratio. Main geometry parameters calculation. Exploitation features of the converters. Starting regime. Motor coupling. Joint converter and motor operation. Regulation of the coupling and converter. Selection of operating fluids. Hydrodynamic transmitters tests.

Practical teaching

Project: Pump impeller.
Exercises: Calculation of the main dimensions of the hydrodynamic converter after the similarity law. Flow parameters calculation on the medium circle in pulling regime of the hydrodynamic converter. Blade sketches of the pump and turbine impellers and guide vanes. Schematic presentation of the hydrodynamic converter. Joint operating mode of the hydrodynamic converter and motor. Characteristics calculation.
Seminary work: Presentation of the work on the task topic.

Prerequisites

Compulsory: Fluid Mechanics B.
Preferable: Fluid Mechanics M, Basics of turbomachinery, Pumps, Hydraulic turbines.

Learning resources

Literature listed in references, lectures in hard copy and electronic form, exercises in hard copy.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	13
laboratory exercises	1
calculation tasks	2
seminar works	7
project design	5
discussion and workshop	2
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	4
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	10	project design	30
laboratory exercises	0	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 30

References

VDI стандард: VDI 2153 - Hydrodynamic power transmission (Definitions - Design - Mode of Action), 1994.
Naunheimer H., Bertsche B., Lechner G. (2007): Fahrzeuggetriebe, Grundlagen, Auswahl, Auslegung und Konstruktion, 2. издање, Springer.
Krsmanović Lj., Gajić A. (1998): Turbomachinery - Hydrodynamic power transmitters, Faculty of Mechanical Engineering, Belgrade. (in Serbian)
Bogdanović B., Nikodijević D., Vulić A. (1998): Hydraulic and hydromechanical power transmitters, Faculty of Mechanical Engineering, Niš. (in Serbian)
Kelić V. N. (1989): Hydrotransmitters, 2nd edition, Naučna knjiga, Belgrade. (in Serbian)

Hydraulic turbines

ID: 0808
Responsible/Holder professor IVAN O. BOŽIĆ
Teaching profesor(s): BOŽIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: hydropower engineering

Goals

Achieving academic competence in the fields of hydraulic turbines and hydropower.
Mastering theoretical knowledge of flow process through the turbines and energy transformation therein (fluid and mechanical system interaction).
Obtaining practical knowledge in optimal energy and cavitation performances calculation of hydraulic turbines.
Having the relevant know-how for the turbine industry, design companies and power plants.

Learning outcomes

On successful completion of this course the students will be able to:
- recognize different types and constructions of hydraulic turbines,
- describe the principles of operation, explain and analyze fluid flow in various hydraulic turbines,
- define, calculate and analyze the specific geometry, energy and cavitation parameters of hydraulic turbines,
- construct the essential components and explain their roles from the point of the optimal energy transfer process in various hydraulic turbines,
- design and choose the optimal type and geometry of hydraulic turbines flow passages with the aim of high efficiency operation of hydropower plants,
- define, analyze and apply universal characteristics and operational hill charts for hydraulic turbines, and their scale up (model to prototype).

Theoretical teaching

Principles of operation, application and classification of hydraulic turbines. Water resource and its potential. Basic and main parameters of the turbine. Theoretical basis of flow through the turbine and energy transforming by fluid and mechanical systems interaction. Flow calculation in the turbine runner. Cavitation in turbines, cavitation coefficient and determination of the suction height. Hydraulic turbines similarity laws. Unit and specific parameters of the turbines. Energy and cavitation model parameters scale-up to a turbine prototype. Regulation of turbine discharge. Turbine characteristics: linear and universal. Operation (hill-chart) characteristics of the turbines. Turbine flow passages. Contemporary turbine constructions. Runaway characteristics. Transients in the turbines.

Practical teaching

Auditory exercises and calculation examples:

Hydropower plants operation fundamentals. Historical development, classification, properties and application of turbines. Determination of basic and main parameters (gross and net head, discharge, power, efficiency, hydraulic and mechanical power losses, rotational speed). Application of Euler's equations for the turbine. Determination of velocity triangles, relation between specific energies of turbine unit and runner, degree of reaction and hydraulic axial force. Determination of unit and specific turbine parameters. Scale-up of turbine model hydraulic efficiency characteristics and cavitation coefficient to a turbine prototype. Determination of suction height. Determination of universal and operation (hillchart) turbine characteristics. Cam curve determination. Construction of Pelton, Francis, Kaplan and bulb turbine. Choice and calculation of the spiral cases, stators, guide vanes and draft tubes of turbines. The energy recovery factor of turbine. Nomenclature of turbines.
Explanatory exercises in the laboratory for hydraulic machines and energy systems, and numerical simulations:
Presentation of hydraulic turbine constructions and description of a particular turbine passage function. Installations for testing hydraulic turbines and description of their operation. Presentation of numerical experiment - the turbine flow calculation using the contemporary CFD techniques.
Project (carrying out the project based on instructions): Choice of turbine and calculation of its basic dimensions in accordance with the given input parameters.

Prerequisites

Defined in the Curriculum

Learning resources

Božić, I.: Auditory exercises handouts
Laboratory hydraulic machines and energy systems - devices, installations for testing turbines, measuring equipment and exhibits
Faculty Computer Classroom

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	4
calculation tasks	11
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	5	final exam	40
calculation tasks	10		

Requirements to take the exam (number of points) 35

References

Мирослав Бенишек „Хидрауличне турбине“, Универзитет у Београду - Машински факултет у Београду, 2020
Иван Божић „Хидрауличне турбине - Практични примери са изводима из теорије“, Машински факултет у Београду, 2017
Божић, И.: Обновљиви извори енергије - мале хидроелектране, Универзитет у Београду - Машински факултет, 2022
Ковалев Н, „Справочник по гидротурбинам“, Машиностроение, Ленинград, 1984
Giesecke J., Heimerl S., Mosonyi E.: "Wasserkraftanlegen – Planung, Bau und Betrieb", Springer – Verlag, Berlin, Heidelberg., 2014

Hydropower measurements

ID: 0927
Responsible/Holder professor DEJAN B. ILIĆ
Teaching profesor(s): ILIĆ DEJAN; BOŽIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: hydropower engineering

Goals

Measurements have a very significant role in engineering practice and research activities. The measurements in hydro-energy systems include measuring fluid flow quantities and energy characteristics of hydraulic machinery, in order to determine the energy performance of turbines, pumps, fans and other turbomachines. In framework of this subject, the characteristics of valves and methods for determining the cavitation characteristics of hydraulic machines and equipment are studied in detail.

Learning outcomes

On successful completion of this course, students should be able to:
1. Organize and carry out testing of hydraulic machines (turbines, pumps, fans and turbocompressors) in the laboratory, following applicable international standards,
2. Process, present and analyze test results and calculate measurement uncertainty of the measured values,
3. Perform a comparative analysis of number of ways for measuring the energy parameters of hydraulic machines,
4. Recalculated efficiency from a model to a prototype of turbine,
5. Explain the calibration of pressure, flow and torque measuring devices, process the measurement results of calibration and calculate measuring uncertainty following applicable international standards and recommendations.

Theoretical teaching

- The importance of testing in hydro-energy systems. Model testing of hydraulic machineries;
- Standards and recommendations for model tests. Overview of measuring parameters;
- Turbine model test in the laboratory;
- Energy and cavitation characteristics determination of turbine models - the universal characteristics;
- Turbine test in hydro-power plants;
- Pump model tests in the laboratory;
- Energy and cavitation characteristics determination in pump models - the universal characteristics;
- Pumps test in pumping stations;
- Fan test in laboratory and ventilation systems;
- Compressor test in laboratory and compressor systems;
- Hydro-mechanical equipment test in the laboratory;
- Energy and cavitation characteristics determination of hydro-mechanical equipment

(valves).

Practical teaching

Auditory exercises:
- Measurements of physical quantities in hydro-energy system;
- Determination of pump energy and cavitation characteristics;
- Determination of turbine energy and cavitation characteristics;
- Determination of pump energy and cavitation characteristics at pump station;
- Determination of the energy performance of turbines in hydro-power plant.

Laboratory Exercise:
- Calibration of measuring equipment;
- Determination of universal characteristics of the pump and turbine model;
- Fan test in laboratory and ventilation systems.

Prerequisites

Requirements for examination: Pumps, Hydraulic turbines, Fans and turbocompressors.
Preferred: Mechanical engineering measurements and sensors.

Learning resources

[1] Hand-outs,
[2] Installation for testing the energy and cavitation features of turbine models, small hydro-power plants and hydro-mechanical equipment,
[3] Pelton turbine test rig
[4] Installation for flow visualization, determing pump hydraulic characteristics, variety of pump control possibilities, determing duct hydraulic characteristics
[5] Installation for flow meter calibration by volume method, testing of pumps and hydro-mechanical equipment
[6] Installation for flow meter calibration by volume method (56 l/s)
[7] Test rig for defining energy characteristics of the axial fans and swirl flow in diffusers (swirl chamber)
[8] Test rig with booster fan for fan and fluid flow phenomena investigations
[9] Installation for calibrating pressure gauges
[10] Calibration tunnel for velocity and pressure probes
[11] Test rig for exploring swirl flow in straight ducts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	25

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	10
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0

calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	70	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Ilić D. B., Ćantrak Đ. S. (2022): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
Miroslav Benišek "Hydraulic Turbines," Mechanical Engineering in Belgrade, 2020.
M Benišek., M Nedeljkovic., R Kilibarda., Gerasimović D. "The measurement techniques. Exercises in flow measurements", Mechanical Engineering, Belgrade 2006.

Hydropower plants and equipment

ID: 0810
Responsible/Holder professor IVAN O. BOŽIĆ
Teaching profesor(s): BOŽIĆ IVAN; ILIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: hydropower engineering

Goals

Achieving academic competence in the field of hydropower plants, equipment and hydro energy.
Obtaining practical knowledge in hydropower plants designing and the content of the technical project documentation.
Mastering knowledge of how to choose and calculate hydromechanical equipment installed in hydroelectric and pump stations.
Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.
Improving individual creative abilities in performing professional design of hydro energy systems.

Learning outcomes

On successful completion of this course the students will be able to:
- define, plan and organize the phases of project design, build up and operation of hydropower plants within electro energy and water supply systems,
- design the optimal hydro mechanical equipment (trash racks, valves, pipes etc.),
- apply the empirical data to the choice and calculation of hydraulic machinery and equipment with the aim of high efficiency operation of hydro power plants and pump stations,
- analyze the transient operating regimes and unsteady fluid flow (water hammer) in various energy systems,
- collect, analyze and present the calculation results,
- choose the optimal solution to the specific case by analyzing more possible solutions from the point of energy and economy,
- work as a part of a team as well as demonstrate their entrepreneurial skills.

Theoretical teaching

Significance and types of hydro plants in electric power and water management systems. Basic laws regarding the construction. Design of hydropower (HPP) and pump plants. HPP powerhouse. Hydromechanical equipment in power plants. Fundamentals of hydro-generators. Transients in hydropower plants. Pump stations. Selection and installation of pumps in the pump stations. Pump stations equipment. Complex hydro systems. Installation and calculation of piping. Water-hammer. Water-hammer calculation methods. Protection hydro plants from water-hammer. Fan and compressor systems. Small hydropower plants.

Auxiliary systems in hydro plants. Energy and economic project analysis.

Practical teaching

Hydroplants. The design phases and the accompanying technical documentation. Providing the data basis for the design. The basic parameters of power plants. The choice of turbine parameters during designing process. Practical calculation examples from hydromechanical systems design. Water-hammer calculation examples. Sample calculation of water level oscillations in the water tank. Additional systems in plants. The examples of fan and compressor systems. Choice of types, number of pipelines and the pipes diameters. Trash rack and its cleaning mechanisms. Valve sample calculation.Valve cavitation.
Visiting hydro plants in the water management and electric power systems.

Prerequisites

Defined in the Curriculum

Learning resources

Benisek, M.: Lecture handouts (Hydro-mechanical plants, Hydro-mechanical equipment)
Bozic, I.: Auditory exercise handouts (Hydro-mechanical plants)
Laboratory for hydraulic machines and energy systems - devices and installations.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	6
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	25
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Иван О. Божић „Обновљиви извори енергије - мале хидроелектране“, Универзитет у Београду - Машински факултет, 2022
Ђорђевић, Б.: Хидроенергетско коришћење вода, Грађевински факултет, Београд, 2003.
Бенишек, М.: Хидрауличне турбине, Машински факултет у Београду, 2021
Иван О. Божић „Хидрауличне турбине - Практични примери са изводима из теорије“, Универзитет у Београду - Машински факултет, 2017
Ильиных, И.И.: Гидроэлектростании, Энергоатомиздат, Москва, 1988.

Mechanical engineering measurements and sensors

ID: 0926
Responsible/Holder professor DEJAN B. ILIĆ
Teaching profesor(s): ILIĆ DEJAN; ILIĆ JELENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: hydropower engineering

Goals

Research, development and practice in science and engineering cannot be imagined without the experimental methods that are combined in the field of measurement techniques. The aim of this course is to provide basic and specific knowledge in the field of experimental methods necessary for mechanical engineers, with special reference to flow measurement techniques. The subject involves measuring the nonelectrical quantities in mechanical engineering and their transformation into electrical quantities using sensors. Through specific measurements in the laboratory, students are introduced to the field of practical experimental methods.

Learning outcomes

On successful completion of this course, students should be able to:
1. Apply theoretical knowledge in practical measurements of some quantities in mechanical engineering,
2. Describe measurements methods of some quantities (velocity, flow, pressure and fluid temperature) and specify classical and contemporary measuring techniques,
3. Process and present the measurement results,
4. Calculate the measurement uncertainty,
5. Explain the calibration of velocity, pressure and flow measuring devices,
6. Describe the types and characteristics of sensors.

Theoretical teaching

Theoretical lecturing is realized through the following core learning areas:
- Error of direct and indirect measurements. Measurement uncertainty.
- Theoretical basis of measurement non-compressible and compressible fluid flow.
- Measurement of pressure and velocity of fluid flow.
- Measuring velocity as vector quantities.
- Temperature measurements.
- Measurement of fluid flow.
- Measurement of humidity. Measuring the frequency of rotation, force, torque and power drive and driven machinery.
- Sensors (types, properties, characteristics, materials). Resistive, capacitive, inductive and generator sensors.

Practical teaching

Auditory exercises:

- Errors of direct and indirect measurements of measurement quantities. Measurement uncertainty.
- Measurement of pressure and velocity of fluid flow. Pressure gauges and anemometers.
- Measuring velocity as vector quantities.
- Measuring compressible flow parameters.
- Measurement of fluid flow. Flow-meters.
- Sensors (types, characteristics, dynamic characteristics, materials).
- Resistant, capacitive, inductive and generator sensors.

Laboratory exercises:
- Determining the pressure distribution around the contour of the cylindrical probe,
- Cylindrical probes calibration,
- Measurements of temperature sensors.

Prerequisites

Desirable: Thermodynamics, Fluid Mechanics, Physics and measurements.

Learning resources

[1] M Benišek., M Nedeljkovic., R Kilibarda., Gerasimović D. "The measurement techniques. Exercises in flow measurements", Mechanical Engineering, Belgrade 2006.,
[2] Ilić D. B. - Hand-outs from the written lectures,
[3] Ilić D. B., Ćantrak Đ. S. (2017 and 2022): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade,Belgrade. (in Serbian),
[4] The experimental installation for velocity and pressure probe calibration, available in the laboratory of the Department,
[5] The experimental installation for calibration of the pressure devices, available in the laboratory of the Department,
[6] Laboratory of the Institute of physics of Technical faculties.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	15
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	22	final exam	30
calculation tasks	3		

Requirements to take the exam (number of points) 30

References

Ilić D. B., Ćantrak Đ. S. (2022): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
Vušković I .: "Fundamentals of measurement techniques", Mechanical Engineering, University of Belgrade, Belgrade, 1977.
Holman J.: "Experimental methods for engineers", Internatiional student edition, Mc Graw – Hill Company, 1984.
Tropea C., Yarin A., Fosss J. (Eds.): Springer Handbook of Experimental Fluid Mechanics, Springer-Verlag, Berlin, Heidelberg, 2007.
Stankovic D .: "Physical Technical measurements - sensors", Electrical Engineering, Belgrade, 1997.

Pumps

ID: 1422
Responsible/Holder professor ĐORĐE S. ČANTRAK
Teaching profesor(s): ČANTRAK ĐORĐE
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: hydropower engineering

Goals

Acquiring the knowledge of engineering application of pumps as machines for raising the energy to fluid. Ability to work in practice on various types of installations, as well as to design installations that contain a pump as a built-in element with its function.

Learning outcomes

Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps, 2. calculate the energy parameters of the pump, 3. calculate and apply dimensionless parameters (coefficients) of the pump, 4. determine the duty point of the system, 5. apply the energy characteristics of the pump when coupling and regulating the pump, 6. apply the most energy efficient way of regulation of the pumps, 7. choose the adequate pump, 7. calculate the cavitation reserve of the pump and plant.

Theoretical teaching

Description of pumps. Energy balance. Defining internal head, impeller head and head. Definition of the pump head. Determination of the pump head by definition and according to the Bernoulli equation. Euler's equation for turbomachinery. Influence of output angle on impeller head and impeller reaction. Reduction of impeller head - the impact of the final number of blades. Powers and efficiency rates of pumps. Similarity laws. Coefficients of pump. The main flow phenomena in turbomachinery. Turbulent swirl flow phenomenon. The spiral casing. Classification of pumps by types. Cavitation. Cavitation reserve. Cavitation coefficient. Determination of the pump suction head. Influence of liquid viscosity on pump operating characteristics. Calculation of basic dimensions of pumps. Sealing at pumps. Coupling and regulation of pumps. Selection of pumps. Pump testing. Pumps in various facilities. Piston pumps - description, classification and principle of operation. Uneven flow. Indicator diagrams. Determination of power and pumping height. Description of rotary piston pumps.

Practical teaching

Computational examples: Energy balance. Determination of pump head in the plant and according to the route of the pipeline. Euler's equation for turbomachinery. Degree of reaction. Slip factor. Powers and efficiency rates of pumps. Similarity laws. Coefficients of pumps. Determination of pump suction head. Operation and regulation of pumps in simple and complex pipelines. Pumps in various plants. Demonstration laboratory exercises: Institute (laboratory) for hydraulic machinery - demonstration of pump constructions and description of the role of individual parts. Pump installations and description of their work.

Prerequisites

Passed Fluid Mechanics B.

Learning resources

1. Protić Z., Nedeljković M. (2021): Pumps and fans. Problems, solutions, theory, 7th ed. Faculty of Mechanical Engineering, University of Belgrade, Belgrade.
2. Čantrak Đ. (2022): Handouts for the subjects Pumps, Pumps and fans, Turbomachinery, Fans and turbocompressors, The First part, Faculty of Mechanical Engineering, University of Belgrade, Belgrade (only electronic edition)
3. Laboratory for hydraulic machinery - devices, installations, measuring equipment.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	26
laboratory exercises	2
calculation tasks	2
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	10
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	70	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

Protić Z., Nedeljković M. (2021): Pumps and fans, Problems, solutions, theory, 7th edition, Faculty of Mechanical Engineering, Belgrade (in Serbian)
Babić M, Stojković S. (1992): Turbomachinery, Prosveta, Belgrade (in Serbian).
Babić M. (1980): Practical Problems in Turbomachinery, Naučna knjiga, Belgrade, (in Serbian).
Krsmanović Lj., Gajić A. (1996): Turbomachinery-Pumps, University of Belgrade, Belgrade (in Serbian).
Genić S.,Stamenić M.,Živković B.,Čantrak Đ.,Nikolić A.,Brdarević Lj. (2017):Manual for energy

managers' training in the industry energetics,Fac. of Mech. Eng.,University of Belgrade,Belgrade (in Serb)

Pumps and fans

ID: 1423
Responsible/Holder professor ĐORĐE S. ČANTRAK
Teaching profesor(s): ČANTRAK ĐORĐE; JANKOVIĆ NOVICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: hydropower engineering

Goals

Acquiring the knowledge of engineering application of pumps and fans as machines for raising the energy to fluid. Ability to work in practice in various industries, as well as to design installations that contain a pump or fan as a built-in element with its function.

Learning outcomes

Upon successful completion of this course, students should be able to: 1. recognise and describe various types and designs of pumps/fans, 2. calculate the energy parameters of the pump/fan, 3. calculate and apply dimensionless parameters (coefficients) of the pump/fan, 4. determine the operating point of the system and pump/fan, 5. choose the adequate pump/fan, 6. apply the energy most efficient way of regulation of the pump/fan when coupling, 7. calculate the cavitation reserve of the pump and facility, 8. calculate the characteristics of the fan at a different density.

Theoretical teaching

Description of pumps and fans (PV). Energy balance. Defining internal head, impeller head and head. Definition of the PV head. Determination of the PV head by definition and according to the Bernoulli equation. Euler's equation for turbomachinery. Influence of the impeller outlet angle on impeller head and impeller degree of reaction. Reduction of impeller head - the impact of the final number of blades. Powers and efficiency rates of PV. Similarity laws. Coefficients of PV. The main flow phenomena in turbomachinery. Turbulent swirling flow phenomena. Classification of PV by types. Cavitation. Cavitation reserve. Cavitation coefficient. Determination of pump suction head. Influence of working fluid properties on PV characteristics - influence of liquid viscosity on pump operating characteristics, and influence of gas density on fan characteristics. Calculation of basic dimensions of PV. Coupling and regulation of PV. Choice of PV. PV testing. Application of PV in various plants. Reciprocating pumps - description, classification and principle of operation. Uneven flow. Indicator diagrams. Determination of power and pumping height. Description of radial piston pumps.

Practical teaching

Computational examples: Energy balance. Determination of PV head in the plant and according to the route of the pipeline. Euler's equation for turbomachinery. Slip factor. Powers and efficiency rates of PV. Similarity laws. Coefficients of PV. Cavitation reserve. Determination of pump head. Coupling and regulating PV. PV in various plants. Piston pumps - mode of operation. Demonstration laboratory exercises: Laboratories of the Department for hydraulic machinery and energy systems - demonstration of the PV

constructions and description of the role of individual parts. PV installations and description of their work.
Demonstration laboratory exercise with a pump facility: operation of the pump with a simple and complex pipeline (determining the duty point of the pump and corresponding flow rates), determining the characteristic curves of the pump and determining the hydraulic curve of the pipeline.

Prerequisites

Knowledge of fluid mechanics.

Learning resources

1. Čantrak Đ. (2022): Handouts for the subjects Pumps, Pumps and fans, Turbomachinery, Fans and turbocompressors, The First part, Faculty of Mechanical Engineering, University of Belgrade, Belgrade (only electronic edition)
2. Laboratory for hydraulic machinery - devices, installations, measuring equipment.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	26
laboratory exercises	2
calculation tasks	2
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	10
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	70	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

Protić Z., Nedeljković M. (2021) Pumps and fans. Problems, solutions, theory, 7th ed. Faculty of Mechanical Engineering, University of Belgrade, Belgrade.
Čantrak Đ.S.(2022):Investigation of the Turbulent Rankine Vortex in Pipe behind Axial Fan Impeller Using Optical (PIV and LDA) Measurement Methods and

Visualization,NTI,Vol.59,No.1,MTI,Belgrade(Serb)
Babić M. (1980): Practical Problems in Turbomachinery, Naučna knjiga, Belgrade, (in Serbian).
Krsmanović Lj., Gajić A. (1990): Fans, Faculty of Mechanical Engineering, Belgrade (in Serbian).
Genić S.,Stamenić M.,Živković B.,Čantrak Đ.,Nikolić A.,Brdarević Lj. (2017):Manual for energy managers' training in the industry energetics,Fac. of Mech. Eng.,University of Belgrade,Belgrade (in Serb)

Renewable energy resources - small hydropower plants

ID: 0928
Responsible/Holder professor IVAN O. BOŽIĆ
Teaching profesor(s): BOŽIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: hydropower engineering

Goals

Achieving academic compentence in the field of small hydropower plants, hydromechanical equipment and hydro energy.
Obtaining practical knowledge in small hydropower plants designing and the content of the technical project documentation.
Mastering knowledge of how to choose and calculate hydromechanical equipment installed in small hydroelectric stations.
Developing the ability to find the optimal solution by combining a wide range of acquired theoretical and practical knowledge and using multicriteria methods.
Improving individual creative abilities in performing professional design of small hydropower plants.

Learning outcomes

On successful completion of this course the students will be able to:
- define, plan and organize the phases of project design, build up and operation of small hydropower plants,
- apply the empirical data to the choice and calculation of hydraulic turbines and equipment (trash racks, valves, pipes etc.) with the aim of high efficiency operation of small hydro power plants,
- check the adopted geometry and operating characteristics by basic analysis of the transient operating regimes and water hammer phenomenon,
- collect, analyze and present the calculation results,
- choose the best solution to the specific case by analyzing more possible solutions from the point of energy efficiency,
- work as a part of a team as well as demonstrate their entrepreneurial skills.

Theoretical teaching

Renewable energy resources. Significance, historical development and types of small hydro plants (SHPP). Opportunities for hydropower use in the world and in Serbia. Law regulations regarding the SHPP construction and electricity generation therein. Input data basis for SHPP design. Main SHPP parameters. SHPP design. Piping installation and calculation. SHPP powerhouse. Small, mini and micro hydraulic turbines. Hydromechanical equipment in SHPP. Fundamentals of governing systems and electrical equipment. Transients in small hydropower plants. Waterhammer. Waterhammer calculation methods. SHPP waterhammer protection. Auxiliary systems in small hydro plants. Energy and economic project analysis.

Practical teaching

The design phases and the accompanying technical documentation. Analysis of the input data basis for the design. The basic parameters of SHPP. The calculation of main turbine parameters during designing process (dimensions of runner, spiral case, draft tube, suction head, reference level of turbine in relation to tail water level, minimum, nominal and maximun power). Turbines' energy and cavitation characteristics. Turbine regulation and governing systems. Practical calculation examples from hydromechanical systems design. Additional systems in SHPP. Waterhammer calculation examples. Choice of types, number of pipelines and the pipes diameters. Trash rack and its cleaning mechanisms. Valve sample calculation. Determination of hydraulic measurements methods.

Demonstration of small Pelton turbine operation in the Laboratory of Hydraulic Machinery and Energy Systems. Visiting small hydro plants in the electric power systems.

Prerequisites

It is desirable to have some of the BSc or MSc subjects on Hydraulic machinery and energy systems department passed or attended.

Learning resources

Benisek, M.: Lecture handouts (Hydro-mechanical plants, Hydro-mechanical equipment)
Bozic, I.: Auditory exercise handouts (Hydro-mechanical plants)
Laboratory for hydraulic machines and energy systems - devices and installations.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	2
calculation tasks	8
seminar works	0
project design	6
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	20	project design	0
laboratory exercises	5	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 40

References

Иван О. Божић „Обновљиви извори енергије - мале хидроелектране“, Универзитет у Београду - Машински факултет, 2022
Ђорђевић, Б.: Хидроенергетско коришћење вода, Грађевински факултет у Београду, 2001.
Иван О. Божић „Хидрауличне турбине - Практични примери са изводима из теорије“, Универзитет у Београду - Машински факултет, 2017
Warnick, C.C.: Hydropower engineering, Prentice-Hall.Inc, Englewood Cliffs, New Jersey, 1984
Ристић Б., Миленковић Д.: Мале хидроелектране-водне турбине, Научна књига, Београд, 1996

Skill Praxis M - HEN

ID: 1210
Responsible/Holder professor DEJAN B. ILIĆ
Teaching profesor(s): ILIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: hydropower engineering

Goals

The goal of professional practice is that students in addition to theoretical work within subjects at the faculty get to know and experience the jobs in factories, institutes, laboratories and similar commercial enterprises and thereby gain insight into the activities to be performed. During the practice, students must keep a diary in which they enter a description of the tasks performed, and write down their conclusions and observations. Following the practice, students must write a report that is to be discussed about with the subject teacher.

Learning outcomes

On successful completion of this course, students should be able to:
1. Write a report with a completed skill praxis,
2. Describe the operation and organization of the appropriate energy system or facility,
3. Demonstrate acquired practical experience and skills, related to specific jobs in the appropriate energy systems or facilities,
4. Acquire and develop team skills in work environment (communication with colleagues, professional ethics, etc.).

Theoretical teaching

The course content is practical work, which consists of spending working time in certain organizations that perform various activities in mechanical engineering. The choice of a theme as well as a business or research organization is made in consultation with the concerned teacher. Students may perform their practice in: design and energy consulting profession organizations, organizations that produce and maintain power equipment, organizations that build and maintain power plants, waterworks companies and laboratories of the Department of hydraulic machines and power systems.

Practical teaching

In the design and consultancy organizations, students are introduced to the process of design and analysis of power plants, acquire practical knowledge of engineering graphics, use of modern computer programs for designing and analyzing equipment and facilities, implementation of measures for rational use of energy and environmental protection and others. In organizations that produce and maintain power equipment they are acquainted with the process of equipment production, technological lines of production, quality control, and others. Within the companies for the construction and maintenance of power plants they acquire knowledge about the organization of construction, layout of equipment and technological systems in plants, and others. In power plants they get to know the appropriate

processes, technology systems, fixtures and equipment, methods, process analysis, measurement of process parameters, operating the plant, and others. In the laboratories of the Department of hydraulic machines and power systems they can become familiar with the available equipment and measuring equipment.

Prerequisites

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Learning resources

[1] Instructions for writing reports from professional practice, website FME, 2020.
[2] Guidelines for handling the equipment and facilities in the laboratories of the Department,
[3] Installation for testing the energy and cavitation features of turbine models, small hydro-power plants and hydro-mechanical equipment, available in the laboratory of the Department,
[4] Pelton turbine test rig
[5] Facility for studying cavitation phenomenon in pumps and hydrofoils with the visualization possibility
[6] Installation for flow visualization, determing pump hydraulic characteristics, variety of pump control possibilities, determing duct hydraulic characteristics
[7] Installation for flow meter calibration by volume method, testing of pumps and hydro-mechanical equipment
[8] Installation for flow meter calibration by volume method (56 l/s)
[9] Test rig for defining energy characteristics of the axial fans and swirl flow in diffusers (swirl chamber)
[10] Test rig with booster fan for fan and fluid flow phenomena investigations
[11] Installation for calibrating pressure gauges
[12] Calibration tunnel for velocity and pressure probes
[13] Test rig for exploring swirl flow in straight ducts
[14] PIV system
[15] LDA system
[16] CNC

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Ilić D. B., Ćantrak Đ. S. (2022): Manual for fluid flow measurements in laboratory, Fac. of Mechanical Eng. Univ. of Belgrade, Belgrade. (in Serbian)
M Benišek., M Nedeljkovic., R Kilibarda., Gerasimović D. "The measurement techniques. Exercises in flow measurements", Mechanical Engineering, Belgrade 2006.
Zoran Protić, Miloš Nedeljković: Pumps and fans: problems, solutions, theory, Faculty of Mechanical Engineering in Belgrade, 2021.

Theory of Turbomachinery

ID: 1000
Responsible/Holder professor DEJAN B. ILIĆ
Teaching profesor(s): ILIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: hydropower engineering

Goals

Introduction of theoretical knowledge of fluid flow in turbomachinery. Studying of energy and exploitation characteristics of turbomachinery in dimensional and non-dimensional forms and their application in mechanical systems. Obtaining of practical skills application of hydraulic turbines, pumps, fans and turbocompressors in power systems.

Learning outcomes

On successful completion of this course, students should be able to:
1. Identify and describe the different types and designs of turbomachinery (hydraulic turbines, pumps, fans and turbocompressors),
2. Explain the flow process and exchange of energy in turbomachinery,
3. Identify and analyze energy and exploitation characteristics of turbomachinery,
4. Explain the cavitation phenomenon in pumps and hydraulic turbines.

Theoretical teaching

- Description, classification, and the working principle of turbomachinery.
- The principles of energy exchange анд energy balance in turbomachinery. Phenomena in fluid flow in turbomachinery.
- The theoretical basis of thermodynamic. Multi-stage compression in the compressors (work and efficiencies).
- Definition of the internal work and impeller work. Euler equation for turbomachinery. Specific hydraulic energy.
- The impact of the impeller outlet angle on the impeller head and on the reaction factor.
- Impeller head reduction - the impact of a finite number of blades.
- Powers and efficiencies of pumps. Losses in turbomachinery.
- The laws of similarity. Characteristic coefficients of turbomachinery.
- Cavitation - phenomenon, stages. Cavitation reserve. The cavitation coefficient.
- Control of turbomachinery.
- Hydro (aero) profiles. Method of lifting surfaces.

Practical teaching

Turbomachinery in hydraulic, ventilation and compressor systems. Different types of runners and impellers. Exploatation of turbomachines. Laboratory exercises - showing turbomachinery constructions and description of the role of individual parts. Calculation examples of the lectured material: Calculation of specific hydraulic energy of pumps, fans and compressors. Euler equations for turbomachines. Powers and efficiencies of turbomachinery.

Operating characteristics of turbomachinery. The laws of similarity and non-dimensionless characteristics. Cavitation reserve. Control of turbomachinery.

Prerequisites

Compulsory examinations passed: Fluid Mechanics, Thermodynamics.
Preferred exams passed: Basis of Turbomachinery, Pumps and Fans.

Learning resources

Lectures in written and partially in electronic form, handouts for the exercises.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	10
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	40
test/colloquium	0	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Ljubisav Krsmanović, Aleksandar Gajić: Turbomachinery: theoretical fundamentals, Faculty of Mechanical Engineering in Belgrade, 2005.
Miroslav Benišek "Hydraulic Turbines," Mechanical Engineering in Belgrade, 2020.
Zoran Protić, Miloš Nedeljković: Pumps and fans: problems, solutions, theory, Faculty of Mechanical Engineering in Belgrade, 2021.

Turbomachinery

ID: 1001
Responsible/Holder professor ĐORĐE S. ČANTRAK
Teaching profesor(s): ČANTRAK ĐORĐE
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: hydropower engineering

Goals

Theoretical background in turbomachinery basic principles. Practical, engineering knowledge in turbomachinery and their applications, with focus on rotodynamic pumps, fans and turbocompressors.

Learning outcomes

Upon successful completion of this course, students should be able to:
1. identify and describe the various types and constructions of turbomachinery, as well as the principles of their work,
2. calculate and apply dimensionless parameters (characteristic coefficients),
3. determine the duty point of the hydraulic turbomachine and system,
4. select the appropriate pump or fan, as well as the most energy efficient way of their regulation,
5. calculate the pump duty point in terms of cavitation,
6. calculate the thermodynamic and energy parameters of the turbocompressor,
7. plan the fan testing according to the international standard.

Theoretical teaching

Description of various types of turbomachines. Design of hydraulic machinery and turbocompressors. Main geometry characteristics. Definition of the quantities for energy balance. Euler equation for turbomachines. Thermodynamic basis of turbocompressors. Expressions for power and energy efficiency rates for hydraulic machines and turbocompressors. Similarity law. Dimensionless quantities. Slip factor definition. Definition of the degree of reaction. Cordier diagram. Cavitation. Calculation of the basic geometry parameters of turbopumps, fans and turbocompressors. Application of pumps and fans in various facilities - determination of the system and machines duty points. Regulation of the operation of the pumps, fans and turbocompressors. Unstable Q-H curves. Optimal parameters determination for increasing system energy efficiency. Calculation of the fan-electromotor start time. Sealing. Influence of the working fluid properties on the pump and fan characteristics. International standards for testing of the fans and turbopumps. Operating curves of hydraulic turbo transmission.

Practical teaching

1. Exercises: Application and regulation of the turbopumps and fans. Determination of the system and machine duty points. Selection of the pumps and fans.
Thermodynamic analysis for turbocompressors.

Dimensionless quantities determination (pumps, fans and turbocompressors).
2. Presentation of the axial turbocompressor project.
3. Laboratory exercises:
3.1. Demonstration in the Laboratory for hydraulic machinery:
- pumps, hydraulic turbine, fans, hydraulic turbo transmission and turbcompressors - constructions
- systems with turbomachines.
3.2. Exercises: Determination of the pump/fan energy characteristics.

Prerequisites

Passed exams: Fluid Mechanics B and Thermodynamics B.

Learning resources

1. Books listed in literature and reference list available for students.
2. Lectures and exercises outlines.
3. Instructions for design of the multistage axial turbocompressor and centrifugal pump.
4. Laboratory with test rigs and measurement equipment for hydraulic turbomachinery - pumps, turbines, fans, hydraulic turbo transmission, as well as turboblowers and turbocompressors.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	21
laboratory exercises	3
calculation tasks	6
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	1
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Protić Z., Nedeljković M. (2021): Pumps and fans, Problems, solutions, theory, 7th edition, Faculty of Mechanical Engineering, Belgrade (in Serbian)
Obradović N. (1962): Fundamentals of turbomachinery, Građevinska knjiga, Belgrade (in Serbian)
Genić S.,Stamenić M.,Živković B.,Čantrak Đ.,Nikolić A.,Brdarević Lj. (2017):Manual for energy managers' training in the industry energetics,Fac. of Mech. Eng.,University of Belgrade,Belgrade (in Serb)
Babić M., Stojković S. (1992): Turbomachinery, Prosveta, Belgrade. (in Serbian)
Logan E. Jr. (1993): Turbomachinery, Basic theory and applications, 2nd edition, Marcel Dekker, Inc., New York

INDUSTRIAL ENGINEERING

Engineering statistics

Application of methods and techniques of industrial engineering in shipbuilding

Appraisal of Projects in IT field

Database Systems

Design of logistic and warehouse systems

Ergonomic design

Ergonomic designing

Foreign language

Improving the quality of business processes - Lean 6 Sigma

Industrial logistic

Industrial Management

Man - machine system design

Management Information Systems

Operations Research

Organization Design

Production and Operations Management 2

Risk management in Terotechnology

Skill Praxis M - IIE

Techno-economic analysis and project management

Engineering statistics

ID: 1457
Responsible/Holder professor MIRJANA Ž. MISITA
Teaching profesor(s): MISITA MIRJANA; MILANOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

The objectives of the course are to familiarize students with the basics of statistical methods used in industrial practice. The first step involves analyzing the characteristics of the data. The focus of the course is on identifying the problem, choosing the appropriate method through defined procedures and drawing conclusions, both mathematical and engineering. On the basis of engineering conclusions, the results are interpreted and appropriate engineering decisions are made.

Learning outcomes

After passing the exam, students are expected to know how to use: 1. statistical methods for objective problem solving in practice, 2. to draw the necessary conclusions using parametric and non-parametric research that includes hypothesis testing, one-way and two-way analysis of variance, simple and multiple regression and correlation, the 3rd goal of learning and practicing is correct problem setting, 4. determining the methodology of problem solving based on the results of descriptive statistics 5. implementing the appropriate statistical procedure defined by the steps of the procedure 6. correct engineering interpretation of the obtained results, with knowledge of their mathematical interpretation and 7. Getting to know the programming language R.

Theoretical teaching

Theoretical teaching of the following statistical areas: basic concepts of statistics, graphical presentation of data, descriptive statistics of data through the determination of basic statistics, parametric confidence intervals, parametric hypothesis tests for the mean, difference between means, variance, ratio of variances - for large and small samples, as well as for proportion and ratio of proportions. In addition, the bases for making decisions based on the p level of the test. Non-parametric tests including the test of functional dependence (Kolmogorov), tests of comparison of two distributions (Kolmogorov-Smirnov, Mann-Whitney, median test, median difference test and Darling Anderson test). Parametric analysis of variance which refers both to the basic parametric models of one-factor analysis of variance and to two-factor analysis of variance, as well as to the available non-parametric methods for its analysis. Regression tests include single and multiple linear regression and correlation, as well as their modifications, for parametric tests. Nonparametric tests including one-factor nonparametric analysis of variance, determination of the degree of curve using Cherbyshev polynomials, and correlation tests between data for nonparametric statistics.

Practical teaching

Practical teaching follows theoretical teaching with tasks aimed at identifying the problem, identifying the method for solving the problem, setting the problem, implementing the appropriate procedure for solving the problem and making appropriate conclusions. Students are trained to program problem-solving procedures using programming in appropriate software environments.. In addition, special attention is paid to training students to use specially created tables for the application of parametric and non-parametric hypothesis tests. Special attention will be paid to training students to use tables to identify parametric confidence intervals, and especially parametric hypotheses, setting up an algorithm for solving problems and using tables to choose a hypothesis testing procedure, as well as making correct conclusions based on the obtained results. Exercise tasks are done by calculation, they are partially solved on computers, using appropriate software packages.

Prerequisites

according to the curriculum of the industrial engineering department

Learning resources

Before each class of lectures and exercises, students receive handouts and other necessary materials in electronic form. If necessary, students receive materials in advance that will be needed for monitoring and active participation in classes. Radojević, S, Veljković Z, Quantitative methods, CD, MF

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	25	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Radojević, S, Veljković Z, Quantitative methods, Faculty of Mechanical Engineering in Belgrade, 2012.
Montgomery, DC, Runger, GC Applied Statistics and Probability for Engineers, Fourth Edition, Wiley, 2007

Application of methods and techniques of industrial engineering in shipbuilding

ID: 1543
Responsible/Holder professor MIRJANA Ž. MISITA
Teaching profesor(s): MISITA MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: industrial engineering

Goals

The aim of the course is to introduce the students with the basic methods and techniques of industrial engineering that can be used to increase efficiency and effectiveness in shipbuilding. The given methods and techniques will enable students to develop organizational and management skills for planning, budgeting, organizing, leading and controlling tasks, people and resources and managing quality, costs, time and risks in shipbuilding.

Learning outcomes

Successful completion of this course raises students' awareness of the importance of organizational and management skills in engineering activities and prepares them for commercial leadership in shipbuilding. The acquisition of knowledge in the field of basic - modern theoretical concepts and empirical methods and techniques in industrial engineering relevant to shipbuilding is emphasized.

Theoretical teaching

Introduction to Industrial Engineering. Short-term, medium-term and long-term planning. SWOT analysis (strengths, weaknesses, opportunities, threats). Procurement planning. Organizational planning. Organizational structure. Method of balanced indicators (Balanced Scorecard). Quality planning. Quality and risk management standards. FMEA (Failure Mode and Effects Analysis). FTA (Failure Tree Analysis). Methods and technical project management. Gantt charts. Critical path method - CPM and PERT technique. Planning project risk management. Ishikawa diagram. Pareto method / diagram. Linear programming.

Practical teaching

Practical exercises for the application of PERT and CPM methods, Gantt charts and linear programming techniques in a shipbuilding project. Workshop on clauses and system documents of quality standards and risk management (team work tasks). Each student implements each method / technique in an individual practical example, through exercises in the areas of PERT / CPM, Linear programming, Gantt chart, SWOT, BSC, Ishikawa-diagram, Pareto method/diagram, FMEA and FTA.

Prerequisites

No preconditions required

Learning resources

Excerpts from lectures and instructions for exercises. The use of other literature is also recommended, especially during the preparation of exercises.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	10
elaboration and examples (revision)	2
active teaching (practical)	**12**
auditory exercises	3
laboratory exercises	1
calculation tasks	3
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	20
test/colloquium	40	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Salvendy, G. (2007). Industrial Engineering Handbook, John Wiley & Sons Ltd.;
Sage, A.P., & Rouse, W.B. (2014). Handbook of systems engineering and management. John Wiley & Sons. ;
Swanson, R. (1995). The quality improvement handbook: team guide to tools and techniques. CRC Press, 2014.;
Tonchia, S. (2018). Industrial project management: International Standards and Best Practices for Engineering and Construction Contracting. Springer.;

Appraisal of Projects in IT field

ID: 1418
Responsible/Holder professor IVAN N. MIHAJLOVIĆ
Teaching profesor(s): MIHAJLOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

Understanding the importance of the process of planning, evaluating and evaluating projects in the field of information technology. Introduction to different methodological approaches for the analysis of IT / IS projects. Mastering sophisticated techniques of financial and economic analysis as well as standard techniques for managing IT / IS projects. Mastering techniques and routines for identifying and monetary quantification of difficult to detect costs and effects implied by the implementation of IT / IS projects.

Learning outcomes

After completing the course the student should: identify the project idea, prepare a database with all costs and effects of IT / IS projects, calculate criteria for selection of project alternatives, gain knowledge and routines for recognizing difficult costs and effects of IT / IS projects, organize networks project resource flow activities with the choice of optimal paths and minimum costs and assess the uncertainty and risk of IT / IS projects.

Theoretical teaching

Projects in the field of information technology, planning and appraisal/evaluation of IT / IS projects, methods of evaluation and evaluation of IT projects, standard (classical) methods for commercial evaluation of IT projects, standard methods for economic appraisal/evaluation of IT projects, possibilities of applying standard methods on IT / IS projects- Concept Screening, Business Model Canvas, quantification of financial and economic net effects of IT / IS projects, uncertainty and risk analysis in planning-implementation of software packages WHAT IF - DATA TABLE, WHAT IF – SCENARIO MANAGER, CRYSTAL BALL, evaluation and valuation of IT / IS projects, management of IT / IS projects-implementation of software package MSPROJECT, PLAN BEE.

Practical teaching

Practical classes consist of classroom and laboratory exercises that follow the content of the course. Within the classroom exercises through examples, simple demonstrations of theoretical material are made with explanations of each step in the evaluation procedure of IT / IS projects. Within the laboratory exercises, real examples of evaluation, evaluation and management of IT / IS projects are prepared with the use of appropriate software packages.

Prerequisites

Required: Basic information, economic and statistical knowledge. Preferred: completed courses Databases, WEB design.

Learning resources

Software: EXCEL, MSPROJECT, QM FOR WINDOWS, PLAN BEE, handout, books: Economic analysis of projects, Mastering Software Project Management, PMBOK guide

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	10
calculation tasks	10
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	40	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Nikola Dondur: Economic Analysis of Projects, Faculty of Mechanical Engineering, Belgrade, Belgrade, 2002 (in Serbian)
M Chemuturi, T. M. Cagley, Mastering Software Project Management, J Ross Publishing, 2010.
Ghosh, U. K. (2021). Appraisal and Selection of Projects: A Multi-faceted Approach. CRC Press.
PMBOK Guide

Database Systems

ID: 0521
Responsible/Holder professor MIRJANA Ž. MISITA
Teaching profesor(s): MISITA MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

The aim of this course is to prepare students for working with complex databases in production companies. The aim of this course is usage of industrial engineering methods and techniques in the creation of different database queries and scripts. Also, the aim of course is usage of complex database for improvement of decision-making process and management of business-production system.

Learning outcomes

Upon successful completion of this course, students should be able to:
- use SQL language,
- write queries for application industrial engineering methods using SQL language (For example: The level of utilization of machine capacity, the efficiency of production processes, ABC analysis, etc.).
- Analyze the results obtained by the queries established for business analysis,
- Estimates of efficacy of queries a established for the different methods of industrial engineering.

Theoretical teaching

1. Basic concepts of - database, databases, knowledge bases. Types of databases - hierarchical, network, relational model, object-oriented data model. Systems for database management. Standard SQL language. SQL data types. Queries. Examples of SQL functions.
2. Methods and techniques of industrial engineering - scripts in the SQL language. Defining the scripts for: rationalization of operating costs (QC diagram, critical point, ABC method) for calculating the machine capacity efficiency degree, and other scripts that involve application of industrial engineering methods and techniques in the analysis of operations of the relevant business-production system.

Practical teaching

Design of database, tables and indexes. Using of SQL query. Operators and functions in the SQL language. For the relevant example in practice, by using SQL language, defining scripts for: rationalization of operating costs (QC diagram, critical point, ABC method) for calculating the degree of efficiency of machine capacity, and other scripts that involve application of industrial engineering methods and techniques in the analysis of operations of the relevant business-production system.

Prerequisites

Enrolled 3rd semestar of Master study.

Learning resources

1. Handouts,
2. Computer classroom,
3. Software tool: MySQL,
4. Resuources form http://www.mysqul.com/
5. Database from concrete enterprise, in order to get practice on real example.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	26
elaboration and examples (revision)	4
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	30
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Johnson, J., Database - Models, Languages, Design, Oxford University Press, Oxford, 1997.
Beaulieu, A., Learning SQL, O'Relly Media, 2009.
Geherke, J., Database Management System, McGraw-Hill, New-York. 2003.

Design of logistic and warehouse systems

ID: 1370
Responsible/Holder professor UGLJEŠA S. BUGARIĆ
Teaching profesor(s): BUGARIĆ UGLJEŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

Achieving competency and academic skills in the process of industrial system design. Special emphasis is focused on development of creative skills and overwhelm with specific practical skills needed for professional practice using operational research methods, procedures of analysis and synthesis for obtaining final goal which is optimal practical solution.

Learning outcomes

Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of solutions in design process based on knowledge applying in practice using professional ethics as well as development of crucial and self-critical thinking and approach.

Theoretical teaching

Logistic system in industrial environment (connection of production system with transport system, management of demand and purchase and warehouse system). Design system documentation (fusibility study, conceptual solution, conceptual design, tender documentation, main technological-mechanical project, other main projects, final contractor project and project of carried out state). Previous analysis needed for system design (general conditions for urban planning, logistics and transport connections, energetic potential). Design process procedure. Project realisation and generation of results.

Practical teaching

Audit lessons (Introduction in design process for defined logistic-distribution system. Activity analysis for forming conceptual solution and conceptual design, activities connected with choosing of technological and other equipment, activities on forming main technological-mechanical project and final contractor project).
Project workmanship (Workmanship of the logistic-distribution system project. Defining of necessary parameters and surroundings for the given system design. Defining of needed system capacities. Forming of assignments for the other projects. Realisation of main technological-mechanical project).

Prerequisites

There is no special conditions needed for course attending.

Learning resources

1. Bugaric, U., Petrovic, D.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.

2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011. (in print)
3. Bugaric, U.: Methodology for analysis of single position machines work, Foundation Andrejevic, Belgrade, 2003.
4. Zrnić, Đ., Petrović, D.: Factory design – assortment of solved examples, Faculty of Mechanical engineering Belgrade, Belgrade, 1990.
5. Zrnić, Đ., Petrović, D.: Stochastic process in transport, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.
6. Practical instruction in industrial environment.
7. Personal computers.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	4
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	26
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	40
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Asimow, M.: Introduction to Design, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
Hall, A. D.: A methodology for systems engineering, Van Nostrand, Princeton, New Jersey, 1962.
Kleinrock, L.: Queueing Systems, Volume I: Theory, John Wiley & Sons, New York, 1975.
Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.

Ergonomic design

ID: 1041
Responsible/Holder professor ALEKSANDAR G. ŽUNJIĆ
Teaching profesor(s): ŽUNJIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: industrial engineering

Goals

Students should acquire specific practical skills that include an integrated ergonomic approach for the design of a comprehensive solution to different problems. The aim of this course is the acquisition of basic academic knowledge in the field of ergonomic design, which can be used for design of different products, as well as for redesigning and improvement on the system man - machine.

Learning outcomes

Upon successful completion of this course, students should be able to:

• Identify the different types of errors in the man - machine system and to apply adequate solutions aimed at eliminating of errors
• Design the indicators based on the application of ergonomic recommendations
• Design the controls based on the application of ergonomic recommendations
• Apply the ergonomic principles and recommendations on the design of the working environment and to conduct an assessment of the working conditions based on the application of experimental procedures
• Recognize the benefits and learn about the possibilities of applying software intended for computer-aided ergonomic design
• Apply the anthropometry in designing various products and transportation systems
• Perform ergonomic assessment of an interface
• Understand and recognize the ergonomic characteristics of the quality of products
• Identify the factors that affect the comfort and safety of a vehicle from the ergonomic aspect

Theoretical teaching

Introduction to ergonomic design. Management of errors in the man - machine system. Design of indicators.Design of controls.Application of anthropometry in ergonomic designing.Ergonomic product design and evaluation of interface. Comfort and safety of vehicles. Computer supported ergonomic design (CAED).

Practical teaching

Project task - Anthropometric designing of products. Auditory exercise - Design of cabins of cranes and hoists. Laboratory exercise - Assessment of design solution of the working environment conditions.

Prerequisites

The necessary condition for attending the course is that the student have enrolled to the appropriate semester.

Learning resources

Žunjić A, 2016, Script for Ergonomic design, Faculty of Mechanical Engineering, Belgrade. Žunjić A. and Ćulić M., 2007, Practicum for laboratory exercises in industrial ergonomics, Faculty of Mechanical engineering, Belgrade - available in the bookstore and library of the Faculty of Mechanical Engineering. Klarin M. and Žunjić A., 2007, Industrial ergonomics, textbook, Faculty of Mechanical engineering, Belgrade - available in the bookstore and library of the Faculty of Mechanical Engineering. Sound level meter, konimeter, psychrometer, lux meter, anthropometric measuring equipment.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	2
laboratory exercises	8
calculation tasks	0
seminar works	0
project design	8
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	20	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Žunjić A, 2016, Script for Ergonomic design, Faculty of Mechanical Engineering, Belgrade.
Handbook of human factors and ergonomics in consumer product design: uses and applications, 2011, Edited by Karwowski W., Soares M. and Stanton N., Taylor & Francis, London.
Sanders M. and McCormick E., 1993, Human factors in engineering and design, McGraw - Hill, Singapore.
Woodson W., 1981, Human factors design handbook, McGraw-Hill Book Company, New York.

Ergonomic designing

ID: 0417
Responsible/Holder professor ALEKSANDAR G. ŽUNJIĆ
Teaching profesor(s): ŽUNJIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: industrial engineering

Goals

The aim of this course is the acquisition of basic academic knowledge in the field of ergonomic designing, which can be used for designing of different products, as well as for redesigning and improvement of system man - machine - environment. Students should acquire specific practical skills that include an integrated ergonomic approach for the purpose of a comprehensive settlement of various designing problems.

Learning outcomes

Upon successful completion of this course, students should be able to:

• Apply ergonomic approach to all stages of the design process, during the design of simple or complex systems
• To apply various ergonomic tools for the purpose of realization of a project
• Design the indicators based on the application of ergonomic recommendations and carry out the assessment of the adequacy of indicators based on the application of the experimental procedure
• Design the controls based on the application of ergonomic recommendations
• Apply the ergonomic principles and recommendations on designing workplaces
• Apply the ergonomic principles and recommendations on the design of the working environment and to conduct an assessment of the working conditions based on the application of experimental procedures
• Recognize the benefits and learn about the possibilities of applying software intended for computer-aided ergonomic design
• Apply the anthropometry in designing various products and transportation systems
• Perform ergonomic assessment of an interface
• Understand and recognize the ergonomic characteristics of the quality of products
• Identify the factors that affect the comfort and safety of a vehicle from the ergonomic aspect
• Carry out the selection of the appropriate ergonomic method for design or evaluation of a system

Theoretical teaching

Introduction to ergonomic designing. The ergonomic approach to designing of complex systems. Ergonomic tools for managing and implementation of engineering projects. Designing of indicators. Designing of controls. Workplace designing. Designing of conditions of the working environment. Computer-supported ergonomic designing (CSED). Application of anthropometry in the ergonomic designing. Ergonomic product designing and evaluation

of interfaces. Safety and comfort of vehicles. Ergonomic research methods.

Practical teaching

Writing of a seminar paper - each student selects one of a number of topics, for which he is writing seminar paper in the form of professional work. The first laboratory exercise: Assessment of conditions of working environment - the criteria for assessing of conditions of working environment are presented and carries out the assessment of the conditions of a working environment at the selected workplace. The project task - Application of anthropometry in designing. The second laboratory exercise: Readability of analogue visual displays - the criteria for the assessment of readability are presented and testing of analogue visual displays is performed in the laboratory conditions.

Prerequisites

The necessary condition for attending the course is that the student have enrolled to the appropriate semester.

Learning resources

Tachistoscope, sound level meter, konimeter, psychrometer, lux meter, anthropometric measuring equipment, available in the lab. 417.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	8
calculation tasks	0
seminar works	10
project design	12
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	4
check and assessment of projects	4
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	15
test/colloquium	0	project design	20
laboratory exercises	15	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Žunjić A. and Ćulić M., 2007, Practicum for laboratory exercises in industrial ergonomics, Faculty of Mechanical engineering, Belgrade.
Klarin M. and Žunjić A., 2007, Industrial ergonomics, textbook, Faculty of Mechanical engineering, Belgrade.
Woodson W., 1981, Human factors design handbook, McGraw-Hill Book Company, New York.
Handbook of human factors and ergonomics in consumer product design: uses and applications, 2011, Edited by Karwowski W., Soares M. and Stanton N., Taylor & Francis, London.
Sanders M. and McCormick E., 1993, Human factors in engineering and design, McGraw - Hill, Singapore.

Foreign language

ID: 0805
Responsible/Holder professor TIJANA S. VESIĆ-PAVLOVIĆ
Teaching profesor(s): VESIĆ-PAVLOVIĆ TIJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: oral
Parent department: industrial engineering

Goals

Mastering English terms in the field of mechanical engineering and gaining skills for using professional literature in English, which contributes to students' active professional development and lifelong learning.

Learning outcomes

Upon the completion of this course, students will be able to:
- use advanced professional vocabulary in both written and oral English language,
- write an abstract in English,
- analyze a scientific paper in English in terms of characteristic constructions.

Theoretical teaching

Thematic contents in different branches of mechanical engineering, focusing on characteristic constructions and vocabulary in professional oral and written language. Mastering the formulations used in scientific papers in different fields of mechanical engineering. The structure of a scientific paper in English.

Practical teaching

Oral and written exercises, interpreting charts and schemes in English. The presentation of a chosen scientific paper in English, making summaries, writing biography and job application.

Prerequisites

Defined by the curriculum of the study programme/module.

Learning resources

M. Dunn, D. Howey, A. Ilic. English for Mechanical Engineering in Higher Education Studies. Garnet Education, Reading, 2010.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING		OTHER	
active teaching (theoretical)	**12**	**knowledge checks**	**6**
lectures	9	assessment of calculation tasks	0
elaboration and examples (revision)	3	check and assessment of lab reports	0

active teaching (practical)	**12**	check and assessment of seminar works	0
auditory exercises	7	check and assessment of projects	6
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	0
project design	5		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	50
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

M. Ibbotson, Cambridge English for Engineering, Cambridge University Press, Cambridge, 2008.
M. Ibbotson, Professional English in Use: Engineering. Technical English for Professionals. Cambridge University Press, Cambridge, 2009

Improving the quality of business processes - Lean 6 Sigma

ID: 1458
Responsible/Holder professor IVAN N. MIHAJLOVIĆ
Teaching profesor(s): MIHAJLOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: industrial engineering

Goals

The aim of the course is to acquaint students with modern approaches and methods for improving the quality of production processes, using Lean management approaches and the Six Sigma methodology, and students to be able to apply the aforementioned tools.

Learning outcomes

Upon completion of the course, students are able to: 1. Understand the concept of Lean - resource-saving production. 2. Understand Lean tools and capacity utilization, including Kaizen and Gemba procedures. 3. They understand and apply quality control methods in production, including the Six Sigma methodology. 4. They understand the basics of integrating the Lean concept and the Six Sigma methodology. 5. They master the methodology of experiment design, which includes the method of setting up, conducting the experiment and realizing the analysis and post-analysis of the modern approach of statistical design of experiments, including the interpretation of regression and correlation analysis.

Theoretical teaching

1. Basics of the Lean resource-saving production approach - introduction: value according to the LEAN concept; Five key principles in the LEAN concept; Value stream mapping and analysis; Material flow and material flow optimization tools; Difference between Pull and Push systems; Perfection; Seven losses in the LEAN concept; Operational planning and scheduling; Gantt charts and the LOB method. 2. Lean synchronization and capacity utilization, comparison and integration with MRP methodology: Kaizen; Gemba; LEAN synchronization; Concept of best work practice; List of Materials - BOM; Inputs and outputs of MRP; Production master plan and its inputs. 3. Quality control in production and the 6 Sigma concept: Structural problem solving; Steps of the 8D technique; KPI metrics; Kaizen charter form; Relationship between quality level and potential profit; Statistical process control; 6 Sugma and connection with control charts; DMAIC. 4 Lean 6 Sigma integration and basic tools of practical application: Levels of LEAN 6 Sigma experts; LEAN 6 Sigma techniques and connection with DMAIC stages; Voice of customers method and its application; Stages of new product development and application of QFD and DFM. 5. Experiment design - basic principles and examples from practice: Modeling; Modeling objectives; Five key steps in designing experiments.

Practical teaching

1. Identification of Values in the product/service; Monitoring the flow of value and the flow of materials; Analysis of 7 losses; Constriction of balance line - LOB; 2. Creation of the bill of

materials (BOM) of the product; Creation of MRP, based on LOB, using QM for Windows application; 3. Identification of metrics (KPI) of the considered process; Construction of X/R using QM for Windows application and PathMaker software; 4. Creating a process flow map; Cause-Effect Diagram (Ishikawa); Pareto diagram; Application of the Why-Why method in identifying the causes of disruptions in the process; 5. Experiment design, application of methods on a practical example.

Prerequisites

Enrolled semester.

Learning resources

Handouts from lectures and instructions for exercises. The use of other literature is also recommended, especially during the preparation of exercises.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	0
laboratory exercises	0
calculation tasks	4
seminar works	0
project design	8
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	1
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	1
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	25	project design	30
laboratory exercises	0	final exam	30
calculation tasks	15		

Requirements to take the exam (number of points) 0

References

B. Popović, M. Klarin, Z. Veljković, Six Sigma System in Realization of Process Results - Processing for Six Sigma, Faculty of Mechanical Engineering UB, 2008
Theisens, H. C. (2020). Lean Six Sigma Green Belt: Mindset, Skill set and Tool set. Van Haren.
Sproull, B. (2019). Theory of Constraints, Lean, and Six Sigma Improvement Methodology: Making the Case for Integration. Productivity Press.
Montgomery, D. C. (2020). Introduction to statistical quality control. John Wiley & Sons.

Handouts - theory and practice

Industrial logistic

ID: 1369
Responsible/Holder professor UGLJEŠA S. BUGARIĆ
Teaching profesor(s): BUGARIĆ UGLJEŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

Achieving competency and academic skills in the process of industrial system design. Special emphasis is focused on development of creative skills and overwhelm with specific practical skills needed for professional practice using operational research methods, procedures of analysis and synthesis for obtaining final goal which is optimal practical solution.

Learning outcomes

Curriculum overcome enables converge of the following skills: analysis, synthesis and prediction of solutions in design process based on knowledge applying in practice using professional ethics as well as development of crucial and self-critical thinking and approach.

Theoretical teaching

Logistic system in industrial environment (role of logistic system in industry, functions which system must achieved and its benefit for industry). Elements of logistic system (production based on end user demand, distribution and warehouse systems). Basic sub-systems of logistic system (production with defined capacity, transport with defined technology and distribution warehouse system). Place and role of the warehouse in logistic system. Application and effects of application of logistic systems in industry (territory coverage with defining location of production and end user, reduction of transport and storage costs and increase of flexibility towards end user).

Practical teaching

Audit lessons (Introduction in design process for defined logistic system – defining elements of logistic system and basic sub-systems for chosen logistic system. Introduction in warehouse design of palletized goods – defining of: reception area, main warehouse, distribution – order picking, shipping and warehouse management system).
Project workmanship (Determining of the optimal location of the logistic system in macro surrounding – positioning of warehouse regarding to production and end user as a function of transport system. Project of warehouse for palletized goods - defining of: packing and capacity, work technology, layout, reception and shipping and warehouse management system).

Prerequisites

There is no special conditions needed for course attending.

Learning resources

1. Bugarić, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.
2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011. (in print)
3. Zrnić, Đ., Petrović, D.: Factory design – assortment of solved examples, Faculty of Mechanical engineering Belgrade, Belgrade, 1990.
4. Zrnić, Đ., Petrović, D.: Stochastic process in transport, Faculty of Mechanical engineering Belgrade, Belgrade, 1994.
5. Bloomberg, D. J., LeMay, S. B., Hanna, J. B.: Logistics, Prentice Hall, New York, 2002.
6. Practical instruction in industrial environment.
7. Personal computers.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	40
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Asimow, M.: Introduction to Design, Prentice-Hall, Englewood Cliffs, New Jersey, 1962.
Hall, A. D.: A methodology for systems engineering, Van Nostrand, Princeton, New Jersey, 1962.
Cooper, B. R.: Introduction to queueing theory (second edition), Elsevier North Holland, New York, 1981.

Industrial Management

ID: 1417
Responsible/Holder professor IVAN N. MIHAJLOVIĆ
Teaching profesor(s): MIHAJLOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

The aim of this course is to acquaint students with the basic principles, methods and techniques of management in general, and especially in industrial enterprises. The goal is to acquire knowledge and skills that will be a solid basis for further acquisition of competencies for independent and responsible participation in business decision-making processes in modern conditions.

Learning outcomes

Mastering the material from the subject Industrial Management provides modern knowledge of the theory and practice of business management in general, and especially in industrial enterprises, with an emphasis on achieving competence to strengthen innovation as a key factor in competitiveness in turbulent business environment, domestic and foreign.

Theoretical teaching

Management and entrepreneurship: external environment, social responsibility and business ethics. Types of managers. Managerial roles. Industry and its transformation. Planning, strategic planning and strategic management. Forecasting and forecasting. Organization and organizing as a managerial resource. Decision making as a problem solving process. Human resources as company assets. Conflicts and conflict management. Creativity and innovation management. The concept of "learning organization". Principles of technological innovation management. Basic principles of knowledge management. Guidance. Leadership styles. Motivation. Communication systems. Control as management feedback. Industrial project management. Quality as a management variable. Ecological management. Globalization and management.

Practical teaching

The exercises consist of auditory exercises, i.e. discussions and workshops in which selected topics are additionally elaborated, as well as characteristic industrial cases from domestic and world practice. Special attention will be paid to the issue of innovation, and especially technological innovation as a factor of competitiveness. Also, the issues of the transition from management to leadership will be analyzed in more detail, as well as other issues in the field of modern business management. In addition, the exercises are used for preparatory consultations for the preparation and defense of seminar papers.

Prerequisites

none

Learning resources

In addition to the cited literature, other resources will be used, primarily handouts and selected links on the Internet, as well as prepared business cases from domestic and foreign practice.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	20
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	40	project design	20
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

C.M.Chang, Engineering Management: Challenges in the New Millenium, Pearson Prentice Hall, New Jersey, 2005
John Jeston and Johan Nelis, Business Process Management: Practical Guidelines to Successful Implementations, Butterworth-Heinemann, 2006

Man - machine system design

ID: 0520
Responsible/Holder professor ALEKSANDAR G. ŽUNJIĆ
Teaching profesor(s): ŽUNJIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: oral
Parent department: industrial engineering

Goals

The aim of this course is the acquisition of basic academic knowledge in the field of man - machine system design, which can be used for designing of different products and industrial systems, as well as for redesigning and improvement of system man - machine - environment. Students should acquire specific practical skills that include an integrated ergonomic approach for the purpose of a comprehensive settlement of various designing problems.

Learning outcomes

Upon successful completion of this course, students should be able to:

• Identify the main types of mechanical hazards
• Carry out the selection and to apply the basic types of safety protections on machines
• Perform the identification of all other types of hazards in the working environment and to implement hazard analysis in a man - machine system
• Apply basic procedures for hazard prevention
• To realize the complete program for realization of safe products within the organization
• Identify different types of errors in the man - machine system and to apply appropriate solutions aimed at eliminating errors
• Conduct an ergonomic evaluation of design solutions of manuals
• Design technical and project documentation in accordance with the ergonomic recommendations

Theoretical teaching

Mechanical hazards and safe operation of machinery. Analysis of risk in the system man - machine and their prevention. Safety and reliability of products. Management of errors in the man - machine system. Ergonomics of designing of technical and project documentation. Recommendations for designing of technical and project documentation.

Practical teaching

First project task - Identification of hazards in the workplace. Auditory exercise - Risk assessment in the man - machine system. Second project task - Ergonomic assessment of design solutions of manuals.

Prerequisites

The necessary condition for attending the course is that the student have enrolled to the

appropriate semester.

Learning resources

Žunjić A., 2016, Script for man - machine system design, Faculty of Mechanical Engineering, Belgrade.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	18
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	7
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	50
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Žunjić A., 2016, Script for man - machine system design, Faculty of Mechanical Engineering, Belgrade.
Handbook of human factors and ergonomics in consumer product design: uses and applications, Edited by Karwowski W., Soares M. and Stanton N., Taylor & Francis, London.
Sanders M. and McCormick E., 1993, Human factors in engineering and design, McGraw - Hill, Singapore.

Management Information Systems

ID: 0523
Responsible/Holder professor MIRJANA Ž. MISITA
Teaching profesor(s): MISITA MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

The aim of this course is to introduce students to contemporary theoretical and practical aspects of management information systems. Students need to acquire practical knowledge and skills that will enable them to enhance the quality of decisions in the field of industrial engineering, by using the contemporary software tools. Decision support systems and expert systems.

Learning outcomes

Upon successful completion of this course, students should be able to:
- Use software tools for decision support,
- Design models for decision-making process in DSS tools,
- Using expert systems in the field of industrial engineering,
- Projected base of knowledge in expert systems,
- Estimates of efficiency designed models in the specific case study.

Theoretical teaching

The term of Management information system (MIS). Decision-making process. Methods and techniques used in decision-making by managers. New IT and Web applications in functional areas. Executive information systems. Decision support systems. Knowledge management. Intelligent support systems. Expert systems. Other intelligent systems. Hybrid systems. Contemporary software in management.

Practical teaching

Task 1. By using software tools - decision support systems it is necessary to design models, generate a hierarchy of criteria and alternatives by introducing of qualitative and quantitative scales, introducing uncertainty, or by using functions to describe real problems in manufacturing practices. Conduct ranking according to the AHP or SMART methods. Sensitivity Analysis. Presentation of project assignment.
Task 2. By using an expert system shell it is necessary to design a knowledge base for the real engineering problem, link the production rules. Test the expert system. Presentation of project assignment.
Task 3. Connect the two previous project tasks and form a hybrid system. Presentation of project assignment.

Prerequisites

Enrolled 1st semester of the Master study.

Learning resources

1. Handouts,
2. Computer classroom,
3. Software packages: decision support system and expert system.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	26
elaboration and examples (revision)	4
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	30
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 10

References

Milanovic D. Dragan, Misita Mirjana, Information systems for management and decision making, Faculty of Mechanical Engineering, Belgrade, 2008
Turban E., Aronson J., Decision Support and Business Intelligence Systems, Pearson International Edition, 9th edition, 2010.

Operations Research

ID: 0421
Responsible/Holder professor UGLJEŠA S. BUGARIĆ
Teaching profesor(s): BUGARIĆ UGLJEŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: industrial engineering

Goals

Course goal is overwhelm with academic and scientific methods and quantitative techniques for obtaining alternative (optimal) solutions of real world problems on which basis user can perform analysis and synthesis of given solutions, make decision and predict consequences.

Learning outcomes

Solution of concrete problems with application of scientific methods, procedures and techniques using analysis, synthesis and prediction of solutions and consequences as well as overwhelm with methods, procedures and research processes and application of knowledge (gained skills) in practice.

Theoretical teaching

Introduction. Problem classification. Linear programming (graphical solution, simplex method, dual theory, sensitivity analysis). Transportation problem (open and closed). Linear regression (Least square method). Nonlinear programming (definition of convex function and set, one-variable and multivariable unconstrained and constrained optimization, Karush-Kuhn-Tucker (KKT) conditions, Gradient Search Procedure). Quadratic programming. Dynamical programming, Project management (structure analysis, time analysis using PERT/CPM, critical path, cost analysis – PERT/Cost). Service systems – Queuing theory (queuing theory models – single and multi server with out and with partial and complete help between servers, with finite and infinite source of customers, optimisation of service systems). Simulation of service systems (approach to simulation, Monte Carlo method, generation of random numbers, processing and presentation of simulation results). Decision analysis. Forecasting (forecasting methods).

Practical teaching

Audit lessons (examples of linear programming, transportation problem, linear regression, nonlinear programming, quadratic programming, dynamical programming. Examples of project management – structure analysis, time analysis cost analysis. Examples of application of queuing theory models – finite and infinite source of customers, single and multi server without and with partial and complete help between servers. Examples of service system optimisation. Application of simulation and Monte Carlo method in analysis and modelling of service systems. Examples from area of decision making and forecasting).
Laboratory work (use of adequate software).

Prerequisites

There is no special conditions needed for course attending

Learning resources

1. Bugaric, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2008-2011.
2. Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011.
3. Bugaric, U.: Methodology for analysis of single position machines work, Foundation Andrejevic, Belgrade, 2003.
4. Software: QtsPlus 3.0 (Queuing theory software Plus).
5. Software: QSopt Version 1.0 (Linear programming problems).
6. Software: IOR Tutorial (Interactive Operations Research).
7. Software: MS – Project (Project management).
8. Personal computers.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	21
laboratory exercises	9
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	9
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Petrić, J.: Operations Research (book 1 & 2), Savremena administracija, Belgrade, 1990.
Žiljak, V.: Computer simulation, Školska knjiga, Zagreb, 1982.
Clymer, J. R.: Systems analysis using simulation and Markov models, Prentice-Hall International Inc., 1990.
Churchman, C. W., Ackoff, R. L., Arnoff, E. L.: Introduction to Operations research, John Willey

& Sons Inc., 1957.
Hillier, F. S., Lieberman, G. J.: Introduction to operations research (seventh edition), McGraw-Hill, New York, 2000.

Organization Design

ID: 0574
Responsible/Holder professor VESNA K. SPASOJEVIĆ-BRKIĆ
Teaching profesor(s): SPASOJEVIĆ-BRKIĆ VESNA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to define the interdependence of the elements of organizational structure and processes so that in a given or anticipated situation organizationaly shaped organizational system (enterprise or its parts) achieves the persued objectives and goals.

Learning outcomes

Through this course students acquire knowledge and skills in the fields of acquisition of theoretical and practical knowledge in the field of intentional and controlled development and changes in the organization to improve efficiency and effectiveness, and working conditions in the organization, alignment of organizational and technical / technological factors and changing of organizational culture and climate and setting the optimal model organization with respect to the objectives and available resources.By the end of the Organisation Design course student will be able to:
-tackle an organisation design project
-sequence and approach the design effectively
-apply various tools and techniques to make good organisation
-design decisions
-control the consequences and risks of design changes
-recognize design project blockers and challenges and
-address design project blockers and challenges.

Theoretical teaching

Basic concepts of the design of organizations. Elements of organizational theory. Development of organizational theory. The concepts of organizational design. Directions of the past development of organizational theory. Situational model. Mintzberg`s model. Wilson`s model.Inkson`s model. Lawrence & Lorshov`s model. Frieblander`s model. Denning-Brown`s model. HPI model. Managerial grid model. Grainer`s model. Experience of local authors in designing the organization.Empirical organizational, technical, technological and cultural changes in organizational systems and its relation to performances.

Practical teaching

Data collection about the business and production operations relevant factors in real conditions. The analysis of situational factors (environment, size, age and type of company). Analysis of strategic variables (growth and development strategies). Analysis of structural factors (technology 'type of production and organizational structure). Analysis of behavioral

variables (organizational culture and climate). The analysis of business performances (development, operational and financial performance of companies). The proposal of new macro and micro organizational structure of the company. Check the proposed solution of the organizational structure OrgCon software package.

Prerequisites

Students need to enroll 9th semester.

Learning resources

Handout from lectures and instructions for exercises. It is recommended to use other literature, especially during the exercises.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	3
laboratory exercises	0
calculation tasks	7
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	1
check and assessment of projects	5
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	20
test/colloquium	10	project design	35
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

1. Spasojevic Brkic V., Contingency theory and Quality Management, Faculty of Mechanical Engineering, Belgrade, 2009.
2. Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management of production, Faculty of Mechanical Engineering,Belgrade. 1996.
3.Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes,Faculty of Mechanical Engineering, Belgrade, 1996.
4.Cvijanović J., Designing Organizations, Institute of Economics, 1992.
5. Hatch, M. J. Organization theory: Modern, symbolic, and postmodern perspectives. Oxford

university press, 2018.

Production and Operations Management 2

ID: 0413
Responsible/Holder professor DRAGAN D. MILANOVIĆ
Teaching profesor(s): MILANOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

Studying the management process of business-production system in its interaction with the environment.Identification of problems in business-production systems and the process of solving them, with implementation procedure. Investigation and design of production macro and micro organizational structure. Management of business-production system and provision of all resources necessary for production normal operation.

Learning outcomes

Upon the successful completion of this course, students should be able to:
- discuss the problems of business-production planning, organization and management,
- integrate subsystems into a functional whole,
- select the methods and techniques for problem solving,
- apply the methods and techniques for business-production problem solving,
- solve the problems of business-production management,
- evaluate and cooperate in solution implementation.

Theoretical teaching

Complex optimization of business-production systems in thier interaction with the environment. Classification of business-production systems by the character of the technological process. Types of production organizational structure. Methods and techniques for scanning the current state of engineering-technological basics of production. Business-production problems and the process of solving them, with implementation procedure. Organizational structure of production and accessory units, operation and operational relations with organizational unit. Time management as an irretrievable resource, production cycle and delivery terms, flow coefficient, internal reserves and possibility of utilizing them. Design of macro, micro and intra organizational structure. Static and dynamic aspect with contents of jobs per organizational unit. Cybernetic model design for direct organization of production preparation and provision of all resources needed for normal operation of all work places. Methods and techniques of work place scanning.

Practical teaching

Exercises are realized through project task in the enterprise. Project task should establish the most important organizational problems in an enterprise and propose how to solve them in order to improve organizational level in general and rationalize business operations and production. The design of jobs at work place is stressed. Job description, work conditions, job

classification and work place matrix. Students are supposed to make concrete proposal for rationalization and improvement of operation of certain organizational wholes in business-production system by applying contemporary methods and techniques of industrial management.

Prerequisites

Production and Operations Management 1 (not obligatory); semester certified.

Learning resources

The enterprise where the project is to be realized, so that students get familiarized with realistic conditions of production, scan the current state-of-art and collect documentation. The Chair allows students to use equipment for scanning work conditions at work place. Use of additional literature is recommendable, depending on the project theme.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	25
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

V.Bulat: Organization of production, FME, Belgrade, 1999 /In Serbian/
T.Jovanovic, D.D.Milanovic, V.Spasojevic: Contemporary organization of production management,FME,Belgrade, 1996 /In Serbian/
T.Jovanovic, D.D.Milanovic, Z.Veljkovic: Collection of tasks in quantitative methods, FME, Belgrade, 1996 /In Serbian/

Risk management in Terotechnology

ID: 0513
Responsible/Holder professor VESNA K. SPASOJEVIĆ-BRKIĆ
Teaching profesor(s): SPASOJEVIĆ-BRKIĆ VESNA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

The aim of this course is to acquire the necessary knowledge and practical skills that will enable students to apply production and maintenance systems based on risk management, due to knowledge in the identification, analysis, risk assessment and decision-making on the basis of those facts.

Learning outcomes

Student after completing the course is able to: a) recognize /describe core systems, methods and strategies of terotechnology procedures b) applies terotechnology method based on risk, c) applies models RIMAP (Risk Inspection Maintenance Procedures) d) applies RCM models (Models for reliability based maintenance) in practice, and e) elect / propose appropriate solutions for the mitigation of risk. Upon successful completion of this course, students are able to choose the appropriate method, collect the data source required for the implementation of certain methods of risk management, conduct methodological procedure, conduct specific methods of processing results, critically consider and make decisions on the mitigation of risk depending on the results.

Theoretical teaching

Introduction to terotechnology. Terotechnological procedures, operations and technologies. Aims and objectives of terotechnological activities. The principles of maintenance. Maintenance policy. Maintenance systems. The organizational structure of maintenance function. Maintenance methods and strategies. Maintenance methods based on risk. Maintaining the reliability - Reliability Centered Maintenance - RCM. Qualitative risk assessment. Risk-based Inspection - RBI. The concept of risk-based maintenance - RBIM. Risk Based Life Cycle Management of technical resources - RBLM. Risk Based Management - RBM. Maintenance procedures based on risk - RIMAP. Risk management tools - Pareto, Ishikawa, FMEA, FTA. Risk assessment at workplaces and in environment. Role of anthropometry in OSHA. Application of risk management in national industrial practice.

Practical teaching

Collection and systematization of data collected in companies. Evaluation of data on individual risks. Preliminary risk matrix. Calculation of individual riskc. Risk matrix. Preliminary evaluation of the possible scenarios of origin effects. Risk tools application - Pareto, Ishikawa, FMEA, FTA. Detailed analysis of one or more of the selected scenarios, including probability analysis to achieve them. Detailed technical analysis of possible consequences of different scenarios. The overall analysis of possible consequences and

analysis in terms of insurance and reinsurance.

Prerequisites

Enrolled semester.

Learning resources

Handouts from lectures and instructions for exercises. It is recommended to use other literature, especially during the exercises.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	15
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	25	project design	25
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

1. Klarin M., Ivanovic G., Stanojevic P., Raicevic R. , Principles of Terotechnological Procedures, Faculty of Mechanical Engineering, Belgrade, 1994.
2. Smith D., Reliability, Maintainability and Risk - Practical methods for engineers, Elsevier Butterworth-Heinemann, Oxford, 2005.
3. Zio E., AN INTRODUCTION TO THE BASICS OF RELIABlTY and RISK ANALYSIS, World Scientific Publishing Co., 2007.
Panchal, D., Chatterjee, P., Pamucar, D., & Tyagi, M. (Eds.). Reliability and Risk Modeling of Engineering Systems. Springer, 2021.
Handouts - theory and practice, 2023.

Skill Praxis M - IIE

ID: 1250
Responsible/Holder professor MIRJANA Ž. MISITA
Teaching profesor(s): MISITA MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: industrial engineering

Goals

The aim of the course is improvement of the practical knowledge acquired on master studies courses through familiarizing students with the environment in which they will develop professional career and the recognition of the basic functions of the business system in the field of industrial engineering, as well as the role and tasks of mechanical / industrial engineers in such a business system.

Learning outcomes

This course attendance enables the following:
- Student recognizes the organization and functioning of the environment in which they will apply the acquired knowledge in their future professional career, based on the information / data collected in the field.
- Student connects the knowledge acquired in other courses.
- Student identifies and critically examines models of organization and flow of business information.
- Student recognizes the basic processes in the design, production, maintenance, inventory management, quality and safety and health at work, in the context of his future professional competencies and critically analyze them.
- Student establishes the personal contacts and friendships that will be able to use during the study or when entering into future employment.
Upon completion of the course, students have practical knowledge and skills in the field of business organization and sustainable development of enterprises.

Theoretical teaching

The theoretical knowledge acquired during studies at the Faculty of Mechanical Engineering is used.

Practical teaching

Company visits and analysis based on real data collected in the fields:
Topic 1.: The history and the activity in which the practice is carried out.
Topic 2.: The layout of the company
Topic 3.: Organizational chart of the company
Topic 4.: Staffing structure
Theme 5.: Sales and procurement services
Topic 6.: Development sector (if any)
Topic 7.: Production planning sector

Theme 8.: The manufacturing sector - Capacities and production cycle
Topic 9.: Sector / Subsector of Quality Management
Topic 10.: Storage and transport
Topic 11: Maintenance management systems,
using the methods of industrial engineering.
After completion of practical training, students must make a report that will defend to the responsible teacher.

Prerequisites

Enrolled semester

Learning resources

Data from pilot enterprises: documents, reports, databases, e-data.

Methods and techniques of industrial engineering described in learning resources:

1. Bulat V., Organization of production, Faculty of Mechanical Engineering, Belgrade, 1999.(in Serbian)
2. Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
3. Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
4. Tersine J.R., Production/Operations Management: Concepts, Structure and Analysis, Appleton & Lange, New York, 2005.
5. Sources collected in the companies

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	30
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	60

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	40

test/colloquium	0	project design	0
laboratory exercises	0	final exam	60
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Jovanovic T., Milanovic D. D., V Spasojevic., Modern organization and management, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
Bulat V., Organization of production, Faculty of Mechanical Engineering, Belgrade, 1999.(in Serbian)
Klarin M., Industrial Engineering, Volume 1, The organization and planning of production processes, Faculty of Mechanical Engineering, Belgrade, 1996. (in Serbian)
Tersine J.R., Production/Operations Management: Concepts, Structure and Analysis, Appleton & Lange, New York, 2005.

Techno-economic analysis and project management

ID: 1248
Responsible/Holder professor UGLJEŠA S. BUGARIĆ
Teaching profesor(s): BUGARIĆ UGLJEŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: industrial engineering

Goals

Students acquaintance with the goals of techno-economic analysis and the goals, processes and stages of project management. Acquaintance and mastering with modern methods, techniques, tools and areas of knowledge necessary for successful project management.

Learning outcomes

Upon completion of the course syllabus students will be able to:
• Explains the concept of the project and its most important characteristics, the organizational structure of project management, the role of stakeholders in project realization,
• Understand the concept of project management methodology and project management processes,
• Apply techno-economic analysis tools and techniques for project rentability,
• Develops a WBS structural diagram in order to define the scope of the project,
• Use a Gantt chart and network diagram to plan and track the order and dependencies of activities,
• Explains the importance of managing project costs,
• Explain quality control methods and techniques,
• Apply tools and techniques to support human resource management, risk management and procurement on the project,
• Recognize the importance of communication management in order to create good relationships for all stakeholders involved in project implementation,
• Apply adequate software in project management.

Theoretical teaching

Definition and concept of the project. Classification and basic characteristics of projects. The concept of project management. Techno-economic analysis (static and dynamic measures of project profitability assessment). Organizational structures for project management. Participants in project implementation. Project life cycle. Project Management Processes (Group of processes for: project initiation, project planning, project execution, project monitoring and control, project completion). Project integration management. Project Scope Management. Project time management. Project Cost Management, Project Quality Management. Human resource management. Project communication management. Project risk management. Procurement management for the project. Introduction to basics and navigation in SAP solutions based on SAP ERP.

Practical teaching

Determination of payback period, determination of present and future value of money, determination of net present value and profitability index. Network diagram structure analysis. Time analysis by the CPM method. Time analysis by PERT method. Determination of project completion probabilities and project costs using analytical methods and simulation. Project cost analysis and monitoring. Determination of risk in project realization. Working in specialized software packages (MS - Project, Exercises & Case Study - SAP module PS - Project Management).

Prerequisites

None

Learning resources

1. Software: SAP ERP.
2. Software: MS Office.
3. Software: MS – Project (Project management).
4. Personal computers.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	15
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Јовановић П., Управљање пројектом, ФОН, Београд, 2006.
Kerzner H: “Project Management”, VIII издање, John Wiley & Sons, New Jersey, 2003.

Bugaric, U.: Lecture handouts, Faculty of Mechanical engineering Belgrade, Belgrade, 2019.
Bugaric, U., Petrovic, D.: Servicing system modelling, Faculty of Mechanical engineering Belgrade, Belgrade, 2011.
PMBOK - guide, Project management institute, 4th edition, FTN, Novi Sad, 2010. (in Serbian).

INFORMATION TECHNOLOGIES

Algorithms and data structures

C/C++

Computer Graphics and Virtual Reality

Computer Networks

Data Exquisite in Mechanical Engineering

Distributed Systems in Mechanical Engineering

Embedded systems and IoT in mechanical engineering

Engineering Software Design

Numerical Methods in Continuum Mechanics

Object oriented paradigm

Optimization Methods

Programmable Control Systems

Skill Praxis M - MIT

Algorithms and data structures

ID: 1491
Responsible/Holder professor MAJA B. ROSIĆ VITAS
Teaching profesor(s): ROSIĆ VITAS MAJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: information technologies

Goals

• Basic facts of algorithm theory. • Abstract data type and basic implementation. • Data structures in mechanical engineering. • Using standard algorithms in solving simple problems in mechanical engineering.

Learning outcomes

After successful completion of the program provided for in this case the student can: • To find data structure to solve the problem. • Use data structures and standard algorithms in solving simple problems in mechanical engineering. • To find suboptimal algorithm to solve smple problems in mechanical engineering. • To use standard algorithms to solve complex problems in mechanical engineering.

Theoretical teaching

Basic facts about algorithms. Basic facts about abstract data type. Array. Lists. Buffers. Stack. Queue. Trees. Binary tree. Binary hip. Set. Hash. Dictionary. Varies sorting and searching algorithms with apply in mechanical engineering. Hanoi towers. Quick sorting and searching. Big numbers. Polygon triangulation. Flag problem. Optimal and suboptimal salesman problem. N-Queens problem. Stable marriage problem. practical teaching Workshops with basic examples.

Practical teaching

It consists of auditory, laboratory exercises that follow the course content.

Prerequisites

Knowledge of C/C++ languages. Basic knowledge of program design methodology. Fundamentals of software engineering.

Learning resources

The necessary software is under the GNU license - free of charge. In LINUX, C/C++ is immediately available. If you use another operating system, C/C++ compiler can be downloaded from the appropriate Web site

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	OTHER

active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	10
research	**0**

knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5
test/colloquium	35
laboratory exercises	0
calculation tasks	0

seminar works	15
project design	15
final exam	30

Requirements to take the exam (number of points) 0

References

T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein, Introduction to Algorithms, The MIT Press, Cambridge, 2009.

C/C++

ID: 1489
Responsible/Holder professor GORAN M. LAZOVIĆ
Teaching profesor(s): LAZOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: information technologies

Goals

Introduce to C/C++; Structure of C/C++ and usability. Solving simple problems in mechanical engineering using C/C++. Art of pointers. Saving acquisition data in files, use that files and discuss results.

Learning outcomes

After successful completion of the program provided for in this case the student can: Program simple programs in C/C++ to solve problems in mechanical engineering. Use basic patterns in C/C++. Use pointers and simple data structures. Solve simple mechanical engineering problems with acquisition data in files.

Theoretical teaching

Basic types. Constants. Operators and priority of operators. Blocks. If statement. Cycles. goto, break and exit statements. Domain rules and variable declaration. Statical and registar variables. Definition and declaration of functions. Initialisation and recursion. Structures and fields. char arrays and strings. Basic facts about pointers. Arrays and pointers. Adress aritmetic based on pointers. Command line arguments. Pointers to functions. Standard streams. Files and buffers. Some rules on using memory.

Practical teaching

Workshops with basic examples in C/C++.

Prerequisites

Knowledge of Programming, Computer tools, Numerical methods, Mathematics 1, Mathematics 2.

Learning resources

The necessary software for this case under the GNU license - free of charge. If necessary use the Linux C/C++ as it is available to you immediately. If you use another operating system, C/C++ can be downloaded from the appropriate Web site (see URL) or the URL. To run the software it is enough to possess simplest PC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	OTHER

active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	8
project design	4
discussion and workshop	3
research	**0**

knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	4
colloquium, with assessment	0
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5
test/colloquium	35
laboratory exercises	0
calculation tasks	0

seminar works	30
project design	0
final exam	30

Requirements to take the exam (number of points) 35

References

Laslo Kraus; Programski jezik C++ sa rešenim zadacima; Akademska misao; 2014
Stanley B. Lippman, Josee Lajoie, Barbara E. Moo; C++ Primer; Addison-Wesley Professional; 2012

Computer Graphics and Virtual Reality

ID: 1496
Responsible/Holder professor ALEKSANDAR Č. BENGIN
Teaching profesor(s): BENGIN ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: information technologies

Goals

Introduction to the study of the basic principles of computer graphics, elementary and complex
transformations integrated in the radar space. Delimited and improved models of use of ready-made software solutions in the control of control graphic products in 2D and 3D models conceived on the radar platform. Integrating knowledge in the realm of virtual things through 2D and 3D elements' systems eliminates' flat 'screens and modern hardware solutions designed on library synergy and capable of having hardware.

Learning outcomes

After successful completion of the program provided by this subject student can:
• apply the acquired knowledge in the scientific, technical and engineering applications of virtual reality technology,
• to design engineering software based on computer graphics,
• to integrate knowledge in the field of video game physicality.

Theoretical teaching

Definitions of computer graphics. Analysis of raster and vector computer graphics. Record vector. The concept of pixels and address space. Elements of geometric transformations (scaling, translation, rotation of 2D and 3D objects in computer space). Graphic "engine". Analysis of usage of Open GL system and WEB GL system. Overview of advanced engineering packages for real-time virtualization of models and phenomena. Presentation of current hardware solutions for 3D object scans, transformation of physical into electrical and IT sizes in order to visualize objects and phenomena. Fundamentals of Algorithm for Image and Sound Analysis. Basics of virtual reality with elements of engineering problems analysis. Fundamentals of Video Game Theory. Historical review. Analysis of sprites and transitions to modern engines.

Practical teaching

It consists of auditory, laboratory exercises that monitor the content of the course.

Prerequisites

Required: Basic computer culture based on PC usage, independent of operating system.

Learning resources

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NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	17
calculation tasks	0
seminar works	7
project design	3
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	35	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

LaValle S. M,, Virtual Reality,, Cambridge University Press, 2019;
Virtual Reality Technology, Second Edition with CD-ROM Grigore C. Burdea, Philippe Coiffet ISBN: 0-471-36089-9 Wiley-IEEE Press; 2 edition (June, 2003)
Sherman R, Craig A., Understanding Virtual Reality: Interface, Application, and Design, 2nd Edition, Eselvier, 2018.

Computer Networks

ID: 1303
Responsible/Holder professor GORAN S. VOROTOVIĆ
Teaching profesor(s): VOROTOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: information technologies

Goals

Course objective:
• Introduction to the concept, standard tasks and operation of computer networks.
• Introduction to the protocol and other factors that control, manage and participate in creating a variety of processes and resources of computer networks and computers.

Learning outcomes

The acquired knowledge allows students:
• to identify and suggest the type of computer network,
• to understand the problems that arise whendesigning computer networks,
• to create a project of computer network that includes a sugestion purchase of necessary equipment.

Theoretical teaching

The basics of networking. The basic components of computer networks. Hardware. Software. The reasons for networking. The network environment.Use of Information. Passive network equipment. The active network equipment.Protocols. Computer interfaces. Standard computer networks. The division of computer networks. Grouping according to the capacity of computer networks for the transmission of data, the speed of transmission, according to a hierarchical or geographic area, according to the topology or logical and physical layout of nodes, as compared to nodes in a network, the architecture of computer networks and the access to computer networks.
The complexity and reference models.The role of the layers. OSI reference model. TSP / IP. Physical layer. USB, FireWire, IrDA, Bluetooth, Ethernet, WiFi, ISDN, xDLS. Link layer. The division of link layer. Access Control (MAC), Logical Link Control (LLC). Flow control. Control error. Link layer protocols. Ethernet. ARP.Token Ring. FDDI.
Network layer. Internet Protocol (IP).Networks and network classes. CIDR. ICMP.IGMP.IPX. RARP. BOOTP. DHCP. IPv6.
Transport layer. TCP, UDP, SCTP, SPX, iSCSI.
Application layer. SSH. Remote Desktop. DNS. FTP. Electronic mail. SMB / CIFS. HTTP. NTP. SNMP.Voice over IP. Instant Meassaging. Video conference. Operating systems in computer networks. Implementation of network support. Comparison and analysis of some features of contemporary operating systems. Security. Accessibility. Performance. Possible attacks and protect computer networks. Firewall. IDS and IPS systems.

Practical teaching

It consists of auditory, laboratory exercises thatfollow the content of course.

Prerequisites

Required: Basic computer culture based on the use of a PC, regardless of operating systems.WEB design in mechanical engineering,Software Engineering.

Learning resources

The necessary software for this case under the GNU license - free of charge.
• To run the necessary software is enough to havethe simplest PC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	17
calculation tasks	0
seminar works	7
project design	3
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	15	project design	20
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Birman, Kenneth. Reliable Distributed Systems: Technologies, Web Services and Applications. New York: Springer-Verlag, 2005.
Gray, J. and Reuter, A. Transaction Processing: Concepts and Techniques. San Mateo, CA: Morgan Kaufmann, 1993.
Јамес Ф. Куросе, Кеитх W. Росс, Умрежавање рачунара, Цет, Београд, 2005.
de Andrade, R.; Hodel, K. N.; Justo, J. F.; Laganá, A. M.; Santos, M. M.; Gu, Z. (2018). "Analytical and Experimental Performance Evaluations of CAN-FD Bus". IEEE Access. 6: 21287 - 21295.

Data Exquisite in Mechanical Engineering

ID: 1493
Responsible/Holder professor GORAN S. VOROTOVIĆ
Teaching profesor(s): VOROTOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: information technologies

Goals

Course objective:

• Numerical and mathematical analysis capabilities for each measurement.
• Design and write programs for analyzing measurements.
• Comparison analysis of numerical data processing and analysis software.
• Implementation of PHP and JAVA Script.

Learning outcomes

The acquired knowledge allows:

• That be entered professional do the measurements and determine the necessary and forward the required size,
• That the measurement is so mathematical, numerical and statistical analysis and then to be graphical and logical preparation for further analysis,
• That, using PHP or Java Script, or both, make software to perform accurate data processing which is a pre-determined mathematically.

Theoretical teaching

BASIC THEORY OF SAMPLES. Population and simple sample with replacement and without returning. Sampling - the empirical distribution as a possible Code of Conduct of the population.

TREATMENT OF STATISTICAL BASIS
The concept of statistical meetings. Mean values of statistical assemblage. Dispersion. Models of the distribution. The trend in the study of statistics. Time series in the study of statistics. Statistical indicators in the study. Hypotheses and tests.

ARISING FROM PROBABILITY. The mathematical probability of an event. Addition theorem of probability. Multiplication theorem of probability. Permutations, combinations and variations of elements of one set.

REPETITORIA numerical methods. Some algebraic problems. Interpolation polynomials. Lagrange interpolation polynomials (Joseph-Louis Lagrange). Newton (Isaac Newton) interpolation polynomials. Numerical integration. Newton-Coates (Isaac Newton - Roger Cotes) formula. Simpson (Thomas Simpson) formula.

IMMEDIATE MEASUREMENT ACCURACY Equal and unequal. Determining the value of measured values. Determination of measurement error. Distribution law of random sizes.

INDIRECT MEASUREMENT ACCURACY OF EQUAL. Determining the average size of the errors of certain indirect measurement. Determining the size of the average error of certain indirect measurement of the same accuracy. The general case of indirect measurement of the system of equations equal accuracy.

INDIRECT MEASUREMENT ACCURACY unequal. Normal equations indirect measurements of unequal accuracy. Control in solving the normal equation of unequal accuracy.

CONDITIONAL MEASUREMENTS SIZE. The process of measuring the conditional correlations. The process of reducing the indirect measurements.
Basic Theory of Correlation. Two-dimensional distribution laws of random sizes.

Practical teaching

It consists of auditory, laboratory exercises that accompany the course.

Prerequisites

Required: Basic computer culture based on the use of a PC, regardless of operating sistema.Osnovno knowledge of mathematical logic.

Learning resources

Audience is available licensed software owned by the faculty. Listeners freeware software is available.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	17
calculation tasks	0
seminar works	7
project design	3
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30

test/colloquium	35	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Č. Mitrovic, S. Radojevic, The Data Exquisite in Mechanical Engineering, a textbook (in preparation) Faculty of Mechanical Engineering, Belgrade, 2022.

Distributed Systems in Mechanical Engineering

ID: 1448
Responsible/Holder professor GORAN S. VOROTOVIĆ
Teaching profesor(s): VOROTOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: information technologies

Goals

• Introduction to the paradigm of distributing data
• Knowledge of basic protocols for the transfer and sharing of distributed data.
• Designing local area networks based on different technologies
• Introduction to multiprocessor distributed systems in the automotive and aircraft industry
• Introduction to algorithms that are typical of multi-processor distributed systems

Learning outcomes

Стечено знање омогућава студенту:

• to recognize the conditions for the formation of local area networks
• to allocate names to resources on the net
• to control and menage assigned resources
• to understand the multi-processor and redistribution of data among them

Theoretical teaching

Local and remote computer network as a weak coupled systems. The concept of server and service provider
Indoor network systems. Assignment of rights and names in the closed network systems. Application of these systems in the automotive and aircraft industry.
Local area network-LAN
Connect local area networks. The protocols in use. Bluetooth protocol for small local networks. Routing and ranges in routing.
Recommendations in the formation of IEEE local computer networks and their links.
IP protocol.
Wireless local area networks. Use of multi-radio waves in the small computer networks. User control in a wireless network
Multiprocessor systems. Algorithms for controlling the resources used in operating systems for multiprocessor hardware systems.
The case studies specific to the automotive industry. Case studies characteristic of the civil and military aerospace industry.

Practical teaching

It consists of auditory, laboratory exercises that accompany the course. We should particularly look at case studies in the auto industry and the aviation industry.

Prerequisites

Required: Basic computer culture based on the use of a PC, regardless of operating system.

Learning resources

- The necessary software for this case under the GNU license - free of charge.
- To run the necessary software is enough to have the simplest PC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	20
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10
test/colloquium	15	project design	30
laboratory exercises	5	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Birman, Kenneth. Reliable Distributed Systems: Technologies, Web Services and Applications. New York: Springer-Verlag, 2005.
Gray, J. and Reuter, A. Transaction Processing: Concepts and Techniques. San Mateo, CA: Morgan Kaufmann, 1993.
Џамес Ф. Куросе, Кеитх W. Росс, Умрежавање рачунара, Цет, Београд, 2005.
de Andrade, R.; Hodel, K. N.; Justo, J. F.; Laganá, A. M.; Santos, M. M.; Gu, Z. (2018). "Analytical and Experimental Performance Evaluations of CAN-FD Bus". IEEE Access. 6: 21287 - 21295.

Embedded systems and IoT in mechanical engineering

ID: 1494
Responsible/Holder professor GORAN M. LAZOVIĆ
Teaching profesor(s): LAZOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: information technologies

Goals

Acquisition of theoretical and practical knowledge in the field of embedded systems and Internet of Things.

Learning outcomes

Students are trained for practical work with embedded systems in the Internet environment. Students have theoretical knowledge of Internet architecture and embedded systems.

Theoretical teaching

1. History and reference models, ISO-OSI. 2. TCP-IP reference model. 3. Network hardware and software. 4. Protocols, HDLC, PPP. 5. Local area networks. 6. Routing algorithms. 7. Network layer, IP protocol. 8. Management protocols, ICMP, ARP, DHCP, RIP. 9. Transport level, TCP, UDP. 10. Application level, sockets, DNS, email, FTP, www, http.

Practical teaching

It consists of auditory, laboratory exercises that monitor the content of the course.

Prerequisites

Basic computer culture based on PC usage, independent of operating system.

Learning resources

-

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	17
calculation tasks	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3

seminar works	7	final exam	5
project design	3		
discussion and workshop	3		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	35	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

de Andrade, R.; Hodel, K. N.; Justo, J. F.; Lagana, A. M.; Santos, M. M.; Gu, Z.; Analytical and Experimental Performance Evaluations of CAN-FD Bus; IEEE Access. 6: 21287 - 21295; 2018
James F. Kurose, Keith W. Ross; Umrežavanje računara, Cet, Beograd, 2005.
Gray, J. and Reuter, A. Transaction Processing: Concepts and Techniques. San Mateo; CA: Morgan Kaufmann, 1993.
Birman, Kenneth. Reliable Distributed Systems: Technologies, Web Services and Applications; New York: Springer-Verlag; 2005
G. Vorotović at all; Possibilities of BLOB and CLOB Integration Into the Core of IoT and Using the SQL Platform for Distributing a Large Amount of Data to HTML, JAVA, and PHP Plat; IGI Global 2017

Engineering Software Design

ID: 1495
Responsible/Holder professor MIRKO R. DINULOVIĆ
Teaching profesor(s): DINULOVIĆ MIRKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: information technologies

Goals

Prepare inputs for the engineering software based on standard calculations.
• Preparation of engineering calculations for effective programming and obtain efficient programs.
• Testing and verification of software engineering. Validation of software engineering.
• Use SQL to get information from databases.
• Use SQL for engineering decision making.
• Organization, normalization of data in the database.
• Privacy, data archiving. Issues of software licensing.

Learning outcomes

After successful completion of the program provided for in this case the student can:
• Prepare a budget for programming.
• to assess the quality of information obtained from the input data that are processed program written
for a defined budget.
• use the database for specific problems in mechanical engineering.
• use SQL as a generator of low-level information for software engineering.

Theoretical teaching

1. Basic numerical methods in the calculations.
2. Designing software for selected numerical methods and calculations. Finding the zero function.
Numerical differentiation and numerical integration.
3. Designing software for selected numerical methods and calculations. Numerical solution of partial
differential equations and first order. Basic statistics.
4. Relational algebra, relations, and indexing. Basic SQL commands to create objects.
5. Basic SQL commands to update the object and relational operations.
7. Testing program. Validation of results and errors in calculation.
8. Software Licensing.

Practical teaching

It consists of the auditory, laboratory exercises that accompany the course.
Case Studies. The commemoration of the database design, different tools.
Database-based storage of drawings, photographs and complex objects.

Prerequisites

Database design. Software Engineering.C/C++

Learning resources

The necessary software for this case under the GNU license - free of charge. If you use Linux you needed
Python is readily available. If you use another operating system, Python can be downloaded from the
appropriate Web site (see URL) or the URL. To run the software necessary to possess enough simplest
PC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	1
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	19
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	0	final exam	40
calculation tasks	10		

Requirements to take the exam (number of points) 0

References

Jery R. Hanly, Essential C++ for Engineers and Scientists, Addison Wesley, ISBN 0-201-74125-3;, 2002

Numerical Methods in Continuum Mechanics

ID: 1149
Responsible/Holder professor ALEKSANDAR Č. BENGIN
Teaching profesor(s): BENGIN ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: information technologies

Goals

Introducing students with engineering simulations based on continuum mechanics. Understanding a well-defined problem as a unity of physical laws and additional conditions that define uniqueness and existence of a solution. Learning about the influence of the type of problem on the choice and type of additional conditions, as well as the choice of approximation to solve typical problems in continuum mechanic. Training students to independently develop computer programs for simulation of prototypical equations.

Learning outcomes

By successfully adopting the program of the course, a student: acquires theoretical knowledge
sufficient to recognize the type of the problem as well as the type and number of additional conditions necessary to completely and uniquely define the problem that is being simulated; recognizes basic approximation schemes of the typical problems; masters the principles and foundations of programming related to simulations of continuum; observes the structure of the

Theoretical teaching

Introduction to engineering simulations, Analytic solutions of partial differential equations, Finite difference method, Parabollic partial differential equations, Non linear parabolic partial differential equations, Stability analysis, Elliptic partial differential equations, Conjugent gradient method, Multigrid method, Hiperbolic partial differential equations.

Practical teaching

Practical training accompanies materials presented during theoretical lectures. In the beginning, students are registered and they familiarize with working in Linux operating system. After that, illustrative examples are completely presented starting with the problem formulation, presentation of the appropriate equations and their approximation, stability and convergence studies, code and reading of the necessary input data, finishing with presenting solutions graphically. Students solve their homework independently and present it to their colleagues.

Prerequisites

Without prerequisites.

Learning resources

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	20
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	10
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	40
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

Vladimir N. Kukudzhanov, Numerical Continuum Mechanics, de Gruyter, 2012.
Michael Schäfer, Computational Engineering – Introduction to Numerical Methods, Springer, 2006.
Joel H. Ferziger, Milovan Perić, Computational Methods for Fluid Dynamics, Springer, 2002.

Object oriented paradigm

ID: 1490
Responsible/Holder professor GORAN M. LAZOVIĆ
Teaching profesor(s): LAZOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: information technologies

Goals

Introduction to OOP paradigm. Purposeful use of classes, objects, inheritance, encapsulates, methods and hiding. Basic knowledge of classes, derived classes, methods. Object-oriented methodology for designing data structures and applicable programs. Problems that are naturally solved using object-oriented design and programming methodology.

Learning outcomes

With acquired knowledge student can: Rrecognize the conditions for using object-oriented design and programming methodology, Design simple user class and link them with the system classes, Design simple methods by using system design methods, Use the programming languages C++ and Java.

Theoretical teaching

Compilers, interpreters and machines. Weak and strong typed programming languages. Object and class, relationship and real-life examples and techniques. The natural definition of class, subclass, supclass. The term instance - the object. Fundamentals of programming language C++. The differences between the programming languages C and C++. Defining classes in C++. Application of operations and creating objects. Object-oriented design data, operations, and problems in the programming and implementation. The life span of the object. The basics of Java programming. The differences between the programming languages C++ and Java. Defining the class and supclass in programming languages C++ and Java. Inheritance in C++ and Java, the advantages and disadvantages. Overloading of operators and creating threads and
streamline, as well as specific structures in Java. Encapsulating objects and classes. Advantages and disadvantages.

Practical teaching

It consists of auditory, laboratory exercises that accompany the course. Reminding of the PHP programming. Basic examples of the programming language C++ and Java.

Prerequisites

Knowledge of C language. Basic knowledge of design methodology. Fundamentals of software engineering.

Learning resources

The necessary software for this case under the GNU license - free of charge. If necessary use a

Linux as C++ and JAVA are immediately available. If you use another operating system C++ can be downloaded from the appropriate Web site (see URL) or the URL. To run the software iti is enoght to possess simplest PC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	1
laboratory exercises	19
calculation tasks	0
seminar works	5
project design	2
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	35	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

E. Gamma, R. Helm, R. Johnson, and J. Vlissides; Design Patterns: Elements of Reusable Object-Oriented Software; Addison-Wesley Professional;1994

Optimization Methods

ID: 1449
Responsible/Holder professor MAJA B. ROSIĆ VITAS
Teaching profesor(s): ROSIĆ VITAS MAJA; SEDAK MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: information technologies

Goals

The main goal of this course for the student is to give the necessary knowledge of:
• numerical analysis and optimization,
• understanding general principles of design optimization
• formulating the optimization problems and identify critical elements.

Learning outcomes

After completing this course students are able to successfully apply the acquired theoretical and practical knowledge and are able to:
•Identify relevant optimization variables, define the set of functional constraints and limitations for the corresponding optimization model of a given mechanical system.
•Apply linear and non-linear numerical methods for solving the optimization problems and define the appropriate convergence criteria.
•Develop and implement computer programs in software packages Python / MATLAB for solving the set of optimization tasks.
•Analyze the results and check the validity of the proposed optimization models with respect to the change of input parameters.
•Apply the stochastic - heuristic methods and develop hybridized heuristic methods to determine the global solution of the optimization problems of complex mechanical systems.
•Develop new and apply existing numerical methods for solving complex optimization tasks, individually or as part of an appropriate team.

Theoretical teaching

1.Introduction to Modeling and Optimum Design Process. Optimum design problem formulation.
A general mathematical model for optimization.
2.Graphical Optimization.Identification of feasible region. Use of MATLAB for graphical optimization.
3. Unconstrained Optimum Design Problems. Optimality conditions for functions of several variables.
4. Constrained optimum design problems. Necessary conditions: equality constraints.
Necessary conditions: inequality constraints - Karush-Kuhn-Tucker (KKT) conditions.
Postoptimality analysis: physical meaning of Lagrange multipliers.
Engineering design examples with MATLAB.
5. Linear Programming. Problem definition. Standard LP format. Graphical solution.
Characteristics of the solution. Optimum solution for LP problems.

6. Numerical Solution - the Simplex Method.
Basic Steps of the Simplex Method. Simplex Algorithm. Solution using MATLAB's optimization toolbox.
7. Nonlinear Programming. Problem formulation. Graphical solutions. Equality constrained problem. Inequality constrained optimization.
Basic ideas and algorithms for step size determination.
8. Numerical methods - The One-dimensional Problem.
Newton-Raphson method.
Bisection method.
Polynomial Approximation.
Golden section method.
Optimum design examples with MATLAB.
9. Numerical Methods for Unconstrained Optimization.
Numerical Methods - Nongradient methods.
Powell's method.
Numerical Methods-Gradient-Based Methods.
Conjugate Gradient (Fletcher-Reeves) Method.
Davidon-Fletcher- Powel (DFP) method.
10. Numerical Methods for Constrained optimization
Problem definition. Necessary conditions. Method of feasible directions.Gradient projection method.
Exterior penalty function method.
Optimum design examples with MATLAB.

Practical teaching

Consists of the auditory and laboratory exercises.
Projects are main component of this course.

Prerequisites

Knowledge of linear algebra and numerical mathematics. Computer programming in MATLAB.
Some knowledge of basic machine elements and mechanics.

Learning resources

Computer Usage:
Students extensively use the computer and optimization toolbox using MATLAB program.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	21

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	0
colloquium, with assessment	0

calculation tasks	0	test, with assessment	3
seminar works	7	final exam	5
project design	2		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	35	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Jasbir S. Arora " Introduction to Optimum Design", Elsevier Academic Press, 2017.
P. Venkataraman " Applied Optimization with Matlab Programming" John Wiley and sons, inc, 2009.
H. Eschenauer, J. Koski, A. Osyczka: "Multicriteria Design Optimization", Springer-Verlag, 1990.

Programmable Control Systems

ID: 1492
Responsible/Holder professor GORAN M. LAZOVIĆ
Teaching profesor(s): LAZOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: information technologies

Goals

The objective of this course is that students: acquire necessary knowledge in design, programming and implementation of programmable control systems in industry and contemporary manufacturing; master the skills for practical problem solving in industrial control using computer, information and control technologies and appropriate scientific methods.

Learning outcomes

After successfully completing this course, the students should be capable to: Analyze social, economic, production and other effects of programmable control systems; Integrate knowledge in related subjects and implement them in programmable control systems design; Analyze and synthesize combinational automata; Synthesize sequential automata; Carry out electro-pneumatic realization of combinational and sequential automata; Program programmable logic controllers.

Theoretical teaching

1. Programmable and computer control systems in automation: robot controllers, programmable
controllers, controllers in programmable automation and computers.
2. Number systems and codes: positional number systems (decimal, binary, octal, hexadecimal);
conversion of numbers between positional number systems; binary coded decimal; Gray code;
alphanumerical codes.
3. Switching algebra: axioms of Boolean algebra; elementary operations of switching algebra; theorems of switching algebra; logic functions; canonical forms of logic functions (sum of minterms and product of maxterms); minimization of logic functions.
4. Technologies and components: sensors and actuators.
5. Combinational and sequential automata: definition, models, synthesis and analysis; Electropneumatic realization.
6. Programmable logic controllers: functions, hardware, software, input-output modules; programming languages and programming.

Practical teaching

Auditory exercises: examples in automation design, control system analysis and synthesis, programmable controllers programming, and control scheme design.

Prerequisites

None.

Learning resources

IT Laboratory - wind tunnel.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	22
laboratory exercises	0
calculation tasks	0
seminar works	8
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	20	project design	0
laboratory exercises	10	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Pilipović, M., Jakovljević Ž.; Automatizacija proizvodnje; Mašinski fakultet; 2017
Groover, M. P.; Automation, Production Systems and Computer-Integrated Manufacturing; Pearson Education; 2008
Hackworth J. R., Hackworth F. D.; Programmable Logic Controllers: Programming Methods and Aplications; Pearson Education; 2004
Bolton W.; Programmable Logic Controllers; Elsevier; 2006

Skill Praxis M - MIT

ID: 1497
Responsible/Holder professor GORAN S. VOROTOVIĆ
Teaching profesor(s): VOROTOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: project design
Parent department: information technologies

Goals

To provide students with practical experience of staying in an environment in which the student will realize his future career. Identifying the basic functions information system in the field of design, development and production software, as well as roles and tasks of mechanical engineering of information technology in such business system.

Learning outcomes

Training students to apply previously acquired theoretical and practical engineering and scientific knowledge of information technology to solve specific practical engineering problems in the selected companies or Institutions. Activities to introduce students to selected companies or institutions, way of doing business, management and the place and role of IT engineers in their organizational structures.

Theoretical teaching

MIT provides students with practical training by working with reputable companies and scientific research institutions of Serbia in the IT sector.
Practical form for each candidate separately, in agreement with the management companies or research institutions in which pursuing their profession, and in accordance with the development of new information technologies from which the student has previously acquired theoretical knowledge.

Practical teaching

Practical work consists of student involvement in the process of the enterprise or research institutions, consulting and writing diary professional practice in which a student describes the activities and operations that is performed during the professional practice

Prerequisites

Required: Basic IT knowledge. Prior knowledge acquired in previous modules MIT cources listened.

Learning resources

Lectures for MIT courses modules that can be downloaded from the FTP server module MIT: ftp://mit.mas.bg.ac.rs

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	30
check and assessment of lab reports	20
check and assessment of seminar works	30
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	60	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Kandray, D., Programmable Automation Technology - An Introduction to CNC, Robotics and PLC, Industrial Press, 2010.
Birman, Kenneth. Reliable Distributed Systems: Technologies, Web Services and Applications. New York: Springer-Verlag, 2005.
Watts S. Humphrey, The Personal Software ProcessSM (PSPSM), TECHNICAL REPORT CMU/SEI-2000-TR-022 ESC-TR-2000-022, November 2000

INTERNAL COMBUSTION ENGINES

Ecology of Mobile Power Sources

IC Engine Design 1

IC Engine Design 2

IC Engine Testing

Internal Combustion Engine Mechatronics

Internal Combustion Engines Fundamentals

Marine Engines

Mixture formation and combustion in IC engines

Selected topics in IC Engines 1

Selected topics in IC Engines 2

Sensors and Computer Based Measurements

Skill praxis M - MOT

Supercharging of IC Engines

Engine Design Project

Engine Working Processes

Ecology of Mobile Power Sources

ID: 1024
Responsible/Holder professor DRAGAN M. KNEŽEVIĆ
Teaching profesor(s): KNEŽEVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written+oral
Parent department: internal combustion engines

Goals

Acquiring basic knowledge of IC engine's influence on environment. Knowledge of pollutants origin in exhaust of IC engines and the ways of their reduction. Understanding of legal obligations and emission standards.
Pollution by hybrid and electric vehicles and their impact on the natural environment. Vehicles with zero exhaust emissions.
Acquiring basic knowledge of noise sources in IC engines and the methods of noise reduction. Construction of an after-treatment system for exhaust gases.

Learning outcomes

Understanding the influence of human activities on environment, especially of harmful ones. Knowledge of pollutants formation chemistry, the greenhouse gases effects on global climate change, and noise of IC engines. Ability to apply solutions for pollutants and noise reduction.

Theoretical teaching

1. Impact of IC engines on environment - general view (pollutants in exhaust, emission of greenhouse gases, engine noise). 2. Chemistry of pollutants formation in exhaust emissions of spark-ignition and compression-ignition engines, and the ways of their reduction. 3. Law regulations of the engine exhaust pollutants emissions. 4. NEDC (New European Driving Cycle) test and new WLTP (Wordwide Harmonised Light Vehicle Test Procedure)test. The purpose of the WLTP lab test and the way it works. 5. Greenhouse gases emission and their impact on global warming. 6. Engine noise, sources, standards, ways of reduction. 7. Engine exhaust emission regulations. 8. Alternative power system emission and electric-powered vehicles emission. 9.Impact of engine design on pollutants emissions and engine noise. 10.Construction solutions for the after-treatment system of exhaust gases, the principle of operation and type.

Practical teaching

a) Classroom sessions: 1. Numerical examples. 2. Review and analysis of in-cylinder and after-treatment solutions for pollutant exhaust gases reduction: EGR, three-way catalyst, catalyst after-treatment of diesel engine exhaust emission. 3. Review and analysis of engine design solutions for engine noise reduction.
b) Laboratory sessions: 1. Measurements of engine exhaust emissions with and without EGR.

Prerequisites

Mandatory: passed exam Engine Working Processes.

Learning resources

D. Knezevic: Handouts (PDF files); Instructions to carry out lab session and prepare and write report; numerical assignments examples; test bed with IC engine, measurement equipment and software for data acquisition, exhaust gases analizers.
1. J.B. Heywood: Internal Combustion Engine - Fundamentals (second edition), Massachusetts Institute of Technology, Cambridge, Massachusett, 2018.
2. Stojan Petrović, Dragan Knežević; Engines - the basics of the theory of thermal piston engines, University of Belgrade, Faculty of Mechanical Engineering, 2020.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	11
laboratory exercises	3
calculation tasks	4
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	20	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Sher, E. (Ed.): Handbook of air pollution from internal combustion engines. Academic Press, San Diego, 1998. ISBN 0-12-639855-0. (на енглеском)
J.B. Heywood: Мотори са унутрашњим сагоревањем - основе (на енглеском) -second edition, Massachusetts Institute of Technology, Cambridge, Massachusett, 2018. ISBN:978-1-26-011611-3
Gruden, D.: Umweltschutz in der Automobilindustrie. Vieweg+Teubner, Wiesbaden, 2008. ISBN 978-3-8348-0404-4. (на немачком)
Stojan Petrović, Dragan Knežević: Engines - the basics of the theory of thermal piston engines, University of Belgrade, Faculty of Mechanical Engineering, 2020. ISBN 978 – 86 –

6060 – 037

IC Engine Design 1

ID: 1087
Responsible/Holder professor DRAGAN M. KNEŽEVIĆ
Teaching profesor(s): KNEŽEVIĆ DRAGAN; KITANOVIĆ MARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: internal combustion engines

Goals

The aims of the course are to provide theoretical and practical study about engine dynamics,vibrations and design of engine parts. Through the evaluation of engine kinematics, dynamics and engine parts mechanical load and stress students acquires a sense for design of engine parts and complete engine. Basic knowledge about 3D modeling of engine parts and stress calculation using FEM is also provided and enable modern approach to engine design.

Learning outcomes

The merger of theoretical knowledge of mechanics, basics of strength of constructions and machine elements and its applications on engine design. Training students for engine parts and systems design, modeling and calculation. The acquisition of basic theoretical and practical knowledge required for complete engine designing.

Theoretical teaching

1. Kinematics of piston mechanism. Dynamics of piston mechanism and transfer of the forces through engine mechanism. Variations of engine torque and crankshaft rotational speed. Balancing of inertia forces of single cylinder engine and inertia forces and its moments of multi cylinder engines. 2. The role, design, choice of materials and evaluation of mechanical stress of engine piston group elements. Design, choice of materials and evaluation of mechanical stress of engine connecting rod. Design, choice of materials and evaluation of mechanical stress of engine crankshaft and crankshaft bearing. 3. Problem of engine vibrations; vibration on the engine mounts; torsion vibrations of engine crankshaft.

Practical teaching

1. Forces of engine piston mechanism; crankshaft tangential force and the variations of engine torque and crankshaft rotational speed, the role and calculation of engine flywheel; instructions for engine kinematics and dynamics calculation. 2. Examples of engine parts design and thermal and mechanical stress calculation; instructions for mechanical calculation of piston group, connecting rod and crankshaft. 3. The application of 3-D modeling in engine parts design;

Prerequisites

No prerequisites required.

Learning resources

1. D.Knežević: Engine design 1-Handouts,2020., available in PDF format in IC engines

department.
2. Sections of the engines. Various parts of the engines. Complete engines prepared for disassembling and assembling.
3. Kevin L.Hoag: Vehicular Engine Design - Powertrain, SpringerWienNewYork, 2006.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	16
laboratory exercises	0
calculation tasks	6
seminar works	0
project design	8
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	15	project design	30
laboratory exercises	0	final exam	40
calculation tasks	15		

Requirements to take the exam (number of points) 30

References

M.C. Živković: Internal combustion engines, part 2. Engine design 1, Kinematics and dynamics of piston mechanism. Faculty of Mech. Eng., Belgrade, 1983
M.C. Živković, R. Trifunović: Internal combustion engines, part 2. Engine design (in serbian) University of Belgrade, Faculty of Mechanical Engineering, 1990.
Van Basshuysen, R., Schafer, F. (Editors): Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, Warrendale, 2004. ISBN 978-0-7680-1139-5
Kevin L.Hoag: Vehicular Engine Design - Powertrain, SpringerWienNewYork, 2006. ISBN-10 3-211-21130-6

IC Engine Design 2

ID: 1089
Responsible/Holder professor DRAGAN M. KNEŽEVIĆ
Teaching profesor(s): KNEŽEVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: internal combustion engines

Goals

Acquiring new knowledge on role and design features of IC Engine Auxiliary systems - engine cooling & lubricating systems and starting devices. Developing skills to design and calculate working parameters of IC Engine Auxiliary Systems. Practical application and broadening knowledge in the field of Heat Transfer, Machine Design, Tribology and Engineering Materials.
Torsional oscillations of the engine crankshaft. The formation of torsional oscillations, the risk of torsional oscillations, the ways of suppression of torsional oscillations, construction of torsional silencers.

Learning outcomes

Understanding the Design of complex machines and Devices. Recognition and understanding of the importance of subsystems for proper functioning of the system as whole.
Understanding the design principles and role of Cooling System, Heat transfer, Lubrication System and Starter System.
Understanding of the torsion silencer construction.
Capabilities to design and calculate vital components of IC Engine Auxiliary Systems.

Theoretical teaching

IC Engine Cooling System: The role and Engine Thermal Load Issues;Liquid & Air Cooling Systems: Design and calculation; IC Engine Lubrication System: Design & Disposition; Lubricant Characteristics: Engine Requirements; Stribeck's Diagram; Lubrication Pump - Design & Calculation, Lubricant Filtration; IC Engine Starting Devices; Work required for Engine starting and running; Engine starting Devices Design Issues; Pneumatic Starters; Engine Crankshaft Rotation Reversing Devices - Design & Application Issues.

Practical teaching

1. IC Engine Cooling System Design & Calculation - Waste Heat removed through Cooling System, Liquid & Air Cooling System Calculation Examples; 2. Engine Lubrication System Calculation Examples, Waste Heat removed through Lubrication System, Circulating Pump design and calculation;
Project Task: Design and calculation of Cooling/Lubricating System

Prerequisites

Passed exam on course "IC Engines Processes"

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	8
laboratory exercises	0
calculation tasks	8
seminar works	0
project design	10
discussion and workshop	4
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	8
colloquium, with assessment	0
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Challen, B., Baranescu, R. (Editors): Diesel Engine Reference Book - 2nd ed., Butterworth-Heinemann, Woburn, 1999. ISBN 0-7506-2176-1.
Van Basshuysen, R., Schafer, F. (Editors): Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, Warrendale, 2004. ISBN 978-0-7680-1139-5.
John Heywood: Internal Combustion Engine Fundamentals, Mc Graw-Hill, 1988, ISBN-13: 978-0070286375

IC Engine Testing

ID: 0860
Responsible/Holder professor NENAD L. MILJIĆ
Teaching profesor(s): MILJIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: internal combustion engines

Goals

To cover the basic knowledge of experimental work in the field of IC Engines. Broadening of measuring techniques knowledge, used in engineering, through acquaintance with specific measuring equipment, devices and software tools used for IC engine testing. Developing of skills required for developing of IC engines test facilities, choice of adequate measuring equipment, devices and auxiliaries for funding IC engine test bench. Developing of skills required for planning, organization and conducting an IC Engine testing.

Learning outcomes

Practical knowledge in IC engine testing procedures, operations and data analysis. Ability in solving and analysis of practical engineering tasks related to IC engine testing and IC engine test measuring equipment and facilities

Theoretical teaching

Measurement of: Torques and forces; rotational speed and acceleration; gas and fuel mass and volumetric flow (with anemometry); temperatures and pressures; IC engine indicating techniques and measurement equipment; IC Engine exhaust analysis; Engine dynamometers; Fundamentals of IC Engines test benches design; IC engine testing standards, procedures and operations

Practical teaching

Measurement errors and uncertainty (examples with calculation tasks); Introduction to Labview (NI) measurement and programming environment; Calibration of measurement chains; Preparation for laboratory tasks (description of measuring equipment and chains used, task instructions):

Getting acquaintance with the Labview environment and its usage in IC engine testing tasks; Calibration of specific transducer measurement chain (torque, pressure, temperature,...); IC Engine in cylinder pressure indicating; Measurements on engine test bench - gathering data for BSFC characteristics map; Determining the energy balance of an ICE

Prerequisites

Passed exam on course “IC engine working processes”

Learning resources

-Živković, M.C, Trifunović, R.: IC Engine Testing (on Serbian), FME Belgrade

- Lecture Handouts, Lab Exercises Instructions, Calculus examples (pdf)
- Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)
- DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	14
calculation tasks	4
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	6
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	20	project design	0
laboratory exercises	30	final exam	40
calculation tasks	10		

Requirements to take the exam (number of points) 30

References

Plint, M., Martyr, A.: Engine testing - Theory and practice, Butterworth-Heinemann, Oxford, 1997. ISBN 0-7506-1668-7. (на енглеском)
Grohe, H.: Messen an Verbrennungsmotoren, Vogel-Verlag, Würzburg, 1979. ISBN 3-8023-0087-4. (на немачком)
Holman, J. P.: Experimental methods for engineers. McGraw-Hill, 1984. ISBN 0-07-029613-8. (на енглеском)
Nachtigal, C. L.: Instrumentation and control. John Wiley & Sons, Inc., New York, 1990. ISBN 0-471-88045-0. (на енглеском)

Internal Combustion Engine Mechatronics

ID: 1436
Responsible/Holder professor PREDRAG D. MRĐA
Teaching profesor(s): MRĐA PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: internal combustion engines

Goals

Acquisition of basic theoretical and practical knowledge in the field of application of mechatronic systems in internal combustion engines. Gaining experience in the operation and application of sensors and actuators in mechatronic systems of modern engines. Closer acquaintance with the structure of electronic control units (ECU) of modern engines and the specifics of the architecture and functions of microcontrollers, management principles and methods of development and testing of software intended for ECU.

Learning outcomes

Student through this course: Acquires and combines specific professional knowledge in the field of mechanical engineering and electronics. Complements knowledge in the field of engine management as a highly dynamic object. He is trained to form and complete a mechatronic system for the internal combustion engine. Masters the basics of the software development and programming process for the ECU. Masters basic data transfer techniques using ECU communication interfaces.

Theoretical teaching

Introductory considerations on mechatronics on the internal combustion engine. Measuring transducers (sensors) Sensor characteristics. Measuring chain. Sensor calibration. Intelligent sensors. Actuators - Classification. Excitation of high voltage / high current electrical actuators. Digital signal acquisition. Microcontroller peripherals. Microcontroller communication interfaces. Hardware - Architecture and internal structure of microcontrollers. Memory. EUJ protection. Hardware functions specific to engine management. TPU block. EUJ communication interface. Microcontroller networks. Communication protocols. CAN, K-Line. CCP. Software - Assembler, C / C ++ and development environments. Principles of software design. In the cycle. Microcontroller programming. Code generation and testing. SIL, PIL, HIL. Control - Open and closed loop. PID controller. Control of mixture composition and detonation. Application of existing mechatronic systems in advanced engine management and diagnostic techniques;

Practical teaching

Angular position and angular velocity sensors, control and command position, intake air mass flow, engine fluid temperature, pressure and detonation. Computational task in the field of motor sensors and digital acquisition. Ignition system. Injectors. Control of idle engine operation. Actuators of turbocharger group, distribution systems and suction systems of variable characteristics. EM valve drive. AD converter operation simulation. Specifics and

examples of microcontrollers for motor applications. Demonstrations: digital acquisitions, applications of TPU function, communication in CAN network. Demonstration of microcontroller programming, SIL and PIL simulations. Review and analysis of control algorithms. Control the composition of the mixture. Detonation control. Detection of uneven engine operation.

Prerequisites

Passed: Electrical Engineering and Electronics, Fundamentals of Automatic Control, Fundamentals of ICE or Mixture Formation and Combustion in ICE

Learning resources

1. П. Мрђа, С. Поповић, Н. Миљић, Script from Engine Mechatronics, available in electronic form (PDF). 2. Test bench for engine testing 3. Digital and analog acquisition system National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461 4. Phytec pc-565 (Motorola MPC 565) 5. MCT GmbH Mega332 (Motorola MC68332) 6. Atmel SAM3X 7. National Instruments LabView 8. Metrowerks CodeWarrior 8.0 (for Motorola MPC 5xx) 9. WinEco MCT GmbH (платформа Motorola MC68332)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	12
calculation tasks	3
seminar works	0
project design	0
discussion and workshop	1
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	15	final exam	40
calculation tasks	15		

Requirements to take the exam (number of points) 30

References

W. Bolton, Mechatronics, Pearson-Prentice Hall, 2003, ISBN 0 131 21633 3
U. Kincke, L. Nielsen: Automotive Control Systems, Springer Verlag, 2004, ISBN 3-540-23139-

0
R. Isermann, Modelgestuetzte Steuerung, Regelung und Diagnose von Verbrennungsmotoren, Springer Verlag, 2003, ISBN-10:3540442863, ISBN-13: 978-3540442863
BOSCH Gasoline Engine Management, 2015, ISBN 0-7680-0510-8
BOSCH Automotive Sensors, 2002, ISBN-3-934584-50-0

Internal Combustion Engines Fundamentals

ID: 1435
Responsible/Holder professor PREDRAG D. MRĐA
Teaching profesor(s): MRĐA PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: internal combustion engines

Goals

The course provides a comprehensive insight into the matter of teh internal combustion (IC) engines (theoretical cycles, actual process, engine systems, operating characteristics). It is intended for students at the Department for IC engines, as an introduction to a deeper study of specific areas of internal combustion engines, as well as students of those fields where knowledge of IC engines as a propulsion unit (motor vehicles, shipbuilding, railway engineering, mechanization) is necessary.

Learning outcomes

Adopted theoretical and practical knowledge in the field of engines. Connecting fundamental disciplines: thermodynamics, fluid mechanics, mechanics, material resistance, etc. on a complex object such as the internal combustion engine. Acquiring the skills for a competent approach in the selection, organization of operation and maintenance of engines. Acquiring a base for further study of specific problems, construction and design of engines.

Theoretical teaching

1. Introductory considerations. 2. Thermodynamic: engine cycles. 3. Actual engine duty cycle - the process of changing the working substance. 4. Combustion process in engines with external ignition of the mixture. 5. Combustion process in diesel engines. 6. Engine operating parameters. 7. Charging the internal combustion engine. 8. Dynamic engine problems. 9. Engine drive characteristics. 10. Environmental characteristics of the engine

Practical teaching

Exercises: 1. Engine mechanism and typical engine construction 2. Engine working fluid and combustion 3. Thermodynamic: engine cycles - calculation tasks 4. Engine fuel supply systems 5. Operating parameters and heat balance of the engine - calculation tasks 6. Filling and heat balance of engines - calculation tasks 7. Kinematics and dynamics of engine mechanism - calculation tasks 8. Engine systems 9. Engine characteristics - calculation tasks 10. Preparation of laboratory exercise from engine testing. Laboratory exercises: 1. Engine fuel supply systems 2. Test engine test bench run.

Prerequisites

There are no conditions for attending the course

Learning resources

1. Handouts: Internal Combustion Engines Fundamentals, available in PDF format at the

moodle platform. 2. Handouts: Engine testing 3. Digital and analog acquisition system National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461 4. National Instruments LabView

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	9
laboratory exercises	10
calculation tasks	11
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	2
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	45	project design	0
laboratory exercises	15	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Miroljub Tomić, Stojan Petrović: Motori sa unutrašnjim sagorevanjem,Mašinski fakultet u Beogradu, 2004, ISBN-13 978-86-7083-646-4
Richard Stone: Introduction to IC Engines, SAE International, 2012, ISBN-13: 978-0768004953
John Heywood: Internal Combustion Engine Fundamentals, McGraw-Hill Education, 2018, ISBN-13: 978-0070286375
C. R. Ferguson: Internal Combustion Engines Applied Thermosciences, J.Wiley & Sons 2015, ISBN 978-1118533314
Richard Van Basshuysen, Fred Schafer: Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, 2004, ISBN-13 978-0768011395

Marine Engines

ID: 1025
Responsible/Holder professor DRAGAN M. KNEŽEVIĆ
Teaching profesor(s): KNEŽEVIĆ DRAGAN; STUPAR GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written+oral
Parent department: internal combustion engines

Goals

The target of this subject is to give a comprehensive insight into the specific matter of IC marine engines, two-stroke, as well as four- stroke ones, and especially of high power engines with complex engine mechanism. The subject is intended for the students of Shipbuilding department who will be given an introduction for further later research into construction specifications of this class of engines and engine systems during professional practical work experience.

Learning outcomes

General specifications: Adopted basic theoretical and practical knowledge in the field of IC marine engines where fundamental and applied scientific disciplines are entangled. Students acquire basic ability for competent approach to the choice, organization of exploitation and maintenance of diesel engines in the field of marine engine systems.

Theoretical teaching

1.Introductory considerations 2.Specifications of the construction of marine engine parts-immovable and movable, marine engine distribution system 3.Fuel supply system and the supercharging system of the engine. 4. System of lubrication and cooling of the engine. Function, importance and types of lubricating oils for marine engines. Liquid cooling system. Air cooling system. 5. Engine starting and reversing system and operating characteristics of marine engines. Propelling characteristic of the engine. Optimization of the coupling: engine-propeller. 6. Marine engine vibrations. Torsion oscillations of the crankshaft and the transferring shafts. Possibilities of resonance occurrence and the method of its avoidance. 7. Choice of the marine engine as the most important marine driving machine.8. Presentation of marine engine supercharge systems. 9. Marine engine fundaments.

Practical teaching

a) Auditory training: 1. Construction of marine engines. Presentation and analysis of different conceptions, and the construction of marine driving engines, from the lowest to the highest powers. 2. Marine diesel engine fuel supply system. Mechanical regulation systems (pump-pipe- injector, pump- injector), accumulator (common rail) systems, electronic regulated systems. 3.Supercharge engine system- presentation and analysis of the construction of the physical model of turbocharger. 4. Governors of the RPM of marine engines – function and types, division according to the place of assembly, analysis of the construction and the governor operational system. Analysis of the possibilities of electronic governor in optimization of marine diesel engine operating area marine diesel engines.

b) Laboratory training: Engine testing- measuring of the propelling characteristics of the engine.

Prerequisites

No prerequisites required.

Learning resources

Handouts, available in electronic version in PDF format on the site of IC Engine department. Instructions for the demonstration of laboratory experiment and electronic report writing laboratory installation-test bench with IC engine, measuring equipment and the software for measuring data acquisition.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	14
elaboration and examples (revision)	4
active teaching (practical)	**18**
auditory exercises	9
laboratory exercises	9
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	4
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	25	project design	0
laboratory exercises	25	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Handouts, available in electronic version in PDF format on the site of IC Engine department, 2023.
Woodyard, D. F. (Ed.): Pounder's marine diesel engines and gas turbines - 8th edn., Elsevier Butterworth-Heinemann, Oxford,Burlington, 2004. ISBN 0-7506-5846-0.
C.C. Pounder: Marine Diesel Engines, Butterworths & Co. (Publishers) Ltd. 1972., ISBN: 0-408-00077-5
C.T. Wilbur, D.A. Wight: marine Diesel Engines and Gas Turbines, Elsevier Ltd., 2004., ISBN:0-408-01136-X

Mixture formation and combustion in IC engines

ID: 1086
Responsible/Holder professor SLOBODAN J. POPOVIĆ
Teaching profesor(s): POPOVIĆ SLOBODAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: internal combustion engines

Goals

The aims of the course are to provide a comprehensive insight into the subject matter of Engine Fueling and Mixture formation in IC Engines. Broadening existing and acquiring new knowledge in hydrodynamics by studying spray and droplet formation and break-up. Broadening knowledge on geometric and process parameters influencing the quality of air-fuel mixture. Understanding the influence of air-fuel mixture time-space characteristics on engine combustion process dynamics and performance. Acquiring skills in calculating and simulating characteristics of fuel spray and droplet in time, angle and space domain.

Learning outcomes

Students are capable of performing calculation of spray formation and break-up, primary and secondary fuel droplet break-up for given injection system parameters in terms of high pressure pump, fuel line and injector. Students are capable to determine fuel droplet SMD (Sauter Mean Diameter) and time required for droplet evaporation for thermodynamic parameters during engine cycle.

Theoretical teaching

1. Engine requirements in terms of air-fuel mixture strength. Air-fuel mixture characterization - homogeneous, stratified and heterogeneous mixture. Air-mixture strength and characteristics influence on combustion process.
2. Fuel spraying - basic approach. Fuel surface tension, viscosity and density. Reynolds, Weber and Ohnesorge numbers.
3. Gasoline engine mixture formation systems. Carburetor, fuel and air flow characteristics. Carburetor auxiliary systems. Low-pressure fuel injection, Manifold/Port Fuel Injection (MPI/PFI) Systems. High-pressure Direct Injection Systems (DI) with side injector (DIS) and central injector (DIC). Multi-injector systems.
4. Diesel fuel injection systems. Direct and indirect injection, high-pressure injection pumps. Injectors and nozzles. Fuel delivery and injection dynamics. Electronic Control Unit.
5. Spray formation. Spray characteristics - shape, angle and length. Spray analysis using Reynolds, Weber and Ohnesorge numbers. Spray break-up. Droplet formation. Primary and secondary droplet break-up. Spray and droplet break-up calculation and simulation methods. Sauter Mean Diameter (SMD).
6. Fuel droplet evaporation. Droplet evaporation simulation methods.

Practical teaching

a) Auditory exercises: 1. Display and analysis of Carburetor based Engine fueling. Carburetor Design and Calculation. 2. Display and analysis of SI Engines Fuel Injection Systems. Engine Sensors. Fuel Injector rated flow characteristics. Numeric examples for injection time determination. Injection time correction. Generation of basic Engine Injection Map. 3. Diesel Fuel Injection Systems – numerical examples for HPP element & cam lobe design. 4. Fuel spray formation and break-up calculation and simulation methods. Fuel droplet break-up calculation and simulation methods. Sauter Mean Diameter calculation.

b) Laboratory exercises: Testing SI Engines Fuel Injection System components: Injector fuel rate determination (stationary, dynamic), Fuel Rail Dynamic Pressure measurement and analysis, Mass Air Flow-meter (MAFM) Characteristics measurement. Measurement and comparative analysis of MAFM and MAP sensor dynamics. Measurement & Analysis of Ignition System Dynamics.

Prerequisites

Desirable: Good practical knowledge of Matlab/Simulink

Learning resources

1. M. Tomić: IC Engines Fueling and Ignition Systems (in Serbian), Uni. of Belgrade, Faculty of Mechanical Engineering, Belgrade, ISBN 978-86-7083-769-0, 2012.
2. S. Popović: Extracts from Lectures (handouts), available in digital form
3. IC Engine testing Laboratory (with an engine on the test bed)
4. Flow Test Bench (in accordance to ISO 5167)
5. Diesel Injection System test Bench
6. DAQ System: National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461
7. National Instruments LabView

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	11
laboratory exercises	14
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	25	project design	0
laboratory exercises	35	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

J. Heywood: Internal Combustion Engine Fundamentals, McGraw Hill, ISBN-13: 978-1260116106, 2018
G. Stiesch: Modeling Engine Spray and Combustion Processes, Springer-Verlag Berlin Heidelberg, ISBN 978-3-540-00682-4, 2003
C. Baumgarten: Mixture Formation in Internal Combustion Engines, Springer-Verlag Berlin Heidelberg, ISBN 978-3-540-30835-5, 2006
H. Zhao: Advanced direct injection combustion engine technologies and development Vol.1 i 2, Woodhead Publishing, ISBN 978-1-84569-732-7, 2010
C. Arcoumanis, T. Kamimoto: Flow and Combustion in Reciprocating Engines, Springer-Verlag Berlin Heidelberg, ISBN: 978-3-540-64142-1, 2009

Selected topics in IC Engines 1

ID: 1026
Responsible/Holder professor SLOBODAN J. POPOVIĆ
Teaching profesor(s): KITANOVIĆ MARKO; POPOVIĆ SLOBODAN; MRĐA PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: internal combustion engines

Goals

Acquiring new knowledge on role and importance of modelling dynamic processes in IC Engines. Broadening theoretical knowledge and analytical approach to thermodynamics, heat and mass transfer, fluid mechanics and fuel combustion by studying dynamic processes in IC Engine cylinder and collectors. Broadening knowledge and analytical approach to the mixture formation, fuel jet break-up, fuel droplet formation and evaporation. Broadening knowledge and skills in applied computational methods and modular programming. Developing practical skills to design model structures and apply numerical methods within project-oriented tasks related to IC Engines and HPS design and application.

Learning outcomes

Understanding the reality and complexity of Heat Engines working cycles. Capabilities to design models and sub-models structures using multidisciplinary approach. Capabilities to analyse engine and HPS processes and performance using simulation models. Establishing the Cause & Effect relationship between working cycle and engine performance.

Theoretical teaching

1. Gas flow in intake and exhaust ports and collectors. 1-D modelling of dynamic gas flow in pipes. Optimization of Intake and exhaust plenum geometry by maximizing engine volumetric efficiency.
2. Supercharging/Turbocharging of IC Engines. System design and simulation. Optimization of IC Engine-Turbocharger system performance. Charge Air intercooler design and simulation.
3. High efficiency thermodynamic engine cycles. Combining high expansion – to – compression ratio with supercharging in real engines.
4. Fuel mixture formation in High-Pressure injection systems. Simulation and modelling of dynamic procesess in fuel pipes and injectors. Primary and secondary Break-Up, drop formation and evaporation.
5. Mechanical losses in IC engines. Modelling engine friction and auxillaries power consumption. Experimental determination of mechanical losses distribution.
6. In-cylinder and port flow multidimensional modelling using CFD.
7. Selected topics in Engine exhaust and noise emission. Exhaust gas concentration modelling based on chemical reactions kinetics and chemical equilibrium. Exhaust gas emission measurement.
8. Hybrid Powertrain Systems simulation and optimisation. 1-D modelling of dynamic performance of HPS. Optimization oф energy storage capacity and mass, drive performance

and arrangement for best fuel efficiency
9. Alternative fuels. Fuel physical properties and specific design issues related to fuel properties. Specific issues related to mixture formation and combustion of alternative fuels.
10. Engine components Design and manufacturing issues. Specific manufacturing and production technologies. Turbocharger design and production. Impeller design and manufacturing. Impeller and housing materials selection for improved performance.

Practical teaching

Literature and technical solutions survey and theoretical analysis. Development and application of numerical simulation models of engine processes, engine components or systems dynamic performance. System analysis by application of simulation models taylored to specific project-oriented task. Experimental verification. Reporting and results presentation.

Prerequisites

Passed exam on course: IC Engines Processes

Learning resources

Mathworks Matlab/Simulink IDE (Licenced)
AVL Advanced Simulation Tools (AST): Boost, Fire, Excite, Cruise
LMS AMESim
Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)
DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	30
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0

test/colloquium	0	project design	70
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Selected books from premium publishers: Springer Verlag, Teubner, McGraw-Hill, Butterworth-Heinemann, Elsevier
Extensive selection of articles and papers: IMechE, SAE, JSAE, ASME, MTZ/ATZ, Elsevier etc.
J. Heywood: Internal Combustion Engine Fundamentals, McGraw Hill, ISBN-13: 978-1260116106, 2018
R. Pischinger , M. Klell , T. Sams: Thermodynamik der Verbrennungskraftmaschine, ISBN: 978-3-211-99277-7, Springer Verlag, 2010
G. P. Merker et. al.: Simulating combustion and pollutant formation for engine development, Springer Verlag, ISBN 10 3-540-25161-8, 13 978-3-540-25161-3, 2006

Selected topics in IC Engines 2

ID: 1027
Responsible/Holder professor NENAD L. MILJIĆ
Teaching profesor(s): MILJIĆ NENAD; KITANOVIĆ MARKO; MRĐA PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: internal combustion engines

Goals

Acquiring new knowledge in the area of thermal piston machinery through analysis of the working cycle and particularities of piston compressors with reciprocating and rotational pistons. Broadening theoretical knowledge and analytical approach in the field of mathematical modelling and engine simulations through: model based fault diagnosis on various engine subsystems; Mean value models used in real-time engine control; Broadening knowledge in the area of automated engine mapping and calibration trough acquaintance with the state-of-the-art tools and techniques.

Learning outcomes

Built skills for proper selection, calculation and design of piston compressor units. Practical experience gathered through realization of model-based diagnosis system on IC Engine. Understanding of crucial Mean-value models used in Engine control; Practical experience in building and testing a small scale engine subsystem control application; Understanding and acquaintance with the state-of-the-art mapping and modeling tools, principles and procedures.

Theoretical teaching

1. Particularities of the piston mechanism, kinematics and dynamics of piston compressor's piston mechanism; Crankcase force balancing in the multi cylinder / multi stage piston compressors; Compression of real gases, its mixtures and moist mixtures on high pressures; Real thermodynamic cycle of a piston compressor; Multi stage compression; Design and calculation of piston compressor parts; Auxiliaries and flow and pressure control systems; Maintenance issues.
2. Model based principles of technical system fault diagnosis; Model base fault diagnosis of engine subsystems (faults on engine's air path, mixture formation, cylinder processes inequalities, cylinder misfire,...)
3. Engine control algorithms; Mean-value models and their application in engine real time control
4. State-of-the-art methods in the engine mapping and calibration process. Problems and challenges of multi parameter optimization with multiple boundary conditions on modern SI and CI engines. Principles of model based calibration.

Practical teaching

1. Building a code for piston compressor real working process simulation. A project task with a goal for proper determination of the piston compressor unit design concept, its design

calculation.
2. Practical experience of building model based fault diagnosis system (detection of air path leaks or obstructions; detection of cylinder processes inequalities on a multi cylinder engine; misfire detection; model based real-time combustion parameter estimation)
3. Building an engine subsystem control system based on the application of common mean-value models (idle control, ignition system control, mixture formation system control,...)
4. Experience and practical work with the Inca calibration system (ETAS) on a engine test bed.
5. Experience and practical work with the tool for an automated engine mapping and calibration - Cameo (AVL)

Prerequisites

Passed exam on course: "IC Engines Processes" and "Engine Mechatronics"

Learning resources

Mathworks Matlab/Simulink IDE (Licenced)
AVL Advanced Simulation Tools (AST): Boost, Fire, Excite, Cruise
LMS AMESim
AVL Cameo; AVL Concerto;
Laboratories equipped with IC Engine testing equipement (fully equiped IC Engine test benches)
Laboratory instalation with a reciprocating piston and Roots type compressor.
DAQ Measurement equipement (National Instruments PXI based system with Labview Developement software)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	30
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	70
laboratory exercises	0	final exam	30

calculation tasks	0

Requirements to take the exam (number of points) 30

References

R. Jankov: Piston Compressors, Faculty of Mechanical Engineering, Belgrade, 5th edition, 1990, (on Serbian)
Isserman, R.: Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance, Springer, 2006.
Kiencke, U., Nielsen, L. : Automotive Control Systems: For Engine, Driveline, and Vehicle, Springer, 2005
Guzzella, L., Onder, C.: Introduction to Modeling and Control of Internal Combustion Engine Systems, Springer, 2010
Paulweber, M.,Lebert, K.: Mess- und Prüfstandstechnik: Antriebsstrangentwicklung · Hybridisierung · Elektrifizierung, Springer, 2014

Sensors and Computer Based Measurements

ID: 1478
Responsible/Holder professor PREDRAG D. MRĐA
Teaching profesor(s): MRĐA PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: internal combustion engines

Goals

The aim of the course is to provide comprehensive insight into the sensors and digital acquisition systems (DAQ), measurement systems, and mainly, their usage in the field of systems testing in the area of Mechanical Engineering; To introduce students to the world of virtual instrumentation and graphical programming environment (LabVIEW) which is dedicated to the development of DAQ applications. To gain experience in functioning and using DAQ systems through numerous, real-world examples. To get closer acquaintance with the sensors, and digital acquisition software & hardware, in general, and methods of DACQ software development and testing.

Learning outcomes

Ability to integrate sensors and DAQ hardware in measurement chains in order to fulfill specific requirements in the field of mechanical engineering system testing & measurements. Ability to build and test software applications (LabVIEW virtual instruments) for measurement and automation of various mechanical engineering systems. Practical knowledge in computer-based measurements of fundamental engineering data. Supplied basic knowledge and practice in the LabView environment sufficient to apply for a test and potentially get a degree of certified CLAD programmer.

Theoretical teaching

Measurement Techniques; Measurement of Non-Electrical Quantities (Sensors and Sensor Systems,
Displacement and Angles, Speed, Acceleration, Force, Torque, Pressure, Mass, Temperature, Flows, Signal Conditioning); Digital Measurement Techniques (Discretisation of Amplitude and Time, Sampling Theorem, Quantization, A/D, and D/A Converters, Measurement of Frequency, Counters); Architecture and basic principles of data acquisitions systems (DAQS); Measurement Errors and Statistics; Static and Dynamic Behavior of Sensors.

Practical teaching

Introduction to the Virtual Instrumentation (VI) and LabVIEW development environment; Data flow in VI; Troubleshooting and Debugging Vis; Implementing a VI; File I/O Techniques; Common Design Techniques and Patterns; Managing Hardware resources; Synchronization Techniques; Event
Programming; Error Handling; Controlling the User Interface; Improving an Existing VI; Practice labs with various sensors and measurement chains building tasks. Student Project: Building a DAQ with given requirements (complied with the Student's module syllabus);

*National Instruments (NI) Labview courses “Core 1” & “Core 2” are incorporated into the theoretical and practical teaching of this course. This course is in compliance with the “LabVIEW Academia” program and therefore offers students all benefits stated in the LabVIEW Academia agreement.

Prerequisites

No particular requirements for attending this course

Learning resources

Handouts: N. Miljić, Computer Based Measurements & Virtual Instrumentation.
DACQs: National Instruments USB 6008, MyDAQ, PXI.
Graphical Development Environment: National Instruments LabView 2010 with modules and toolkits
(LVA package)
Auxiliary platforms: Demo board for simulation of analog and digital signals; Universal Amplifying / Conditioning board for various sensors; Driver board for DC and step motors.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	16
calculation tasks	0
seminar works	0
project design	3
discussion and workshop	1
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	3
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	45	project design	10
laboratory exercises	0	final exam	40
calculation tasks	5		

Requirements to take the exam (number of points) 42

References

Holman, J. P.: Experimental methods for engineers. McGraw-Hill, 2007. ISBN 0071181652
Labview Core 1 & 2 Course Manual & Exercises, 2012, National Instruments

J. Hoffmann: Taschenbuch der Messtechnik, Carl Hanser Verlag GmbH & Co. KG, 2007, ISBN-13 978-3446409934
Robert Bishop: LabVIEW 2009 Student Edition, Prentice Hall, 2010, ISBN13- 9780132141291
J. Niebuhr, G. Lindner: Physikalische Messtechnik mit Sensoren, Vulkan-Verlag GmbH, 2005, ISBN-10 9783835631519

Skill praxis M - MOT

ID: 1480
Responsible/Holder professor MARKO N. KITANOVIĆ
Teaching profesor(s): KITANOVIĆ MARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: internal combustion engines

Goals

Acquiring practical knowledge of a mechanical engineer's duties. Gaining knowledge about company structure, management and the quality assurance system. Practical knowledge of manufacturing processes and corresponding machine tools. Broadening and acquiring new knowledge in the fields of IC engines research and testing.

Learning outcomes

Understanding the organizational structure and the mutual connections and relationships of individual units within a company. Understanding the importance of teamwork in engineering practice. Gaining practical skills in the field of CAD/CAE/CAM. Acquiring the ability to use modern measuring equipment and software in the field of engine testing.

Theoretical teaching

Introduction. The role and importance of engineering practice in an engineer's education. Instructions for keeping a diary. Recommendations for the selection of work organizations in which professional practice can be carried out. It is envisaged that the first part of professional practice will be carried out in work organizations in the field of design and production of engines and engine equipment, or production organizations that install engines in their products, or in work organizations that deal with engine maintenance. The second part of professional practice takes place in the Internal Combustion Engines Department (ICED) at the Faculty of Mechanical Engineering in Belgrade, where students participate in the design and completion of engine test stands, the design and realization of measuring systems and the software production and testing, as well as in the engine testing processes.

Practical teaching

a) Consultations during practical training. b) Practical training: b1. Practical training in the selected company (2/3 of practical training). b2. Practical training at the Internal Combustion Engines Department (1/3 of practical training).

Prerequisites

Defined by the curriculum of the study program/module. Consent of the work organization where the first part of the practice is carried out.

Learning resources

Instructions for conducting professional practice (in electronic form). Workstations and

licensed software at the Internal Combustion Engines Department. Laboratory installations and engine test stands at the ICED.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	40
test/colloquium	0	project design	0
laboratory exercises	30	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Richard Van Basshuysen and Fred Schafer. Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives. Warrendale: SAE International, 2004. ISBN 0768011396.
Konrad Reif. Gasoline Engine Management. Wiesbaden: Springer, 2015. ISBN 978-3-658-03963-9.
Konrad Reif. Diesel Engine Management. Wiesbaden: Springer, 2014. ISBN 3658039809.
Bernard Challen and Rodica Baranescu. Diesel Engine Reference Book. 2nd ed. Oxford: Butterworth-Heinemann, 1999. ISBN 0750621761.

Supercharging of IC Engines

ID: 0856
Responsible/Holder professor SLOBODAN J. POPOVIĆ
Teaching profesor(s): POPOVIĆ SLOBODAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: internal combustion engines

Goals

Acquiring new knowledge on role and importance of turbocharging in IC Engines. Developing skills to calculate parameters of supercharging and match compressor/turbine to desired engine performance. Broadening knowledge of thermodynamics by studying compressor/turbine performance characteristics and processes occuring in intercooler. Broadening knowledge in machine design by studying specific issues of turbocharger design principles.

Learning outcomes

Understanding the reality of Heat Engines working cycles and complexity of their design. Establishing the Cause & Effect relationship between working cycle and machine design. Capabilities to calculate parameters of IC Engine Supercharging, to make proper selection of Supercharging System components (compressor, turbine, intercooler, Waste-Gate). Abilities related to specific issues of laboratory testing of Supercharging System Components.

Theoretical teaching

1. Definitions and Survey of IC Engine Supercharging Methods; 2. Matching Flow Capacities and Characteristics of IC Engine and Charging Compressor; 3. Mechanical Supercharging; 4. Exhaust Gas Turbocharging; 5. Intercooling; 6. Calculation of Supercharging; Supercharging by means of Gasdynamic effects; 7. Design of Turbochargers; 8. Special issues and specific solutons of Supercharging; 9. Supercharger and Charge Compressor design and application examples; 10. Charge Air Cooler design solutions and examples; 11. Analysis of Supercharger design related to ICE application and performance; 12. Computer modeling and simulation of supercharging using Matlab/Simulink IDE;

Practical teaching

a) 1. Numerical examples in IC Engines Supercharging 2. Display & Analysis of Supercharging Methods, Design and Performance Characteristics of Compressors, Turbines & Intercoolers; 3. Preparation for Laboratory Task; 4. Principles of Modeling & Simulation of Supercharging System Components in Matlab/Simulink; Simulation of Supercharged IC Engine using Matlab/Simulink;

b)Student Project Task: Calculation of Supercharging System and matching Compressor/Turbine Characteristics to desired IC Engine Performance.

c) Laboratory Task: - Testing Compressor on Test Bench;

Prerequisites

Passed exam on course "IC Engines processes".
Good practical knowledge of Matlab/Simulink IDE.

Learning resources

1. M. Cvetić: Extracts from lectures (handouts) in e-form
2. S. Popović: Numerical examples, in e-form
3. IC Engine testing Laboratory (with an engine on the test bed)
4. Turbo-compressor Flow test bench
5. DAQ System: National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461
6. National Instruments LabView Graphical Development Environment
7. Matlab/Simulink Software Package

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	5
calculation tasks	14
seminar works	0
project design	6
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	10	project design	25
laboratory exercises	10	final exam	40
calculation tasks	15		

Requirements to take the exam (number of points) 0

References

H. Hiereth, P. Prenninger: Charging the Internal Combustion Engine, Springer Verlag, ISBN 978-3-211-33033-3, 2003
N. Watson, M. S. Janota: Turbocharging the Internal Combustion Engine. Macmillan Press, London, ISBN 0-333-24290-4, 1982
K. Zinner: Aufladung von Verbrennungsmotoren. Springer-Verlag, Berlin, ISBN 3-540-15902-

9, 1985
J. Heywood: Internal Combustion Engine Fundamentals, McGraw Hill, ISBN-13: 978-1260116106, 2018

Engine Design Project

ID: 1479
Responsible/Holder professor PREDRAG D. MRĐA
Teaching profesor(s): MRĐA PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: internal combustion engines

Goals

Gaining experience through practical work on the design of IC engines. The practical application of knowledge from previous IC engine courses, expansion, and acquisition of new knowledge in the field of design and calculation of machines, materials, and production methods of machine parts. Introduction to modern design methods in mechanical engineering, especially in the field of IC engines. Understanding and gaining practical experience working with computer-aided design and calculation methods (CAD - 2D, 3D, CAE).

Learning outcomes

Understanding complex mechanical structures, the connection of individual parts and components, and the ability to design functional and well-designed machines. The ability to practically apply modern software tools for designing in mechanical engineering. The capability to design, making good material and production methods selection of the most essential parts of internal combustion engines. Selection and dimensioning of auxiliary systems and components needed for proper engine functioning.

Theoretical teaching

The role of standardization and unification in the IC engine design. Phases of the classical approach to the design of the engine (sequential design). Definition of technical terms; Selection of the most important process and operating parameters in constructing a new engine. Making of preliminary design and the main engine project. Preparation of workshop drawings. Testing and refinement of the prototype design; Simultaneous (parallel) design; Computer-aided design; Technology of rapid prototyping; Mathematical modeling of Otto and Diesel-engine working processes; Modeling of the fundamental elements of the Engine structure, the calculation by means of FEM.

Practical teaching

Development of the project of the IC Engine - assembly drawings of the cross and longitudinal sections; 3D modeling (CAD) of one of the most important parts of the Engine and making workshop documentation for that part; Consultations in the preparation of the project.

Prerequisites

Passed exams in Engine Working Processes and IC Engine Design 1.

Learning resources

- M. Cvetić: Extracts from lectures (handouts)
- 2D & 3D CAD CAE Software & Workstations

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	6
elaboration and examples (revision)	6
active teaching (practical)	**12**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	12
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	70
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

М. Живковић: Мотори, 1. свеска - Уводна разматрања, кинематика и динамика клипног механизма, Машински факултет Београд, 1990, YU ISBN 86-7083-135-X.
М. Живковић, Р. Трифуновић: Мотори са унутрашњим сагоревањем 2. део - Конструкција и прорачун основних елемената мотора, Машински факултет Београд, 1990.
Richard Van Basshuysen, Fred Schafer: Internal Combustion Engine Handbook: Basics, Components, Systems, and Perspectives, SAE International, 2004, ISBN-13 978-0768011395

Engine Working Processes

ID: 0852
Responsible/Holder professor SLOBODAN J. POPOVIĆ
Teaching profesor(s): POPOVIĆ SLOBODAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: internal combustion engines

Goals

The aims of the course are: Gaining basic theoretical and practical knowledge about physicality of real engine working processes. Making a complete spark ignition and diesel engine working cycle calculation. Analysis of engine working process integral working parameters and operating characteristics.

Learning outcomes

Merging a theoretical knowledge of thermodynamics and fluid mechanics, connecting and application on real object – internal combustion engine.
Training for basic modeling and calculating of real engine working process, as well as acquiring fundamentals of engine designing.
Mastering of engine working parameters and operating characteristics and of the influences of working process on operating, energetic and ecologic engine characteristics.

Theoretical teaching

1. Analysis of thermodynamic ideal cycles. Engine real working cycle; fundamentals of cycle modeling. 2. Gas exchange process; gas flow through the channels and valves. Gas exchange in 4-stroke engines; valve timing; indicators of gas exchange process quality. Gas exchange in 2-stroke engines. Compression process. 3. Combustion in spark ignition engine; phases, influencing factors and process calculation. 4. Combustion in diesel engine; phases, influencing factors and process calculation. Diesel engine types according to the method of mixture formation. Expansion process. 5. Engine integral working parameters: indicating parameters, mechanical losses and effective parameters. Analysis of engine fuel consumption and specific effective work (mean effective pressure). Engine energetic balance. 6. Engine operating characteristics: speed and load characteristics, propeller and universal characteristics.

Practical teaching

1. Analysis of thermodynamic ideal cycles; numerical examples of engine ideal thermodynamic cycles. 2. Gas exchange process in 4-stoke engines. Numerical examples: evaluation of gas exchange specific work, coefficient of residual gases and volumetric efficiency. Display of various gas exchange systems and types of 2-stroke engines. 3. Display of various spark ignition engines combustion chambers and their comparison. Display of various diesel engines combustion chambers and their comparison. 4. Instruction for engine working process calculation. Example of spark ignition engine working process calculation. Example of diesel engine working process calculation. Examination of student's engine

working process calculation report.

Prerequisites

No prerequisites required.

Learning resources

1. M.C. Živković: Internal combustion engines Vol. 1: Theory of engines, Uni. of Belgrade, Faculty of Mechanical Engineering, ISBN 86-7083-073-6, 1988
2. M. Tomić, S. Petrović: Internal combustion engines, Uni. of Belgrade, Faculty of Mechanical Engineering, ISBN 978-86-7083-817-8 /in Serbian/, 2014
3. S. Popović: Engine working processes- handouts, available in PDF format at the Department of IC engines.
4. Test bench for internal combustion engines testing, Department of IC engines
5. Measuring-data acquisition system National Instruments PXI-1042-RT8186/5401/6123/6229/4070/6602/8461 (APC)
6. National Instruments LabView 7.1 (PPO)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	0
calculation tasks	6
seminar works	0
project design	12
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	15	project design	30
laboratory exercises	0	final exam	40
calculation tasks	15		

Requirements to take the exam (number of points) 0

References

J. Heywood: Internal Combustion Engine Fundamentals, ISBN-13: 978-1260116106, McGraw Hill, 2018
R. Pischinger , M. Klell , T. Sams: Thermodynamik der Verbrennungskraftmaschine, ISBN:

978-3-211-99277-7, Springer Verlag, 2010
C. R. Ferguson: Internal Combustion Engines: Applied Thermosciences, J.Wiley & Sons, ISBN-13: 978-1-118-53331-4, 2016
R. Benson_Introduction to the Thermodynamics of Spark and Compression Ignition Engines_Vol1/2, Pergamon Press Ltd., ISBN: 0 08 022720 X/0 08 022720 1, 1979
M.C. Živković: Internal combustion engines Vol. 1: Theory of engines, Uni. of Belgrade, Faculty of Mechanical Engineering,, ISBN 86-7083-073-6, 1988

MATERIAL HANDLING, CONSTRUCTIOS AND LOGISTICS

Computer Aided Design in Material Handling Practice

Construction, mining and conveying machinery elements

Conveying and Material Handling Machines

Cranes Design

Design of construction and mining machines subsystems

Eco Design

Facility layout and industrial logistics

Fundamentals of Mining and Construction Machines Dynamics

Mining and Construction Machines

Skill praxis M - TKL

Structural and Stress Analysis

Transport and logistic systems design

Computer Aided Design in Material Handling Practice

ID: 0909
Responsible/Holder professor VLADA M. GAŠIĆ
Teaching profesor(s): GAŠIĆ VLADA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: material handling, constructios and logistics

Goals

Basic goals of this course are: 1) introduction to finite element method and applications in design of structures for material handling machines, 2) gaining the practical skills for 2D and 3D design and modeling of structures of material handling machines.

Learning outcomes

After the completion of the course, student is trained to:
•Apply the finite element method (FEM), with linear finite elements, in formulation and calculation of plane trusses and frames
•Perform static analysis of plane truss and frame in FEM software and work and present basic technical report for given engineering problem
•Form the 3D structural model with linear finite elements and give static analysis due to loads
•Use different FEM software for structural analysis
•Do the basic design of gantry crane according to engineering recommendations

Theoretical teaching

Introduction to finite element method. The FEM analysis process for beams and truss elements. Member stiffness matrix. Coordinate transformation. Master stiffness matrix. Force vector. Solving for displacements. Recovery of internal forces and stresses. Examples of finite element models of structures of material handling machines. Modeling of 3D truss systems.

Practical teaching

Matrix method for calculation of displacements, internal forces and stresses in 2D truss system with 5 nodes. Matrix method for calculation of displacement and internal forces at plane two beam-elements model. Modeling the characteristic structures for material handling machines, in finite element software (trusses, beams, frames, cranes). Preparation for input data and analysis of output data. 3D modeling in given software of some parts of material handling machines.

Prerequisites

Necessary: Mathematics 2, Strength of materials
Advisable: Fundamentals of steel structures.

Learning resources

1. Computer room 516

2. FEA softwares

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	8
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	15	project design	0
laboratory exercises	45	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Vlada Gašić: Osnove metalnih konstrukcija u mašinogradnji, Handbook, Faculty of Mechanical Engineering, Belgrade, 2021
Handouts with examples, 2023.

Construction, mining and conveying machinery elements

ID: 1539
Responsible/Holder professor NEBOJŠA B. GNJATOVIĆ
Teaching profesor(s): GNJATOVIĆ NEBOJŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: material handling, constructios and logistics

Goals

Basic course goals are: 1) introducing students to construction, design and calculations of basic construction, mining and conveying machinery elements; 2) mastering of practical skills required for design and calculation of construction, mining and conveying machinery.

Learning outcomes

Goal of this course is to introduce the students to the following skills:
•Modeling and calculation of unique below-the-hook lifting devices;
•Design, modeling and calculations related to fundamental substructures of crawler systems;
•Modeling and calculation of bearing structures of mobile construction, transport and mining machines;
•Design and calculation of stabilizers;
•Computer-aided modeling and creating technical documentation of elements and assemblies of machines used in construction, mining and material handling processes.

Theoretical teaching

Construction, mining and conveying machinery drive. Mechanical and hydraulic power transmission systems. Basic mechanisms of construction, mining and conveying machines. Design and calculation of specific construction, mining and conveying machinery elements.Travel mechanisms. Rail-mounted travel gear. Crawler travel gear. Hydraulic walking gear. Track wheels. Crawler chain link. Two wheel bogie. Crawler bearing structure. Traction systems. Drive and transmission systems calculations. Design and calculation of carriage and traction traverse. Supporting-slewing mechanisms. Types, design solutions, calculation. Mechanisms for excavating device reach alternation. Types, design solutions, calculation. Mechanisms for working devices lifting and propulsion. Stability calculation. Stabilizers.

Practical teaching

Design and calculation of various types of joints. Design and calculation of eye plates and hooks for special purposes. Design and calculation of travel gear track wheels. Travel gear two wheel bogies. Design and finite element analysis of crawler two wheel bogie body. Design and calculation of crawler chain links and pads. Design and calculation of additional bearing structure of mobile machines. Design and calculation of stabilizers. Construction documentation. Consultations.

Prerequisites

Engineering Graphics, Strength of Materials, Material Science, Machine Elements 1, Machine Elements 2, Fundamentals of steel structures

Learning resources

Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Momir M. Plavšić, Construction Machines, Scientific Book, Belgrade, 1990.
Vinko Jevtić - Construction and Mining Machines, Faculty of Mechanical Engineering Nis, 1993.
Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001.

Conveying and Material Handling Machines

ID: 0308
Responsible/Holder professor NENAD Đ. ZRNIĆ
Teaching profesor(s): ZRNIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: material handling, constructios and logistics

Goals

The main goal of this course is to acquaint students with material handling machines and conveying machines, types and design solutions and principles of work. The goal is to introduce students to master the practical skills needed to perform the engineering profession, such as the main machine parameters, load analysis, selection of drive units and calculation of the capacity.

Learning outcomes

By completing this course student acquires ability to:
•determine bulk and solid materials characteristics
•determine conveying machine's throughput/capacity in accordance with project requirements and type of conveyed material
•calculate and choose conveyor drive
•calculate basic parameters and components of belt conveyor
•calculate basic basic parameters and components of apron conveyor
•calculate basic basic parameters and components of screw conveyor
•calculate basic basic parameters and components of bucket elevator

Theoretical teaching

Determination of the transport capacity of material handling and conveying machines. Conveyors, belt conveyors, apron conveyors, flight conveyors, overhead conveyors, elevators, screw conveyors, oscillating conveyors, roller conveyors, gravity conveyors, hoppers, feeders and gates , ropeways, basic performances of machines, structural solutions, basic calculations. material handling machines with translator motion, bridge and gantry cranes, unloading bridges, container cranes, performances, operational principles, analysis of load, calculations. material handling machines with rotational motion, jib cranes, tower cranes, portal cranes in ports, performances, structures, mechanisms. Elevators and industrial trucks, forklifts, storage cranes.

Practical teaching

Calculation of conveyors with belt pulling element, the contour calculation and selection of propulsion belt conveyors, calculation around conveyor sections, calculation of conveyors with chain pulling element, apron and flight conveyors, calculation of bucket elevators, roller conveyors, screw conveyors. Video presentations of modern design of material handling machines, analysis of the machine operation in system, automation of work.

Prerequisites

The conditions are defined by the curriculum of the study program.

Learning resources

Computers, Laboratory 516, ICT / CAH

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	15
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	10
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	60		

Requirements to take the exam (number of points) 35

References

Patrick M McGuire, Conveyors Application, Selection, and Integration, 2021, CRC Press.
Mohammad E. Fayed, Mechanical Conveyors: Selection and Operation, 1996, CRC Press
Nenad Zrnic: Conveying and Material handling machines - Hanouts and written lectures, 2011, DVL.
Slobodan Tosic, D. Ostric: Cranes, Faculty of Mechanical Engineering, 2005, KDA
Slobodan Tosic, Material handling equipment - Mechanization of transport, Mechanical Engineering, Belgrade, 1999, KDA.

Cranes Design

ID: 0139
Responsible/Holder professor NENAD Đ. ZRNIĆ
Teaching profesor(s): ZRNIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: material handling, constructios and logistics

Goals

The main objective of this course is to achieve competence of students to master the principles of cranes design and that is able to be incorporated into the cranes design process in the future engineering work. The goal is to master specific practical skills for the selection of drive units, calculation of support steel structures of cranes and to get the knowledge on the standards for calculation, as well as realization of technical documentations.

Learning outcomes

Upon successful completion of this course, students should be able to:
•identify, classify and analyze regular, occasional and exceptional load at overhead travelling cranes
•perform calculation and selection of the bridge crane geometry
•determine the load of the bridge crane in characteristic cross section
•perform proof of stress, proof of deformation, proof of dynamic stiffness, proof of elastic stability, proof of bolted connection between the main girders and end carriages
•perform calculation and choose stiffnesses
•perform calculation of end carriages
•carry out the verification of the analytical calculation with the results obtained in the FEM software package

Theoretical teaching

The basic principles of cranes design, trends in development, maintenance, transportation and crane installation, testing and registration of cranes, safety measures. Standards for calculation of support structures of cranes, trolley selection, sizing and calculation of trolley supporting structure and its drive. Calculation of support structure of bridge cranes, the selection of geometry of main girders and end carriages, proof of stress, proof of deformation, proof of dynamic stiffness, loads of main girder, proof of welded connections. Elastic stability of girder, local stability of plate, calculation of the connections of main girders and end carriages, calculation of end carriage, specificities in calculation of the single girder bridge cranes.

Practical teaching

Realization of the project of double girder crane, selection of drive units, selection of geometry and calculation of support structures of trolley and crane, proof of elastic stability - buckling of plates, calculation of single girder bridge cranes. Computer exercises, calculation

of supporting structure of bridge cranes by using FEM, with training in the use and application of specialized software package KRASTA (Cranes Statik, non-commercial academic version without restrictions concerning calculations), for static and dynamic analysis of supporting structures of material handling and conveying machines by using finite elements method.

Prerequisites

The conditions are defined by the curriculum of the study program.

Learning resources

1. Nenad Zrnic: handouts - Written lectures, 2011, DVL
2. KRASTA - Program for statical and modal analysis of spatial frames, MANUAL, DVL.
3. Computers, Laboratory 516, ICT / CAH
4. KRASTA software package - program for statical and modal analysis of spatial frames, BSB Kühne GmbH, ICT / CSP

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	40
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Slobodan Tosic, D. Ostric: Cranes, Faculty of Mechanical Engineering, 2005,
J. Verschoof, Cranes Design, Practice and Maintenance 2nd Edition, Wiley, 2002
Slobodan Tosic, D. Ostric: Cranes, Faculty of Mechanical Engineering, 2005, KDA.

Design of construction and mining machines subsystems

ID: 1540
Responsible/Holder professor NEBOJŠA B. GNJATOVIĆ
Teaching profesor(s): GNJATOVIĆ NEBOJŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: material handling, constructios and logistics

Goals

Basic course goals (objectives): 1) introducing students to specificity of working process, construction, design and calculation of fundamental subsystems of construction and mining machines; 2) mastering practical skills which are necessary for design and calculation of construction and mining machines.

Learning outcomes

This course offers the following skill set to the students who complete it:
•Design of backhoe excavators' working devices;
•Design of basic elements of single-bucket excavators' working devices;
•Modeling and calculation of a bucket wheel excavator's working device – bucket wheel body and buckets;
•Design and calculation of the bucket wheel drive system;
•Design and calculation of four and eight-wheel bogie of a crawler mechanism;
•Calculation of basic technical and technological parameters, power and strength of jaw and conic rock crushers;
•Load analysis, modeling, proper supporting, loading and finite element analysis of civil and mining machines' fundamental subassemblies.

Theoretical teaching

Short survey of construction and mining machines development. Shovel excavators. Calculation of working loads caused by soil excavation. Calculation of basic geometrical parameters of bucket of back hoe excavator, power shovel and dragline excavator. Defining parameters of drive and transmission system of working device of shovel excavator. Design solutions of elements of working device of shovel excavator. Shovel excavator's working device strength calculation. Design and calculation of dozer, scraper and grader mechanisms. Multi bucket excavators. Basic design of bucket wheel excavator. Bucket wheel excavator working device. Bucket wheel, buckets. Bucket wheel drive. Determination of bucket wheel boom basic parameters. Bucket chain excavator. Basic design of bucket chain excavator. Working device of bucket chain excavator. Theoretical fundaments of crushing process. Jaw, cone, roll and impact crushers – design, calculation. Theoretical fundaments of screening process. Static and dynamic screens - design, calculation.

Practical teaching

Design of back hoe excavator working device. Shaping of working device basic elements. Selection of hydro cylinder. Design of basic elements of shovel excavator working device.

Design and calculation of dozer working device. Design and calculation of bucket wheel excavator working device. Design and calculation of bucket wheel with buckets. Design, construction and calculation of bucket wheel drive. Design and calculation of four wheel and eight wheel bogie of bucket wheel excavator crawler travel gear. Calculation of basic technical-technological parameters, power and strength of jaw and cone crushers. Construction documentation. Consultations.

Prerequisites

Engineering Graphics, Strength of Materials, Material Science, Machine Elements 1, Machine Elements 2, Fundamentals of steel structures

Learning resources

Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	5
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Momir M. Plavšić, Construction Machines, Scientific Book, Belgrade, 1990.
Vinko Jevtić - Construction and Mining Machines, Faculty of Mechanical Engineering Nis, 1993.
Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001.

Eco Design

ID: 0127
Responsible/Holder professor NENAD Đ. ZRNIĆ
Teaching profesor(s): ZRNIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: material handling, constructios and logistics

Goals

The main objective of this course is to achieve competence and academic skills in the field of eco design and sustainable product development. The goal is mastery of the methodologies to define strategies to improve products and reduce the harmful effects of products on the environment, and understanding of the impact of products on the environment throughout its life cycle and innovative approach to obtaining environmentally improved products.

Learning outcomes

By completing this course student acquires ability to:
•analyse life cycle of a product using tools for life cycle assessment
•implement ecodesign strategies into design process and product development
•suggest measures for improvement of environmental performances of the product
•implement legislative in the field of ecology into design process
•design and develop sustainable product

Theoretical teaching

Introduction into Eco-design, basic concepts and terminology, the impact of products on the environment. Eco-Design strategy, product modeling, recommendations for the selection of materials with low impact on the environment, the impact of production technologies, transport and packaging, as well the phase of product use and product end-of-life on the ecological impacts. The assessment of product life cycle, methodology of environmental impact, practical examples. Environmental communication and the EU measures for environmental protection, directive, eco-labels and declarations. Application of Eco-Design for the improvement of existing products. Design for disposal and recycling of waste products, design for waste minimization, design for dismantling of old equipment.

Practical teaching

Terminology of Eco Design. Examples of impacts of products on the environment. Examples of eco-design strategies. Examples of analysis of product life cycle in terms of Eco-Design. Examples of improvements of existing products. Examples of disposal and recycling of used goods. Eco Design computer tools, training and work in a computer tool EcoDesign Pilot + Assistant + EEG, obtaining an improved product through several stages which include the identification of products, Eco Design strategies and concrete measures for improvement.

Prerequisites

The conditions are defined in the curriculum of the study program.

Learning resources

1. Nenad Zrnic: Ecodesign, Handouts - Written lectures, 2011, DVL.
2. Computers with Internet connection, Lab 455, ICT / CAH
3. EcoDesign Pilot software + + Assistant EEG, TU Wien, ICT / CSP

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Nenad Zrnić, Miloš Djordjević: Ecodesign - Sustainable product development, University of Belgrade, Faculty of Mechanical Engineering, 2012
Ostad - ECODESIGN Sustainable Product Development, Vienna University of Technology, 2006, KCJ.

Facility layout and industrial logistics

ID: 0187
Responsible/Holder professor NENAD Ž. KOSANIĆ
Teaching profesor(s): KOSANIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: material handling, constructios and logistics

Goals

Introducing the students into the factories, factory facilities, transport and warehouse systems design process logic is the main goal. Development of the student system design creative and innovative abilities in order to increase the production, warehouse and logistic activities efficiency, contributing to the overall country industrial development is also the main issue.

Learning outcomes

Upon successful completion of this course, students should be able to:

- Make a project requirement for factory, factory facilities, transport, storage and logistic systems planning.
- Make a calculation of needed technological and additional equipment, working power, working places, needed areas and material flow.
- Make a layout of the factory, factory facilities, transport, storage and logistic systems.
- Calculate the basic elementary subsystems performances (by queueing systems modeling) of the factory, factory facilities, transport, storage and logistic systems.
- Make a cast iron foundry concept study.

Theoretical teaching

Systematic design approach. Systems building. Feasibility studies. Design task. Main production programs. Production and technical production capacities. Factories subsystems and workshops. Technological project documentation. Design procedure. Production systems working regime. Working time fund. Production equipment needs estimation. Working space needs estimation. Working power needs estimation. Layout design. Flexible manufacturing systems definition, application fields and main characteristics. Layout design models. Material flow. Main logistic chain managing principles. Elementary subsystems (knot points) main characteristic. Queuing systems main foundations. Material flow analyzing models. Basic layout design inputs. Energy supply. Heating, ventilation and de-dusting. Master plan. Case studies and topics consulting.

Practical teaching

Queuing model choosing for characteristic production and transport processes modeling. Computer calculation of queuing models statistics (outcome working parameters). Foundry concept study: Smeltery department production equipment needs estimation; Molding sand preparation department technology choosing and production equipment needs estimation;

Core sand preparation department technology choosing and production equipment needs estimation;Mold cleaning department technology choosing and production equipment needs estimation; Foundry warehouse design; Some department crane or conveyer basic design parameters and capacity estimation; Foundry layout design; Foundry one department detailed layout design. Consulting and recommendations for factories, factory facilities, transport and logistic (warehouse-distributive) subsystems and systems modeling and designing.

Prerequisites

Needed: Passed Subject: Mathematical probability and statistics, Material handling equipment, Fundamental of steel structures in heavy machinery.

Learning resources

lab. 516.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	24
elaboration and examples (revision)	6
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	30
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	10	project design	20
laboratory exercises	0	final exam	30
calculation tasks	30		

Requirements to take the exam (number of points) 35

References

Dj. Zrnic, Facility layout design, Faculty of mechanical engineering, University of Belgrade, 1993.
2, Dj. Zrnic, M. Prokic, P. Milovic, Foundry layout design, Faculty of mechanical engineering, University of Belgrade, 1998.
Dj. Zrnic, D. Savic, Material flow simulation, Faculty of mechanical engineering, University of

Belgrade, 1997.
Dj. Zrnic, D. Petrovic, Facility layout design solved example problems, Faculty of mechanical engineering, University of Belgrade,, 1992.
Queuing models software package, Faculty of mechanical engineering, University of Belgrade, 1999., lab, 459.

Fundamentals of Mining and Construction Machines Dynamics

ID: 1542
Responsible/Holder professor NEBOJŠA B. GNJATOVIĆ
Teaching profesor(s): GNJATOVIĆ NEBOJŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: material handling, constructios and logistics

Goals

Basic course goals (objectives): 1) introducing students with specificities of dynamic processes of construction and mining machines . 2) mastering practical skills which are necessary for analysis of dynamic behavior of construction and mining machines.

Learning outcomes

By successfully completing this course the student should acquire the following competences:
•Properly forming the reduced dynamic models of earthmoving machines such as single-bucket excavators and bulldozers;
•Determining elementary technical and exploitation characteristics of the machines used for material preparation and handling (rock crushers and sifters), accounting for dynamic effects occurring in such processes;
•Modeling the excitation of continuous excavators and analysis of the influence of constructional and working parameters of the machine on the excitation caused by resistance to excavation;
•Creating dynamic models of continuous excavators' substructures;
•Identification and analysis of continuous excavators' substructures response to excitation caused by resistance to excavation;
•Calculation and proper selection of basic parameters of conveyor belts with relatively high conveyor speed, dominantly used in mobile continuous earthmoving machines.

Theoretical teaching

Fundamentals of basic excavating machines dynamics – backhoe excavators and bulldozers. Fundamentals of dynamics of raw material fragmenting and sorting machines – crushers and screening machines. Modeling of excitation of excavators for continuous excavation. Influence of design and work parameters on excitation caused by resistance to excavation. Modeling of bearing construction and mechanisms of excavators for continuous excavation. Identification and analysis of excavators for continuous excavation dynamic response on excitation caused by resistance to excavation. Vibrations caused by self-excitation. Dynamic response of bearing structure (construction) on excitation caused by wind. Dynamic of spreaders, mobile machines for continuous excavation (material handling).

Practical teaching

Dynamic models of single bucket excavator excavating devices. Impact of Bulldozer to the obstacle. Calculation of basic parameters of crushing and screening machines. Bucket wheel excavators and trenchers excitation modeling (determination). Analysis of bucket wheel

excavators bearing structure dynamic response on excitation caused by resistance to excavation Dynamic response of bearing structure (construction) on excitation caused by wind. Fundamentals of spreader dynamics. Consultations.

Prerequisites

Required previously passed courses: Strength of Constructions, Structural and Stress Analysis, Mining and Construction Machines.

Learning resources

1. Computers, Laboratory 516
2. Software Mathlab, Catia

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	9
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	15
discussion and workshop	1
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	6
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	35	project design	25
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001.
Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008.
Srđan Bošnjak, Fundamentals of Mining and Construction Machines Dynamics, - Instructions for seminar paper realization, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008.
J.P. Den Hartog, Mechanical Vibrations, McGraw-Hill Book Company, Inc., USA, 2007.

Mining and Construction Machines

ID: 1541
Responsible/Holder professor NEBOJŠA B. GNJATOVIĆ
Teaching profesor(s): GNJATOVIĆ NEBOJŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: material handling, constructios and logistics

Goals

Basic course goals (objectives): 1) introducing students with specificities of working process, design, modeling and calculation of basic (fundamental) subsystems of construction and mining machines and appliances, primarily machines for continuous excavation and machines for crushing and screening. 2) mastering practical skills which are necessary for design and calculation of construction and mining machines.

Learning outcomes

By successfully completing this course the student should be able to competently assess the following problems:
•Choosing a proper design and calculating rotating supports and mechanisms of earthmoving machines' revolving superstructures:
•Choosing a proper design and calculating basic parameters of the earthmoving machines' movement mechanisms;
•Determining and adopting basic parameters of the bucket wheel excavators' (BWE) and bucket chain excavators' drive systems;
•Proper strength calculation of open-pit mining machines' substructures using linear Finite Element Method (FEM);
•Coupling of experimental and analytical data with the goal of properly determining parameters of BWE static stability;
•Comparison of design approaches and calculation of basic parameters of jaw, conic, gyratory, roll crushers and impactors according to required degree of material fragmentation.

Theoretical teaching

Design solutions and calculations of slewing platforms and mechanisms of excavators. Design solutions and calculations of crawlers and walking mechanisms for excavator movement. Use, working process, structural scheme, drive and transmission systems and calculation of bucket wheel excavators and bucket chain excavators. Analytical and experimental methods of determination of static stability parameters. Theoretical fundaments of crushing process. Jaw, cone, roll and impact crushers – design, calculation. Theoretical fundaments of screening process. Static and dynamic screens - design, calculation.

Practical teaching

Calculation of working (excavating) equipment, operating modes, and power of mechanisms of excavators for continuous excavation. 3D modeling of characteristic subassemblies of excavators for continuous excavation. Calculation models of truss substructures of bucket

wheel excavators. Computer simulations of external loads. Load cases. Stress – strain identification. Creation (Development) of technical drawings. Position determination, selection and calculation of basic (main) parameters of stackers (spreaders). Calculation of basic technical (design) and technological parameters, power and strength of jaw and cone crushers and screens. Consultations.

Prerequisites

Defined by the curriculum of the study program

Learning resources

Computers, Laboratory 459(516), Software Mathlab, (Catia)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	20
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	30	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Vinko Jeftić, Construction and Mining Machines, University of Niš, Faculty of Mechanical Engineering, Niš, 1993.
Momir M. Plavšić, Construction Machines, Scientific Book, Belgrade, 1990.
Srđan Bošnjak, Bucket Wheel Trenchers, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2001.,
Srđan Bošnjak, Handouts, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008.,
Srđan Bošnjak, Mining and construction machines - Instructions for writing laboratory

reports, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, 2008.,

Skill praxis M - TKL

ID: 1410
Responsible/Holder professor NENAD Đ. ZRNIĆ
Teaching profesor(s): ZRNIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: material handling, constructios and logistics

Goals

The aim of the course is to acquaint students with tools, machines and devices in the field of mechanization used in various branches of the economy, especially in industry, construction, mining, logistics, transport, tourism, energy, process engineering, service activities, etc

Learning outcomes

By mastering the program of the course, students get acquainted with: 1. Production processes in companies that produce or use equipment for mechanization and material handling, 2. Material Handling and Conveying, 3. Processes of maintenance of equipment and machinery for mechanization and material handling, etc.

Theoretical teaching

Introductory remarks about the mechanization and material handling. Basics of application of safety and health measures at work when using equipment and means for work in general, and especially in the field of mechanization and material handling. Basic principles of operation of devices and machines for mechanization. Fundamentals of technological processes in the industry that produces machines and construction in the field of mechanization. Fundamentals of design of material handling and logistics systems.

Practical teaching

Practical classes are realized through visits to industrial complexes and companies in which machines and devices in the field of mechanization are produced or used. Insight is gained into transport flows in which means of internal transport are used, production-technological processes of making parts for mechanization machines, assembly processes, maintenance of mechanization machines, construction characteristics of cranes and other material handling devices, the role of construction machinery on high-rise buildings, the role of conveyors and rotary excavators on surface mines for coal exploitation, storage and distribution systems, etc. Also, there is a presentation of realized projects by the Department for the needs of the economy in the previous 10-year period. The used methods, basic phases in the design process (from the conceptual design to the final product), as well as technical solutions for the reconstruction of existing machinery for mechanization are presented.

Prerequisites

There are no conditions.

Learning resources

Tošić, S .: Transportni uređajji - Mehanizacija transporta, Beograd, 1999., Ostrić, D., Tošić, S .: Dizalice, Beograd, 2005, Petković, Z .: Metalne konstrukcije u Mašinogradnji, Beograd, 1996., Bošnjak, S .: Rotorni rovokopači, Beograd, 2001., Zrnić, Đ., Prokić, M., Milović, P.: Projektovanje livnica, Beograd, 1988.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	80
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Nenad Zrnić: Manual for Skill praxis M - TKL, Faculty of Mechanical Engineering Belgrade, 2021, pdf.

Structural and Stress Analysis

ID: 0910
Responsible/Holder professor VLADA M. GAŠIĆ
Teaching profesor(s): GAŠIĆ VLADA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: material handling, constructios and logistics

Goals

Basic goal of this course is introduction to principles in design and calculation of steel structures for wide range of material handling machines (mining machines, earthmoving machines, cableways and lifts). Also, goal is development of student creative skills for designing the light but safe structures, i.e. rational structures.

Learning outcomes

After the completion of the course, student is trained to:
•Calculate the shear stresses of the thin-walled closed section, such as on box girder of bridge crane
•Calculate first moments of area of the thin-walled open section
•Obtain the position of the shear centre of the thin-walled open section and form the warping coordinate
•Analyze the warping torsion effects for beams and cantilevers with thin-walled open section, determine the warping loads and calculate the stresses due to bimoment and warping torsion
•Perform the complete stress proof of girders made of thin-walled open section

Theoretical teaching

Theory of elasticity (basics). Stress-strain relations. Torsion of solid and hollow circular section bars. Torsion in thin-walled closed section beams. Torsion in thin-walled open section beams. Shear flow distribution. Shear stress distribution. Shear centre. Warping. Warping constant. Lateral buckling. Equation for rotational angle. Representation of stresses.

Practical teaching

Calculation of section properties for thin-walled open section beams: centre of gravity, first moment of area, second moment of area, torsional constant, warping constant. Determination of shear centre for various thin-walled open sections. Calculation of shear stress distribution and bending stress distribution at characteristic sections performed on several types of thin-walled open section simple beams and cantilevers under loads. Determination of shear centre for thin-walled sections with developed software package.

Prerequisites

Necessary: Mathematics 1,Mathematics 2, Strenght of materials.
Advisable: Fundamentals of steel structures

Learning resources

Computer rooom 516, literature.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	5
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	45	project design	0
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 35

References

Zoran Petkovic: Metalne konstrukcije u masinogradnji 2, Faculty of Mechanical Engineering, Belgrade, 2005.
Vlada Gašić: Osnove metalnih konstrukcija u mašinogradnji, Handbook, Faculty of Mechanical Engineering, Belgrade, 2021

Transport and logistic systems design

ID: 0119
Responsible/Holder professor NENAD Ž. KOSANIĆ
Teaching profesor(s): KOSANIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: material handling, constructios and logistics

Goals

Introducing the students into the advanced transport, warehouse and logistic (warehouse-distributive) systems design process logic is the main goal. Development of the student system design creative and innovative abilities in order to increase the material flow, warehouse and logistic activities efficiency, contributing to the overall country industrial development is also the main issue.

Learning outcomes

Upon successful completion of this course, students should be able to:

- Specify elementary subsystems, elementary subsystem variables, elementary subsystem performance variables and environment variables of the flexible transport systems.
- Calculate the basic elementary subsystems performance variables (by queueing systems modeling) of the flexible transport and logistic systems.
- Make a comparison of different flexible transport system applications.
- Make a calculation of needed capacity, technological and additional storage equipment, working power, working places, needed areas and material flow of the storage and logistic systems.

Theoretical teaching

System, elementary subsystem and environment variables and performance variables of the flexible transport system (FTS). FTS elementary subsystems. "Power and free" system main design characteristic. Flexible monorail system main design characteristic. Rail automated vehicle system main design characteristic. Automated guided vehicle system (AGVS) main design characteristic. Required flexible transport systems vehicle fleet estimation. Warehouse and logistic (warehouse-distributive) systems fundamental design characteristics: goods receiving subsystem, main warehouse subsystem, order picking subsystem, goods dispatching subsystem. One dimensional non strategy and strategy order picking models. Two dimensional order picking models. Case studies (with pointing out most important design parameters). Exercises of lectures.

Practical teaching

Exercises of order picking models. Concept design of conventional warehouses with different warehouse technologies, hay-bay warehouses with different automation level and logistic (warehouse-distributive) systems: Goods receiving and dispatching subsystems area estimation, goods receiving and dispatching subsystems technology choosing, main

warehouse subsystem technology choosing and capacity estimation,order picking subsystem technology choosing and capacity estimation; Storage equipment technical specification; Required applied transport systems vehicle fleet estimation; System performance variable estimation; Storage system layout design; Warehouse and logistic systems design recommendation and consultation.

Prerequisites

Needed: Passed Subject: Mathematical probability and statistics, Material handling equipment, Facility layout and industrial logistics.

Learning resources

Queuing models software package, Faculty of mechanical engineering, University of Belgrade, 1999., lab, 459. 6. Lecture handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	24
elaboration and examples (revision)	6
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	10
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	3
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	30	project design	20
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

1, Dj. Zrnic, Facility layout design, Faculty of mechanical engineering, University of Belgrade, 1993.
2, Dj. Zrnic, M. Prokic, P. Milovic, Foundry layout design, Faculty of mechanical engineering, University of Belgrade, 1998.
3, Dj. Zrnic, D. Savic, Material flow simulation, Faculty of mechanical engineering, University of Belgrade, 1997.

4, Dj. Zrnic, D. Petrovic, Facility layout design solved example problems, Faculty of mechanical engineering, University of Belgrade,, 1992.
Lecture Handouts, 2023.

MATHEMATICS

Probability and statistics

Probability and statistics

ID: 0354
Responsible/Holder professor IVAN D. ARANĐELOVIĆ
Teaching profesor(s): ARANĐELOVIĆ IVAN; PEJČEV ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: mathematics

Goals

Introduction to techniques of probability theory, reliability theory, mathematical statistics and their most important application in technics. Introduction to techniques of regression analysis and stochastic modelling.

Learning outcomes

Upon successful completion of this course, students should be able to:

1) Calculate probability and conditional probability of random events.

2) Determine rules of distributions, characteristic functions, expected value and variance of discrete random variables.

3) Determine distribution functions, density functions, characteristic functions, expected value and variance of continuous random variables.

4) Apply learned technique for solving basic problems of Theory of confidentiality and Mathematical statistics.

5) Determine degree and direction of correlation of one dimensional random variables, applying least squares method.

6) Apply learned technique of probability calculation for modeling work of the technical system by Monte Carlo method.

Theoretical teaching

Basic concepts of probability theory. Random events. Conditional probability of an event. Total probability formula. Bayes formula. Bernoulli's Formula and its approximations. Random variables. Central limit theorem. Regression. Mathematical statistics mission. Generally about estimation of distribution parameters. Estimating expected value and variance of a random variable. Methods for estimating distribution parameters. Confidence intervals. Statistical hypothesis testing. Least squares method. Reliability of technical systems. Nonparametric hypothesis testing. Analysis of variance. Planning of statistical experiment. Random numbers. Monte-Carlo method. Random variables modelling. Technical systems simulation.

Practical teaching

Basic concepts of probability theory. Random events. Conditional probability of an event. Total probability formula. Bayes formula. Bernoulli's Formula and its approximations. Random variables. Central limit theorem. Regression. Mathematical statistics mission. Generally about estimation of distribution parameters. Estimating expected value and variance of a random variable. Methods for estimating distribution parameters. Confidence intervals. Statistical hypothesis testing. Least squares method. Reliability of technical systems. Nonparametric hypothesis testing. Analysis of variance. Planning of statistical experiment. Random numbers. Monte-Carlo method. Random variables modelling. Technical systems simulation.

Prerequisites

No prerequisites.

Learning resources

I. Aranđelović, Z. Mitović, V. Stojanović, Probability and Statistics, Zavod za udžbenike, Beograd 2011.

I. Aranđelović, Theory of random events, Vedes, Beograd 2005.

S. Radojević, V. Simonović, Problems and exercises from Probability and Statistics, Zavod za udžbenike, Beograd 2014.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	15
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0

test/colloquium	50	project design	5
laboratory exercises	0	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 20

References

V. Simonović: Introduction to theory of probability and mathematical statistics, Naučna knjiga, Beograd, 1995.
Z. A. Ivković: Theory of probability and mathematical statistics, Građevinska knjiga, Beograd, 1980.
S. Vukadinović: Elements of theory of probability and statistics, Beograd 1986.
B. Vidaković, D. Banjević, Probability and statistics, exercises , Beograd 1989.
M. Nenadović, Mathematical analysis of measurment dates, Beograd 1988.

MECHANICS

Analitical mechanics

Biomechanics of tissue and organs

Continuum Mechanics

Mechanics M

Mechanics of robots

Mechatronic robotics

Skill Praxis M - MEH

Theory of Mechanical Vibrations

Analitical mechanics

ID: 0825
Responsible/Holder professor OLIVERA M. JEREMIĆ
Teaching profesor(s): JEREMIĆ OLIVERA; OBRADOVIĆ ALEKSANDAR; RADULOVIĆ RADOSLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: mechanics

Goals

-To provide students knowledge of the fundamental principles and methods in Analytical Mechanics
-To enable students to solve practical problems in Analytical Mechanics using acquired knowledge in Analytical Mechanics
- to monitoring novelties in science and engineering

Learning outcomes

-To enable students to master terms, methods and principles in Analytical Mechanics
-To enable students to relate the knowledge from knowledge in other scientific fields with knowledge Analytical Mechanics
-To apply knowledge from Analytical Mechanics in analysis, synthesis and prediction of solutions and consequences of problems in science
- To monitoring novelties in science and engineering

Theoretical teaching

Analytic system dynamics. Free and constrained material systems. Constraints and their classification. Real, possible and virtual displacements. Number of degrees of freedom. Virtual work of forces. Ideal constraints. Lagrange's equations of the first kind. Lagrange's mechanics and differential approaches. Elements of tensor calculus. State of motion of mechanical system in configuration space. Kinetic energy. Generalized forces. Virtual work principle. Lagrange-D'Alembert's principle. Lagrange function. Lagrange's equations of the second kind for holonomic mechanical systems and their structure. First integrals. Lagrange's equations of the second kind for nonholonomic mechanical systems. Hamiltonian mechanics. Hamilton's variables. Phase space. Hamilton's function and its structure. Hamilton's canonic equations for conservative and nonconservative holonomic mechanical systems. Direct method for finding first integrals of Hamilton's canonic equations. Poisson bracket. Liouville's theorem. Whittaker's equations. Routh's equations. Variational principles. Elements of variational calculus. Relation between general dynamic equation and variational calculus. Central equation of dynamic. Second form of Hamilton's principle. Hamilton-Jacobi method of integration of canonic equations. Lagrange principle.

Practical teaching

Analytic system dynamics. Free and constrained material systems. Constraints and their classification. Number of degrees of freedom. Virtual work of forces. Ideal constraints.

Lagrange's equations of the first kind.
Lagrange's mechanics and differential approaches. Elements of tensor calculus in analytical mechanics.Kinetic energy. Generalized forces. Virtual work principle. Lagrange-D'Alembert's principle. Lagrange function. Lagrange's equations of the second kind for holonomic mechanical systems and their structure. First integrals. Lagrange's equations of the second kind for nonholonomic mechanical systems.
Hamiltonian mechanics. Hamilton's variables. Hamilton's function and its structure. Hamilton's canonic equations for conservative and nonconservative holonomic mechanical systems. Direct method for finding first integrals of Hamilton's canonic equations. Whittaker's equations. Routh's equations.
Variational principles. Elements of variational calculus in mechanics. Hamilton-Jacobi method of integration of canonic equations.

Prerequisites

Defined by curriculum.

Learning resources

[1] Leko M., Plavšić M., Solved problems from tensor calculus with application in mechanic, Scientific book, Belgrade,1973.
[2] Fempl S., Elements of variational calculus, Building book, Belgrade, 1965.
[3] Lurje A.I., Analytical mechanics, State publishing house, F.M.literature, Moscow, 1961.
[4] Jeremić, O., Written lectures in Analytical mechanics, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, 2020.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	40

calculation tasks	0

Requirements to take the exam (number of points) 0

References

Simić S.; Analytical Mechanics, Faculty of Technical Sciences, University of Novi Sad, Novi Sad, 2006.
Vuković J.; Selected topics in Mechanics, Written lectures for PhD studies, Faculty of Mechanical Engineering, University of Belgrade, , Belgrade, 2004.
Gantmaher F. R., Analytical Mechanics, Institute for textbooks, Belgrade, 1963.
Jeremić O.; Written lectures in Analytical mechanics, Faculty of Mechanical Engineering, University of Belgrade, Belgrade, 2020.
Radovanović V.; Theoretical mechanics, Lagrangian and Hamiltonian mechanics , Physical faculty, University of Belgrade, Belgrade, 2020.

Biomechanics of tissue and organs

ID: 0559
Responsible/Holder professor MIHAILO P. LAZAREVIĆ
Teaching profesor(s): LAZAREVIĆ MIHAILO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: oral
Parent department: mechanics

Goals

To introduce students to the application of fundamental principles and laws of biomechanics of tissues and organs in order to understand and study them. Establishment of appropriate biomechanical model of tissue and organs using modern theory of viscoelasticity, the possibility of simulations based on them in order to confirm the experimental data, the possibility of applying for the purposes of design and design basis of the same. It allows the potential cooperation with experts in medicine or work in specialized clinical institutions.

Learning outcomes

•Applying basic principles and laws linear theory of elasticity (LTE), the basics of continuum mechanics to understand and study the biomechanical properties and characteristics of human tissues and organs (HTO)
• Identify the most important rheological properties of considered HTO
• Distinguish between (Kelvin-Voigt, Maxwell model, Standard linear solid (SLS) model) on the basis of the linear theory of viscoelasticity (LTV)
• Forming the appropriate rheological models HTO applying LTE in time and frequency domain
• Numerical simulate the previously formed rheological models using programming environment (MATLAB, etc.).
• Identify the properties and characteristics of non-linear and plastic behavior considered HTO

Theoretical teaching

Introduction to the biomechanics of tissues /organs. Introduction to continuum mechanics, transport phenomena, the basics of biofluids. Basic assumptions of linear theory of elasticity (LTE). Modeling based on the theory LTE. Biomechanical properties of blood vessels: the arterial system, venous sistem. Vascular anatomy, ventricular geometry and hemodynamics. Dynamics of biomechanical heart model. Biomechanics of the lungs. Biomechanics of the nervous and lymphatic tissue.
The dynamic behavior of biological tissues / organs: the relaxation of stress, creep, hysteresis. Introduction to the theory of viscoelasticity (TV):
Kelvin-Voigt and Maxwell model. Basic assumptions of the theory of nonlinear elasticity - the finite elastic deformation. Nonlinear dynamic behavior of tissues / organs. Elements of cell rheology. Tolerance of tissue / organ to impact loads.
Injury of the organ / tissue - the biomechanical modeling them. Biomechanical engineering to prevent tissue trauma. Biomechanical aspects of the growth of tissues / organs.

Engineering tissues and organs. History and perspectives of future development of artificial tissue/organ

Practical teaching

Introductory examples of tensor analysis. Biomechanical properties of hard tissues such as tooth-and bone man. Biomechanical properties of soft connective tissues-such as muscle, the muscle fibers. Biological-tissue modeling using LTE. Examples: elastin, collagen, cartilage-props. Modeling the behavior of biological tissue using LTVE: for example lung tissue, blood vessels. Biomechanical models of the respiratory, nervous and lymphatic systems. Structure and function of pulmonary parenhina. Examples of dynamic behavior of biological tissues / organs: the stress relaxation, creep, hysteresis. The case of the dynamic behavior of the diaphragm. An illustrative example of the final elastic deformation. Examples povrde organs / tissues: head and spinal cord-biomechanical models of the same. Tolerance of organs / tissues to impact operećenja. The growth of tissues and organs - such as bones. Examples of artificial models of tissues /organs (body parts).

Prerequisites

desirable courses: Fundamentals of biomedical engineering, Human anatomy and physiology, Biomechanics of the human locomotor system

Learning resources

[1]Y. C.Fung,Biomechanics:Mechanical Properties of Living Tissues, Springer Science & Business Media, 2013.
[2]Писани изводи са предавања (handouts),
[3]М.Лазаревић, Биомеханика ткива и органа,(скрипта у припреми),2022
[4]Joseph D.Bronzino,«Tissue Engineering and Artificial Organs (The Biomedical Engineering Handbook),CRC Press,2006.
[5]D.Schneck,J.Bronzino,Biomechanics principles and applications,CRC Press, New York,2003.
[6]National Instruments-LABVIEW,(ЦСП)
[7]WWWinternetlaboratorije,MATLAB,

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	8
elaboration and examples (revision)	10
active teaching (practical)	**18**
auditory exercises	6
laboratory exercises	3
calculation tasks	5
seminar works	0
project design	4
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	1
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	1
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	45	project design	15
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

S. Cowin, S. B.Doty,Tissue Mechanics, Springer Science+Business Media, LLC,2007
Ed. Joseph D. Bronzino,The Biomedical Engineering HandBook, Second Edition. Boca Raton: CRC Press LLC, 2000
M,Lai,D.Rubin,E.Crempl, Introduction to Continuum Mechanics,2010, Elsevier
H.A. Barnes,J.E Hutton,K. Walters F. R. S, An Introduction to rheologyI,Elsevier Amsterdam ,1993
C. Oomens, M. Brekelmans, F. Baaijens,Biomechanics: Concepts and Computation,Cambridge University Press,,2009

Continuum Mechanics

ID: 1315
Responsible/Holder professor NEMANJA D. ZORIĆ
Teaching profesor(s): ZORIĆ NEMANJA; TOMOVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: seminar works
Parent department: mechanics

Goals

To introduce students continuum mechanics as applied form of classical mechanics. Aim of this subject is to students overcome and understand terms of continuum mechanics, i.e., to familiarize basic principles Euler's and Lagrange's approach to continuum, as well as basic of tensor calculus.

Learning outcomes

Upon successful completion of this course, students should be able to:
• form Green (Lagrangian) strain tensor;
• form Eulerian strain tensor;
• form velocity strain tensor;
• determine the stress tensor components;
• compose general equation of motion (Navia) of any deformable medium;
• form continuity equation (conservation of mass);
• apply the theorem of the change in total energy of a continuous medium in integral form.

Theoretical teaching

Continuum hypothesis. Lagrange's and Euler's approach to continuum. Material derivative. Surface and volume forces. Stress tensor. Symmetry of stress tensor. Cauchy's principle. Major stress and directions of major stress. Extreme values of main stresses. Mohr's circle. Deformation gradient. Deformation tensor. Displacement vector. Infinitesimal deformation and rotation. Deformation energy. Hooke's law. Characteristic of fluids. Divergence and rotor of velocity vector. First Helmholtz's theorem. Velocity of deformation. Acceleration – Kelvin's theorem. Vortex and nonvortex circulations. Law of conservation of mass – continuity equation. Sources and abysses. Euler's equation. Laws of change of momentum and angular momentum. Inner forces. Stress assumptions. Navier-Stokes equations. Constitutive equations.

Practical teaching

Application of tensor algebra and analysis. Determination of stress components. Deformations in Lagrange and Euler sense. Calculation of major deformations. Stress and displacement tensor. Continuity equation. Navier-Stokes equations. Constitutive equations.

Prerequisites

Defined by curriculum.

Learning resources

Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Zorić N., Tomović A., Mehanika kontinuuma za inženjere, Univerzitet u Beogradu, Mašinski fakultet, Beograd 2022.
Reddy, J.N., An Introduction to Continuum Mechanics, Second Edition, Cambridge University Press, 2013.

Mechanics M

ID: 0004
Responsible/Holder professor ZORAN S. MITROVIĆ
Teaching profesor(s): MITROVIĆ ZORAN; OBRADOVIĆ ALEKSANDAR; LAZAREVIĆ MIHAILO; JEREMIĆ OLIVERA; TRIŠOVIĆ NATAŠA; ZORIĆ NEMANJA; RADULOVIĆ RADOSLAV; MANDIĆ PETAR; TOMOVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: mechanics

Goals

The aim of this course is that students learn the elements of the dynamics of the oscillatory motion of a particle, the dynamics of variable mass particle, advanced problems in kinematics of a particle, kinematics of a complex motion of a rigid body and mechanical system of rigid bodies as well as the dynamics of spherical and general rigid body motion, the approximate theory of gyroscope and the impact theory.

Learning outcomes

Upon successful completion of this course, students should be able to:
• Solve problems related to all kinds of rectilinear oscillations of a particle and material systems with one degree of freedom.
• Analyze the motion of variable mass particle.
• Create expressions for velocity and acceleration of a particle in curvilinear coordinates.
• Describe the general motion of a rigid body and carry out the synthesis of translational and rotational motion.
• Distinguish analytical cases of spherical rigid body motion described by Euler dynamic equations and cases of approximate theory of gyroscopic phenomena using Rezal theorem.
• Solve problems related to the impact (collision) of a particle and rigid body.

Theoretical teaching

Rectilinear oscillation (vibration) of a particle. Free and forced, damped and undamped oscillations of a particle. Decrement of oscillations. Tremors. Resonance. Dynamic amplification. Resonant diagrams. Dynamics of a variable mass particle. Kinematics of a particle in curvilinear coordinates. Kinematics of the general motion of a rigid body. Kinematics of the complex motion of a rigid body. Synthesis of motions of a rigid body. Introduction to the kinematics of rigid body systems. Dynamics of spherical and general body motion. Approximate theory of gyroscope. Gyroscopic torque. The basic impact theory. The impact coefficient. Theorems about the changes of linear and angular momentum during the impact.

Practical teaching

Rectilinear oscillation (vibration) of a particle. Free and forced, damped and undamped oscillations of a particle. Decrement of oscillations. Tremors. Resonance. Dynamic amplification. Resonant diagrams. Dynamics of a variable mass particle. Kinematics of a

particle in curvilinear coordinates. Kinematics of the general motion of a rigid body. Kinematics of the complex motion of a rigid body. Synthesis of motions of a rigid body. Introduction to the kinematics of rigid body systems. Dynamics of spherical and general body motion. Approximate theory of gyroscope. Gyroscopic torque. The basic impact theory. The impact coefficient. Theorems about the changes of linear and angular momentum during the impact.

Prerequisites

Defined by the curriculum study of graduate studies program.

Learning resources

Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	10
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Pavišić, M., Golubović, Z., Mitrović., Z., Mechanics, Dynamics of System, MF Belgrade, 2011.
Mladenović, N., Trišović, N., Dynamics, Faculty of Mechanical Engineering, Belgrade, 2015.
Djuric, S., Dynamics and theory of oscillations, MF Belgrade, 1987.
Rusov, L., Dynamics, Naučna knjiga, 1988.
Vuković, J., Simonović, M., Obradović, A., Marković, S., Collections of examples for Dynamics, Faculty of Mechanical Engineering, Belgrade, 2007.

Mechanics of robots

ID: 0007
Responsible/Holder professor MIHAILO P. LAZAREVIĆ
Teaching profesor(s): LAZAREVIĆ MIHAILO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: mechanics

Goals

Introduce students to basic concepts of kinematics and dynamics of robotic systems. It is possible to solve direct and inverse kinematics and dynamics of the robot system (RS) using modern theory based on Rodriguez transformation matrix as well as the theory of finite rotations. Determination (simulation) models of RS - i.e. differential equations of motion of the RS, which are important in practical problems of the RS.Practical simulations RS using Cyberbotics Webots software package and students work with laboratory robot NEUROARM.

Learning outcomes

•Determine the number of degrees of freedom of robotic system (RS)
•Define the matrix of transformation, in the case of (Euler angles, Rezal angles, Hamilton-Rodrigues parameters, ...)
• Forming expressions to determine the basic kinematic characteristics RS using Rodrigues approach: characteristic position vectors of RS, speed and acceleration of the center of inertia of the robot segments (RSE), angular velocity and angular acceleration RSE, speed and acceleration of the robotic gripper
• Forming a kinematic model RS and solve direct and inverse kinematics task of RS
• Analyze singular cases in solving the task of kinematics RS
• Formed terms of linear momentum, angular momentum and kinetic energy of arbitrary segment RS
• Determine the kinetic energy of the whole RS, the basic metric tensor RS, the corresponding generalized forces, Christoffel symbols of the first kind for given RS
• Forming the differential equations of motion using the RS covariant form of Lagrange equations of the second kind and solve other types of direct and inverse task of dynamics
• Numerical simulate the previously formed kinematic / dynamic models using programming environment (MATLAB, Mathematica, etc.)
• Forming the differential equations of motion RS for the case of RS: which is given in the form of a kinematic chain with branching , RS given in the form of a closed kinematic chain.
• Set additional constraint equations in the case of constrained robotic gripper movements
• Distinguish non-redundant and redundant RS and determine the degree of redundancy RS
• Distinguish the basic concepts of control of RS

Theoretical teaching

Basic concepts, definition of robot system (RS). Orthogonal transformation of coordinates.Rodriguez formula and the transformation matrix (MT), arbitrary and reference configuration of RS.Complex MT of coordinates. Position vectors that define the

configuration of the RS, internal and external coordinates of RS. Velocity and acceleration of the center of inertia of an arbitrary robot segment(RSE). Angular velocity and angular acceleration of an arbitrary RSE. Velocity of gripper tip of RS. Direct and inverse kinematics of robot task-as well as singular cases. Constraints of RS. Momentum, angular momentum, kinetic energy of arbitrary robot segment of RS. Kinetic energy and the metric tensor of RS. Generalized forces and the principle of ideality RS-different cases. Differential equations (DIFE)of motion of RS. (DIFE) of motion of the RS in covariant form. Other methods of forming (DIFE) of motion of RS. DIFE of motion of RS given in the form of kinematic chain with the structure of topological three; DIFE of motion of RS given in the form of closed-kinematic chain. Additional equations of contraints. Constrained motion of robotic gripper. Equations of motion of RS with Langrange multipliers. Redundant RS. Basic concepts of control RS.

Practical teaching

Examples of determining the number of degrees of motion of the RS; Calculation the transformation matrix(MT)- in case of Euler angles, and Hamilton-Rodriguez parameters; Determination of kinematic characteristics of the robot segment (RSE): angular velocity and angular acceleration RSE, velocity and acceleration of the observed point-RSE cases of Rezales and Euler angles.Application of Rodriguez transformation matrix, determine position vectors which define the configuration of the RS-in MATLAB environment. Kinematic characteristics of the i-th robot segment. Solving the direct and inverse kinematic task of RS. Determination of (planar) inertia tensor RSE, RS. Obtaining momentum and angular momentum, kinetic energy, the coefficient of the metric tensor RS, generalized forces, Christoffel symbols of the first kind. Solving the direct and inverse dynamics task of the RS. Examples of DIFE of RS simulation in MATLAB-GUI, MATHEMATICA environment, an example of a redundant RS. An example of simulation RS using Cyberbotics Webots package. Example of control of the RS-laboratory robot NeuroArm with 7 degrees of freedom in the MATLAB environment.

Prerequisites

desirable courses: Mechanics 1, Mechanics 2 Mechanics 3,

Learning resources

1.Čović M. V. Lazarević, Mechanics of Robot, MF Belgrade,2021.(Book)
2.Lazarević M. Exercises in mechanics of robot, MF Belgrade,2006.(ZZD)
3.Wittenburg J., Dynamics of Systems of Rigid Bodies, Teubner, Stuttgart, 1977. (XJ)
4.Craig J., Introduction to Robotics, Mechanics and Control, Pearson, 2017.
5.Written abstracts from the lectures (Handouts)
6.Cyberbotics Webots - software package
7.NeuroArm-laboratory robot with 7 degrees of freedom.
8.MATLAB,MATHEMATICA-mathematics software packages

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	**OTHER**

active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	6
calculation tasks	5
seminar works	0
project design	9
discussion and workshop	0
research	**0**

knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0
test/colloquium	40
laboratory exercises	0
calculation tasks	0

seminar works	0
project design	20
final exam	40

Requirements to take the exam (number of points) 30

References

Bruno Siciliano, Oussama Khatib, Springer Handbook of Robotics,Springer-Verlag Berlin Heidelberg 2008.
Thomas R. Kurfess.,Robotics and automation handbook,CRC Press LLC, Boca Raton, Florida,2005
Ahmed A. Shabana, Dynamics of Multibody Systems,Cambridge University Press The Edinburgh Building, Cambridge , UK,2020
M.W. Spong, M. Vidyasagar: Robot Dynamics and Control (Wiley, New York 1991)
R. Paul: Robot Manipulators: Mathematics, Programming and Control (MIT Press, Cambridge 1982)

Mechatronic robotics

ID: 0827
Responsible/Holder professor MIHAILO P. LAZAREVIĆ
Teaching profesor(s): LAZAREVIĆ MIHAILO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: mechanics

Goals

Introduce students to basic concepts of kinematics and dynamics of robotic systems. It is possible to solve direct and inverse kinematics and dynamics of the robot system (RS) using modern theory based on Rodriguez transformation matrix as well as the theory of finite rotations and quaternions. Determination (simulation) models of RS - i.e. differential equations of motion of the RS, which are important in practical problems of the RS.Practical simulations RS using Cyberbotics Webots software package and students work with laboratory robot NEUROARM. Introduce students to the basic control principles of the RS with regard to typical methods and control algorithms of RS.

Learning outcomes

• Determine the type of kinematic chain and the number of degrees of freedom of given robotic system (RS)
•Identify and calculate the matrix of transformation, using the orthogonal coordinate transformation and Rodrigo transformation matrix, the theory of finite rotation and quaternions in the case of (Euler angles, Rezal angles, Hamilton-Rodrigues parameters, ...)
• Determine the analytical form basic kinematic characteristics of the RS with a large number of degrees of freedom using Rodrigues approach: characteristic position vectors of RS, speed and acceleration of the center of inertia of the robot segments (RSE), angular velocity and angular acceleration RSE, speed and acceleration of the robot gripper RS at the same time using computer tools (MATLAB, etc.)
• Forming a kinematic model RS with a large number of degrees of freedom in a matrix form and solve direct and inverse kinematics task of RS
• Determine the analytical form of generalized forces which acting on RS
• Forming the differential equations of motion for different cases of RS of topological structure applying Lagrange equations of second kind, the general laws of mechanics, D'Alembert's principle, Langrange-D'Alembert's principle, Žurden principle and the Gauss' principle
• Numerical simulate the previously formed differential equations of motion RS using suitable programming environment (MATLAB, Mathematica, etc.)
• Forming an appropriate RS model in a graphical environment -Cyberbotics Webots with simultaneous simulation of the same
• Compare the existing concepts of control mechanical systems and choose the appropriate concept of control for the considered RS.

Theoretical teaching

Basic concepts, definition of robot system (RS). Orthogonal transformation of coordinates.Rodriguez formula and the transformation matrix (MT), arbitrary and reference configuration of RS.Complex MT of coordinates. Position vectors that define the configuration of the RS, internal and external coordinates of RS. Velocity and acceleration of the center of inertia of an arbitrary robot segment(RSE). Angular velocity and angular acceleration of an arbitrary RSE. Velocity of gripper tip of RS. Direct and inverse kinematics of robot task-as well as singular cases. Constraints of RS. Momentum, angular momentum, kinetic energy of arbitrary robot segment of RS. Kinetic energy and the metric tensor of RS. Generalized forces and the principle of ideality RS-different cases. Differential equations (DIFE)of motion of RS. (DIFE) of motion of the RS in covariant form. Other methods of forming (DIFE) of motion of RS. DIFE of motion of RS given in the form of kinematic chain with the structure of topological three; DIFE of motion of RS given in the form of closed-kinematic chain. Additional equations of contraints. Constrained motion of robotic gripper. Equations of motion of RS with Langrange multipliers. Redundant RS. Basic concepts of control RS.

Practical teaching

Examples of determining the number of degrees of motion of the RS; Calculation the transformation matrix(MT)- in case of Euler angles, and Hamilton-Rodriguez parameters; Determination of kinematic characteristics of the robot segment (RSE): angular velocity and angular acceleration RSE, velocity and acceleration of the observed point-RSE cases of Rezales and Euler angles.Application of Rodriguez transformation matrix, determine position vectors which define the configuration of the RS-in MATLAB environment. Kinematic characteristics of the i-th robot segment. Solving the direct and inverse kinematic task of RS. Determination of (planar) inertia tensor RSE, RS. Obtaining momentum and angular momentum, kinetic energy, the coefficient of the metric tensor RS, generalized forces, Christoffel symbols of the first kind. Solving the direct and inverse dynamics task of the RS. Examples of DIFE of RS simulation in MATLAB-GUI, MATHEMATICA environment, an example of a redundant RS. An example of simulation RS using Cyberbotics Webots package. Simulation examples of RS control using typical methods of control. One example of the control application on the existing laboratory NeuroArm robot with 7 degrees of freedom in the MATLAB environment.

Prerequisites

desirable courses: Mechanics 1, Mechanics 2 Mechanics 3,

Learning resources

1.Čović M. V. Lazarević, Mechanics of Robot, MF Belgrade,2021.(Book)
2.Lazarević M. Exercises in mechanics of robot, MF Belgrade,2006.(ZZD)
3.Wittenburg J., Dynamics of Systems of Rigid Bodies, Teubner, Stuttgart, 1977. (XJ)
4.Craig J., Introduction to Robotics, Mechanics and Control, Addison-Wesley, 2017.
5.Written abstracts from the lectures,(Handouts)
6.Cyberbotics Webots - software package
7.NeuroArm-laboratory robot with 7 degrees of freedom.
8.MATLAB,MATHEMATICA-mathematics software packages

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	6
calculation tasks	8
seminar works	0
project design	6
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	45	project design	15
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Bruno Siciliano, Oussama Khatib, Springer Handbook of Robotics,Springer-Verlag Berlin Heidelberg 2008.
Thomas R. Kurfess.,Robotics and automation handbook,CRC Press LLC, Boca Raton, Florida,2005
Ahmed A. Shabana, Dynamics of Multibody Systems,Cambridge University Press The Edinburgh Building, Cambridge , UK,2020
M.W. Spong, M. Vidyasagar: Robot Dynamics and Control (Wiley, New York 1991)
Bruno Siciliano,Lorenzo Sciavicco Luigi Villani, Giuseppe Oriolo, Robotics: Modelling, Planning and Control,2009 Springer-Verlag London

Skill Praxis M - MEH

ID: 1202
Responsible/Holder professor ZORAN S. MITROVIĆ
Teaching profesor(s): MITROVIĆ ZORAN; OBRADOVIĆ ALEKSANDAR; LAZAREVIĆ MIHAILO; JEREMIĆ OLIVERA; TRIŠOVIĆ NATAŠA; ZORIĆ NEMANJA; RADULOVIĆ RADOSLAV; MANDIĆ PETAR; TOMOVIĆ ALEKSANDAR; MILOŠEVIĆ-MITIĆ VESNA; STEVANOVIĆ NEVENA; LEČIĆ MILAN; MILIĆEV SNEŽANA; ĆOĆIĆ ALEKSANDAR; SIM
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: oral
Parent department: mechanics

Goals

Practical experience and time spent in an environment where the student realizes his professional career. Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineers in such a business system.

Learning outcomes

Student takes practical experience on the organization and functioning of the environment in which student will apply this knowledge in their future professional career. Student recognizes patterns of communication with colleagues and business information flows. Student identifies the core processes in the design, manufacture, maintenance, in the context of his future professional competence. Personal contact and acquaintance are established, which can be used during training, or future employment.

Theoretical teaching

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Practical teaching

Practical work involves working in organizations which perform a variety of activities related to mechanical engineering. The choice of thematic units and commercial or research organizations is carried out in consultation with the course teacher. Generally, a student may perform in practice: production companies, design and consulting organizations, organizations involved in the maintenance of mechanical equipment, public utility companies and some of the labs at the Faculty of Mechanical Engineering. The practice can also be performed abroad. During practice, students must keep a journal to enter a description of the work performed, the conclusions and observations. After carrying out the practice student must make a report to explain in details mentioned activities to course professor. The report is to be submitted in the form of the paper.

Prerequisites

No

Learning resources

Resources available on the site of professional practice.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	80

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	70
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

M. Milos: Mechanical Engineering Praxis, PDF book, Faculty of Mechanical Engineering, 2016.

Theory of Mechanical Vibrations

ID: 0037
Responsible/Holder professor ALEKSANDAR M. OBRADOVIĆ
Teaching profesor(s): OBRADOVIĆ ALEKSANDAR; MITROVIĆ ZORAN; JEREMIĆ OLIVERA; TRIŠOVIĆ NATAŠA; ZORIĆ NEMANJA; RADULOVIĆ RADOSLAV; MANDIĆ PETAR; TOMOVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: mechanics

Goals

It is necessary to enable the students to independently form and solve linear differential equations of motion of mechanical models of real objects oscillatory moving in different areas of mechanical engineering.

Learning outcomes

Upon successful completion of this course, students will be able to:

•Determine equilibrium position of conservative mechanical system with finite number of degrees of freedom.
•Form differential equations of motions of small mechanical vibrations of a mechanical system about the equilibrium position in matrix form (determine generalized mass, stiffness and damping matrices, as well as vector of generalized forces transformed on Fourier series).
•Analyze free and forced, as well as damped and undamped linear mechanical vibrations, in a clear observation of phenomena in linear mechanical vibration as well as resonance, beating and the dynamic absorber).
•Calculate (analytical and numerical) quantities which characterize vibration processes: natural frequencies, amplitudes, phase angles, logarithmic decrements and modal matrix.
•Determine equations of motion in analytical form using software (Matlab...) for systems with large number of degrees of freedom.
•Describe free undamped mechanical vibrations of elastic bodies with 1-D mass distribution with appropriate partial differential equations, for cases of longitudinal, torsion and lateral vibrations.

•Numerically solve characteristic equation for various cases of boundary conditions and determine angular frequencies. Determine analytical solutions of appropriate partial differential equations in simpler cases initial and boundary conditions.

Theoretical teaching

Stability of equilibrium of the conservative system. Silvester's criteria. Linearization of the differential equations of motion. Vibration of the conservative system. Frequencies. The main mode shapes of vibration. Modal matrix. Conservative systems with special values of natural frequencies (eigenvalues). Vibration of the body on the beam supports. Damped vibration. Forced undamped vibration. Forced vibration. Resonance. Beating. Dynamic amplification

factor. The dynamic absorber without damping. Linear oscillations of non-stationary system. Forced damped vibration of the system. Lateral vibration of string. Longitudinal vibration of prismatic bodies. Torsional vibration of the shaft with circular cross section. Lateral vibration of prismatic bodies.

Practical teaching

Stability of equilibrium of the conservative system. Silvester's criteria. Linearization of the differential equations of motion. Vibration of the conservative system. Frequencies. The main mode shapes of vibration. Modal matrix. Conservative systems with special values of natural frequencies (eigenvalues). Vibration of the body on the beam supports. Damped vibration. Forced undamped vibration. Forced vibration. Resonance. Beating. Dynamic amplification factor. The dynamic absorber without damping. Linear oscillations of non-stationary system. Forced damped vibration of the system. Lateral vibration of string. Longitudinal vibration of prismatic bodies. Torsional vibration of the shaft with circular cross section. Lateral vibration of prismatic bodies.

Prerequisites

None

Learning resources

Vuković, J., Obradović,A., Linear vibrations of mechanical systems, Mašinski fakultet, Beograd, 2021.,

handouts

Ružić D., Čukić R., Dunjić M., Milovančević M., Anđelić N., Milošević-Mitić V.: Strength of Materials,Book 5, Tables, Mašinski Fakultet, Beograd 2007.

Lazić D., Ristanović M.: Introduction to MATLAB , Mašinski fakultet, Beograd 2005.

MATLAB software

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	24
laboratory exercises	6
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	5

research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	45	project design	0
laboratory exercises	15	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Rao S.S.: Mechanical vibrations, Addison-Wesley Publishing Company Inc., 1995.
Vujanović B.: Theory of vibrations, Fakultet tehničkih nauka, Novi Sad 1995.
Kojić M., Mićunović M.: Theory of vibrations, Naučna knjiga, Beograd 1991.
Vujičić V.: Theory of vibrations, Naučna knjiga, Beograd 1977.

MOTOR VEHICLES

Automotive friction systems

Forensic Engineering

Intelligent vehicle systems

Maintenance of Machinery and Equipment

Skill Praxis M - MOV

System Effectiveness

Systems Engineering

Urban and special rail vehicles

Vehicle body structure

Vehicle design

Vehicle Maintenance

Vehicle Mechatronics

Vehicle Propulsion and Suspension Systems

Vehicle Testing

Vehicles and Environment

Automotive friction systems

ID: 0872
Responsible/Holder professor DRAGAN S. ALEKSENDRIĆ
Teaching profesor(s): ALEKSENDRIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

Course objective is to provide an understanding and develop students' skills and knowledge in the area of design, development, and maintenance process of the friction based vehicle systems such as clutch, braking systems, and friction materials.

Learning outcomes

Course outcomes are development of student's abilities to: a) understand requirements being imposed to automotive vehicle systems, b) be able to design, calculate and testing of the motor vehicles braking systems, c) be able to design, calculate and testing of the vehicle main clutches, d) be able to understand and design the automotive brakes and clutches friction material characteristics, e) be able to maintain the friction based vehicle systems.

Theoretical teaching

Theoretical lectures are divided into 7 sections:
1)Introduction – Friction based vehicle systems.
2)Clutch – design, calculation and testing.
3)Braking systems- Introduction
4)Characteristics of vehicle braking systems
5)Design and calculation of vehicle braking systems
6)Characteristics of clucth and brake friction materials.
7)Maintenance of clutch and braking systems- Introduction.

Practical teaching

Students carry an engineering project. Project is related to the following tasks:
1)Calculation of the main friction clutch.
2)Calculation of a passenger car braking system.
3)Calculation of a braking system with the pneumatic transmission.
4)Calculation of a braking system with the air over hydraulic transmission.
5)Calculation of trailer/semi-trailer braking system.

Prerequisites

There is no precondition.

Learning resources

1. D. Aleksendrić, Hand-outs, 2022.
2. D. Aleksendrić, Intelligent braking, Faculty of Mechanical Engineering University of

Belgrade (in press), 2022.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	15
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

Savaresi S., Taneli M. Active Braking Control Systems Design for Vehicles, Springer 2010.
Aleksendric D., Carlone P. Soft Computing in the design and manufacturing of composite materials, Elsevier-Woodhead Publishing, 2015.
J. Todorović, Braking of motor vehicles, Faculty of Mechanical Engineering, 1989.

Forensic Engineering

ID: 0876
Responsible/Holder professor VLADIMIR M. POPOVIĆ
Teaching profesor(s): POPOVIĆ VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

Student is enabled to apply forensic engineering methods, particularly in the area of motor vehicles, which comprises analyses and reconstruction of road accidents. Analogous methods will be applied in other fields of mechanical engineering, depending on the interest of students.

Learning outcomes

Upon successful completion of this course, students should be able to:
- explain the concept of forensics and forensic engineering, with respect to vehicles;
- define and analyze technical system failures, their causes and effects, with a special emphasis on the application in automotive field;
- identify and analyze the causes of traffic accidents in which vehicles participated, with elements of investigation and reconstruction;
- analyze adequate technical solutions and conditions under which accidents might be avoided.

Theoretical teaching

Organized in blocks:
- General knowledge of forensics and forensic engineering, i.e. technical systems failure analyses, their causes and consequences, with a particular emphasis on the area of automotive engineering
- Vehicle and component failures, i.e. accidents causing vehicle damage
- Analyses of road vehicle accident causes and consequences, with the elements of accident site investigation and evidence collection, including accident reconstruction

Practical teaching

Conducted through work on seminar assignment within which each student will individually resolve the subject relevant cases on the basis of case study methodologies. Student will use real data on vehicle (or other technical system of interest) accidents, and they will study the causes and the consequences of such an accident - in particular they will analyze why the accident happened and what could be done to prevent it.

Prerequisites

No special requirements.

Learning resources

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NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	20
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	10
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 60

References

Handouts in digital form, 2023.
R.K. Noon, Forensic Engineering Investigation, CRC Press, Boca Raton, 2001.
M. Huang, Vehicle Crash Mechanics, CRC Press, Boca Raton, 2002.
D.E. Struble, Automotive Accident Reconstruction - Practices and Principles, CRC Press, Boca Raton, 2014.

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Intelligent vehicle systems

ID: 0713
Responsible/Holder professor DRAGAN S. ALEKSENDRIĆ
Teaching profesor(s): ALEKSENDRIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

The goal of intelligent vehicles and accordingly intelligent vehicle systems is to augment vehicle autonomous driving either entirely or partly for the purposes of safety, comfortability, and saving energy. The tasks of intelligent vehicles become more challenging due to dynamic change of complex environment perception and necessity for sensing, modeling and prediction of different influencing factors on the vehicle performance. Autonomous intelligent vehicles have to perceiving and modeling environment in order to control the vehicles. The vehicle motion control faces the challenges of strong nonlinear characteristics due to high mass, especially in the processes of high speed and sudden steering/braking. It needs processing, modelling and prediction non-linear chnages in the vehicles system operation based on large amounts of data from multi-sensors and complex dynamic changes in an environment. Course objective is to provide an understanding the design and development process of intelligent vehicle systems and to develop students' skills and knowledge in the area of intelligent vehicle systems development.

Learning outcomes

Course outcomes are development of student's abilities to: a) understand requirements being imposed to intelligent vehicle and its systems, assemblies, sub – assemblies, and parts, b) analyze the vehicle system operation and understand influences of the new intelligent solutions in the vehicle systems design on the vehicle overall performance and quality of use c) application of artificial intelligence techniques in development of intelligent solutions of the vehicle systems, d) analyze, understand and reconcile the new intelligent solutions in the vehicle system operation with legislation related to the specific vehicle systems and sub systems.

Theoretical teaching

Theoretical lectures are divided into 7 sections:
1)Introduction – Intelligent vehicles and intelligent transport.
2)Monitoring and modeling of tire –road interaction.
3)Intelligent vehicle longitudinal control.
4)Intelligent vehicle lateral control.
5)Intelligent vehicle vertical control.
6)Intelligent vehicle vision systems.
7)Integrated intelligent control.

Practical teaching

Students carry out a group-engineering project. Project is related to introduction of intelligent solutions in the given vehicle system operation. Students have to:
1)critical analyze the design solutions of the given vehicle system.
2)identify possibilities for introduction of the system intelligent abilities.
3)model and predict the system performance based on artificial intelligence techniques
4)test the system intelligent solutions.
5)compare conventional and introduced intelligent system performance.

Prerequisites

There is no precondition.

Learning resources

Aleksendrić D. Intelligent vehicle systems, (hand-out), 2022.
Aleksendrić D. Intelligent braking (book in press). 2022.
Aleksendrić D. Miljkovic Z. Artificial neural networks-solved examples with theoretical background, Faculty of Mechanical Engineering University of Belgrade, 2009.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

H. Chneg: Autonomous intelligent vehicles - Theory, Algorithms, and Implementation , Springer 2011.

L. Li, F.-Y. Wang: Advanced Motion control and Sensing for Intelligent vehicles , Springer 2007.
R. Bishop: Intelligent vehicle technology and trends, © 2005 ARTECH HOUSE, INC.

Maintenance of Machinery and Equipment

ID: 1141
Responsible/Holder professor BRANKO M. VASIĆ
Teaching profesor(s): VASIĆ BRANKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: motor vehicles

Goals

Managing Machine and Equipment Maintenance as part of Asset Management (Asset Management) is a systematic process of planning, maintaining and operating viable physical assets during their useful (economic) lifetime, in order to achieve current and future optimal benefits for all stakeholders in the community.

The effective management of assets is becoming increasingly important to organizations and their interested parties. In order to share the latest thinking, processes, methods and tools in joined up management of any types of asset, this comprehensive one semester course provides techniques and methods for students to explore the organizational implications of the:
International standard for Asset Management with focus on:
- What is Asset management and why it is important to an organization
- The benefits of a management system for asset management
- The key terms, concepts and principles of ISO 55001:2014
- The main requirements of ISO 55001:2014
- Maintenance KPI Key Performance Indicators

Then, with the system of the indicators with focus on:
- economical, technical and organisational
- Methodology for selection and use of key performance indicators for maintenance

and project management and organization of the maintenance system, through:
- An Overview of Key Project Management Concept
- Initiating the Project
- Identifying the Work
- Estimating the Work
- Scheduling the Work
- Creating the Budget

Learning outcomes

Upon this comprehensive one semester course, students will be able to:
- Recognize and be able to apply asset management terminology, definitions and principles
- Identify and manage the expectations of stakeholders with respect to asset management
- Become familiar with internationally recognized asset management methodologies and good practices

- Apply structured approaches available for the improvement of valye realization from assets
- Recognize the valye obtainable from the integrated approach to the life cycle and risk-based management of assets
- Understand what Maintenance is doing
- How maintenance should be measured
- What maintenance is achieving for the business and
- What more it can do to improve operational performance
- Ensure that projects are set-yp for success from the start
- Understand the role of the project manager, business analyst, and others in managing projects
- Develop an integrated project plan inclyding realistic scope, schedules, budgets, and risks
- Learn how to effectively track and report on project progress

Theoretical teaching

Theoretical part of the course is divided into four blocks, consisting of four thematic ynits with a total fond of 4 x 5 = 20 h, 4 h 2,5 = 10 hrs to develop the lecture and master the new material.
The basic teaching blocks include the following areas:
- Asset Management concept and requirements of international standards,
- Machinery maintenance strategies as a key asset management segment,
- Basics of project management,
- Key performance maintenance indicators

Practical teaching

The course content also includes practical lessons. The entire class is divided into four blocks - auditory classes are followed by lectures. Practical classes are realized through 15 hoyrs of exercises and 15 hoyrs of independent stydent work (compyting tasks and seminar work). A total of 15 hoyrs are foreseen for checking knowledge, oyt of which 10 for partial knowledge tests and 5 for final examination of knowledge. The four basic teachers include the following areas:
- Asset Management concept and requirements of international standards,
- Machinery maintenance strategies as a key asset management segment,
- Basics of project management,
- Key performance maintenance indicators.

Prerequisites

Defined by curriculum of module for motor vehicles.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING		**OTHER**	
active teaching (theoretical)	**30**	**knowledge checks**	**15**
lectures	20	assessment of calculation tasks	3

elaboration and examples (revision)	10	check and assessment of lab reports	0
active teaching (practical)	**30**	check and assessment of seminar works	7
auditory exercises	15	check and assessment of projects	0
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	5	test, with assessment	0
seminar works	10	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	35
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	25		

Requirements to take the exam (number of points) 40

References

1. Vasic B., Todorovic J., et al.: Maintenance of Technical Systems, Institute for Research and Design in Commerce & Industry, Belgrade, 2006. (KPN)
2. Vasic B.: Management and engineering in maintenance, Institute for research and design in commerce and industrym Belgradem 2006.
3. Vasic B., Popovic B.: Engineering management methods, Institute for research and design in commerce and industrym Belgradem 2007.
4. Vasic, M., Stanojevic, D., Todorovic M., Dimitrijevic, M., Stanojevic, N. (2016): Maintenance management according to the best European practice, Serbian Maintenance Society, ISBN 978-86-84231-44-6

Skill Praxis M - MOV

ID: 1224
Responsible/Holder professor BRANISLAV B. RAKIĆEVIĆ
Teaching profesor(s): RAKIĆEVIĆ BRANISLAV; ALEKSENDRIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: motor vehicles

Goals

Aim of praxis is to introduce procedures and processes in production of vehicles and their components to students, and also specific activities related to development and production, testing, exploitation and maintenance of vehicles and their systems.

Learning outcomes

With this praxis, students in particular conditions (vehicle production, maintenance, testing and exploitation), achieve practical view on production of elements, components and vehicle systems, as well as on problems of vehicle completion, exploitation and maintenance, according to the plan and the program of practice.

Theoretical teaching

No theoretical classes.

Practical teaching

Students autonomously choose companies to complete the praxis in. Students' activities are performed according to guidelines and instructions on how to behave and on the subjects of interests during the stay in particular company, and also on how to write the praxis diary.

Prerequisites

No special requirements.

Learning resources

Instructions for writing the praxis diary.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING		OTHER	
active teaching (theoretical)	**0**	**knowledge checks**	**90**
lectures	0	assessment of calculation tasks	0
elaboration and examples (revision)	0	check and assessment of lab reports	0
active teaching (practical)	**0**	check and assessment of seminar works	90
auditory exercises	0	check and assessment of projects	0

laboratory exercises	0	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	0
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

M. Milos: Mechanical Engineering Praxis, PDF book, Faculty of Mechanical Engineering, 2016.

System Effectiveness

ID: 0711
Responsible/Holder professor BRANKO M. VASIĆ
Teaching profesor(s): VASIĆ BRANKO; BLAGOJEVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: motor vehicles

Goals

The objectives of the course are to provide a comprehensive insight into the issues (analysis and design) of system effectiveness, primarily in the areas of reliability and availability of technical systems (vehicles).

Learning outcomes

Upon successful completion of this course, students should be able to:
- Explain the concepts of system effectiveness, reliability and failure;
- Analyze the obtained failure time data;
- Apply of the basic laws of probability and statistics to calculate the reliability;
- Obtain theoretical probability density and reliability function based on empirical data on failures of the elements;
- Determine the reliability of a complex system based on the reliability of the elements that form a complex system;
- To form fault tree of technical system and analyze it;
- To design machine elements on the basis of reliability.

Theoretical teaching

Defining the requirements for effectiveness and reliability and availability of system elements and system. The system. The basis of probability theory and statistics and its application in analysis and design of reliability. Definition of failure of the elements and system. Determination of empirical and theoretical characteristics of reliability of the elements of a system and of the systems (histogram, polygon, intensity of failure, the function of frequency, mean value, distribution laws (Weibull, normal, exponential, binomial, Poisson), tests of trust, confidence interval). Determination of reliability block diagrams of simple and complex systems (vehicles) with the application of probability theory of complex events. Fault tree analysis, the analysis of mode, effect and criticality of faults, integrated system approach. Design of vehicle elements for a given level of reliability, relations of workload and critical load, the selection of intensity of failures for specific working conditions and environment.

Practical teaching

The event-failure. Basics of probability theory and statistics. Determination of empirical and theoretical characteristics of reliability of the elements of a system and of the systems (histogram, polygon, intensity of failure, the function of frequency, mean value, distribution laws (Weibull). The compound probability. Reliability block diagram - connection of the elements in the system. Determining the function of system reliability (simple and complex).

Design of reliability. Design based on work and critical loads. Allocation of reliability. Fault tree analysis, analysis methods, effects and criticality of failures.

1. Examples.
2. Examples - Independent work.

Prerequisites

No previous preconditions.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	15
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	8
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	30		

Requirements to take the exam (number of points) 40

References

1. J. Todorovic, B. Vasic: System Effectiveness, Faculty of Mechanical Engineering, Belgrade 1991.
2. Б. Васић, Н. Станојевић: Integrated Cost-Benefit and Multi-Criteria Analyses Based on the Principles of Life Cycle Engineering, MIRCE Science Limited, UK, 2007.
3. B. Vasic, V. Popovic: Engineering management metods, Institute for research and design in comerce & industry, Belgrade, 2007.
Vasic, B. : Management and Engineering in Maintenance, IIPP, 2004.
5. G. Ivanovic, D. Stanivukovic, I. Beker: Reliability of Technical Systems, Faculty of Technical

Sciences, Novi Sad, 2010.

Systems Engineering

ID: 0451
Responsible/Holder professor BRANKO M. VASIĆ
Teaching profesor(s): VASIĆ BRANKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

Course objectives include the achievement of competencies and academic skills as well as methods for their acquisition, in the field of engineering systems. The goals arising from basic tasks and determine the specific results that should be realized within the subject and represent the basis for the control of the results achieved.

Learning outcomes

Upon successful completion of this course, students should be able to:
- Follow and evaluate functional effectiveness of different systems;
- Determine methodology for evaluation of system working during their life cycle;
- Explain term-system work quality: production and/or service;
- Apply different methods and techniques for risk and project management;
- Manage costs of life cycle systems;
- Explain demands of different series of international standards and ways of their using in different types of organizations;
- Connect engineer and manager demands in work processes of different types of organizations;
- Adopt and evaluate decisions in conditions of certainty and uncertainty which occurs during system working;

Theoretical teaching

Course content includes theoretical and practical classes. The entire course is divided into five blocks, of which the theoretical teaching consists out of four sessions with a total of 20 teaching hours per week, while the practical training part of the same four blocks are implemented with 15 hours of exercises and 15 hours of independent student work. For verification of the knowledge a total of 15 hours is provided, of which 10 for partial verification of the knowledge and 5 for the final test of knowledge. Five main teaching blocks include the following areas: (a) Introduction to systems (definitions, concepts, process), (b) The process of system design (preliminary and detailed design, development, testing and evaluation), (v) analysis of system and project evaluation (alternatives and models in decision making, models of economic evaluation, optimization techniques in the design of control), (g) designing for reliability, maintainability, usability (human factors), logistic support, and (d) management of engineering systems (program planning, organization, control).

Practical teaching

Course content includes theoretical and practical classes. The entire course is divided into five blocks - auditory exercises follow the lectures. Practical teaching is done through 15 hours of exercises and 15 hours independent student work (computational tasks and seminar work). For verification of the knowledge a total of 15 hours is provided, of which 10 for partial verification of the knowledge and 5 for the final test of knowledge. Five main teaching blocks include the following areas: (a) Introduction to systems (definitions, concepts, process), (b) The process of system design (preliminary and detailed design, development, testing and evaluation), (v) analysis of system and project evaluation (alternatives and models in decision making, models of economic evaluation, optimization techniques in the design of control), (g) designing for reliability, maintainability, usability (human factors), logistic support, and (d) management of engineering systems (program planning, organization, control).

Prerequisites

Defined by curriculum of module for motor vehicles.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**25**
lectures	15
elaboration and examples (revision)	10
active teaching (practical)	**25**
auditory exercises	15
laboratory exercises	0
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**25**
assessment of calculation tasks	3
check and assessment of lab reports	0
check and assessment of seminar works	7
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	35
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	25		

Requirements to take the exam (number of points) 40

References

1. Vasic B., Todorovic J., et al.: Maintenance of Technical Systems, Institute for Research and Design in Commerce & Industry, Belgrade, 2006. (KPN)
2. Vasic B.: Management and engineering in maintenance, Institute for research and design in commerce and industrym Belgradem 2006.
3. Vasic B., Popovic B.: Engineering management methods, Institute for research and design in commerce and industrym Belgradem 2007.

Urban and special rail vehicles

ID: 1565
Responsible/Holder professor DRAGAN D. STAMENKOVIĆ
Teaching profesor(s): STAMENKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: motor vehicles

Goals

1. Understanding the specifics of urban rail vehicles
2. Understanding the various types of special rail vehicles
3. Qualification for the application of acquired knowledge in the design, development, repair and maintenance of urban rail vehicles and special vehicles

Learning outcomes

After completion of the course, the student should be able to:
1. Explain the functional and design specificity of various types of urban rail vehicles
2. Explain the tasks and functionality of various types of special rail vehicles
3. Explain the specific technologies and technical requirements in combined transport
4. Apply appropriate regulations and standards in the design and maintenance of urban rail vehicles and special rail vehicles

Theoretical teaching

Railway multi-modal transport. Transport unit types. Wagons for combined transport of containers and swap bodies. Wagons for the transportation of semi-trailers with vertical handling. Rolling stock and systems for the transport of complete road vehicles by rail. Semitrailers on bogies. Gauges for combined transport.
Special wagons: tank-wagons, refrigerating wagons, hopper wagons, articulated multiple wagon units...- technical requirements and technical solutions.
The forms of urban and suburban public transport: tram, light rail, metro, regional trains - requirements and specifications. Specific requirements: loads, acceleration, braking, line geometry, platform heights. Low floor design. Doors, staircases, vestibules. Articulation designs. Crash worthy design. Specifics of bogie design for low floor and articulated vehicles. Tyred running gear. Automated metro system requirements. Monorails.
Vehicles on the principle of magnetic levitation: basic principles of magnetic suspension, propulsion and guidance. Systems: Transrapid, MLX, Linimo...-technical solutions.

Practical teaching

Division and classification of units for transport by multi-modal transport: pallets, containers, mobile crates. Stability when loading or unloading wagons with horizontal loading. Procedure for determining the code of semi-trailers for transport in multi-modal rail transport. Analysis of design parameters of wagons for multi-modal transport. Dimensioning of tanks according to RID regulation. Variants of valve systems for tanks for dangerous goods transport. City rail vehicles. Geometry of the basic train unit. Vehicle-platform relationship.

Examples of designs of the running assembly of city rail vehicles. Specifics of guiding through curves of a small radius. Design examples of non-conventional rail systems. Magnetic levitation vehicle design.

Prerequisites

Previously passed exam: Rail vehicles 1 or Theory of traction.

Learning resources

Simic, G., Milkovic, D., Urban and special rail vehicles (hand-out for students), Faculty of Mechanical Engineering, Belgrade, 2021.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	0
calculation tasks	6
seminar works	6
project design	0
discussion and workshop	6
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 40

References

Simic, G., Milkovic, D., Urban and special rail vehicles (hand-out for students), Faculty of Mechanical Engineering, Belgrade, 2021.

Vehicle body structure

ID: 0441
Responsible/Holder professor BRANISLAV B. RAKIĆEVIĆ
Teaching profesor(s): RAKIĆEVIĆ BRANISLAV; MITIĆ SAŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: motor vehicles

Goals

Aims of this course include achieving the competences to conquer specific knowledge and skills needed for overwiewing and understanding problems related to construction, calculation, testing and verification of support structures of different categories of vehicles.

Learning outcomes

After successful completition of this course, students should be trained to:
- Know and explain basic methods and procedures for vehicle's body behaviour identification;
- List and explain characteristic calculation regimes specificities in body calculation;
- Recognize and explain the problems of thin-walled open cross-sections;
- Identify and interpret basic postulates of UN Regulations regarding the strength of bus superstructures;
- Analyze and explain basic problems of strength related to chassis – body interaction;
- Categorize different body types regarding their torsion stiffness and propose the application of appropriate elements for connection;
- Define all aspects needed for completition of commercial vehicles, taking into account related bodybuilder instructions.

Theoretical teaching

(1) Introduction: Constructive concepts of superstructures in accordance with vehicle classification and categorization, characteristic solutions, basic instructions and recommendations; (2) Identification of superstructure behaviour, testing/calculation; methods, parameters and approval criteria; behaviour optimization, characteristic calculations modes; (3) Behaviour specificity of thin-walled open elements of SS; (4) Method of common constructive support surfaces, basic types of superstructures, ways and possibilities for implementation; (5) Finite elements method (FEM) in terms of methodological approach for identification of superstructure behaviour, basic characteristics and specificities; (6) Bus superstructures; specifities, strength of superstructures, domestic and international regulations; (7) Commercial vehicles superstructures; constructive and technological specificities of chassis of commercial vehicles, superstructures (different types, connection types for chassis and superstructure connecting, instructions and recommendations of chassis manufacturers), problems of vehicle completion (requests of valid standards and regulations, aspects of calculation, testing and verification); (8) Passenger vehicles superstructures; crash problems, values related to crashes, possibilities of modelling and experimental verification; (9) Regulations related to vehicle behaviour during crash (UN Regulations, EURO NCAP tests), characteristic parameters and criteria.

Practical teaching

(1) Review of characteristic examples of passenger vehicles superstructures; (2) Review of specificities of superstructures for different bus categories (low-floor city bus, high floor touristic bus...); (3) Review and comments on chassis examples for commercial vehicles, as well as instructions and recommendations of manufacturers for superstructure mounting; (4) Examples of implementation of analytical approach in chassis calculation (ladder-type chassis); (5) Review of problems in calculation using FEM for particularly characteristic examples; (6) Bus superstructures; valid regulations (UN Regulations), requests related to passive safety (UN Regulation No. 66, review, comments and ways for fulfilling all requirements); (7) Individual student thesis related to bus superstructures; (8) Commercial vehicles superstructures; valid regulations (UN Regulations), requests related to passive safety (UN Regulation No. 58, 73,...); (9) Review of construction of some specific superstructures, explanations for different types of connections between chassis and superstructure and their implementation in process of vehicle completing; (10) Comments for possibilites to special purpose vehicles realization and explanations for implementation of instructions and recommendations of chassis manufacturers; procedures for definning the relevant safety and technical characteristics of completed vehicles; (11) Individual student thesis related to special purpose commercial vehicles (different superstructures); (12) Passenger vehicles superstructures; regulations related to vehicle behaviour during crash (UN Regulations, EURO NCAP tests), comments related to characteristic examples.

Prerequisites

No special requirements.

Learning resources

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NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 36

References

L. Morello et al. - The Automotive Body Vol. I - Components Design, Springer, Dordrecht, 2011.
L. Morello et al. - The Automotive Body Vol. II - System Design, Springer, Dordrecht, 2011.
J.C. Brown, A.J. Robertson, S.T. Serpento - Motor Vehicle Structures - Concepts and Fundamentals, Butterworth-Heinemann, Oxford, 2002.
B. Heissing, M. Ersoy (Eds), Chassis Handbook, Vieweg+Teubner Verlag, Wiesbaden, 2011.
D.E. Malen, Fundamentals of Automobile Body Structure Design, SAE, Warrendale, 2011.

Vehicle design

ID: 1333
Responsible/Holder professor IVAN A. BLAGOJEVIĆ
Teaching profesor(s): BLAGOJEVIĆ IVAN; MITIĆ SAŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: motor vehicles

Goals

The goal of the course is to develop the logic of designing the vehicle systems and assemblies, based on the requirements and legal regulations the vehicle has to be in compliance with. Apart from that, assembling the systems into a functional unit that represents the vehicle poses a skill a student shall acquire, while respecting the weight, dimensional and ergonomic limits. Gaining the practical experience in computer aided design, as well as the analysis of different solutions, forms the integral part of the aforementioned process.

Learning outcomes

Upon successful completion of this course students should be able to: identify all the requirements that a system to be designed and later exploited shall meet; analyze the existing solutions of vehicle systems and assemblies to be used or modified for a different vehicle; deduce the load the vehicle assembly is exposed to; apply acquired logic through an independent design of an adequate system for a given project; use modern engineering tools.

Theoretical teaching

The lectures consist of three units. The first unit encompasses vehicle layout, weight and dimensions of a vehicle, as well as legal requirements regarding the vehicle layout. This unit considers the vehicle ergonomics as well. The second unit encompasses power transmission with a special attention paid to gearbox and driven axle design. The third unit encompasses suspension and steering systems, meaning the system components and the parameters that define their kinematics and load. Each unit implies the definition of: initial requirements and parameters the design is based on; adoption of the adequate concept; analysis of existing solutions, identification of adequate system or assembly elements and their positioning and dimensioning; kinematics and basic load analysis the structure is exposed to.

Practical teaching

The practical coursework consists of creating a project for each of the aforementioned units. The showpieces of systems, assemblies and vehicles aid the students in completing the coursework, as well as adequate software tools.

Prerequisites

No special requirements.

Learning resources

Computers with adequate software tools, showpieces of systems, assemblies and vehicles, as

well as their digital illustrations.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	25
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	12
colloquium, with assessment	3
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Rakicevic B.: handouts, 2023.
Mitic S.: handouts, 2023.
Blagojevic I.: Suspension and steering system design - handouts, 2023.

Vehicle Maintenance

ID: 0875
Responsible/Holder professor BRANKO M. VASIĆ
Teaching profesor(s): VASIĆ BRANKO; POPOVIĆ VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

Student acquires relevant theoretical and practical knowledge about after sales activities of a vehicle manufacturer, and in particular concerning vehicle maintenance and the ways of establishing a system of authorized service organizations taking into consideration that without application of an appropriate maintenance system there will be no normal vehicle operation nor vehicle usage.
An automotive engineer must know how to make a vehicle, but also how to use and maintain it in order to enable its mission to be fulfilled in all usage conditions.
An automotive engineer must be educated and trained to design so called "Vehicle Maintenance System" i.e. to design programs and plan of preventive, corrective and combined maintenance as well as to design vehicle service technology and facilities in which it can be applied.

Learning outcomes

Upon successful completion of this course, students should be able to:
-Explain the processes of technical maintenance of different motor vehicle types and categories;
-Do analysis of state changes of motor vehicles and identification of their causes (state changes due to the wrong using in vehicle exploitation, state changes due to the fatigue and wear, state changes due to the wrong maintenance of vehicle;
-Organize and implement different concepts and methodologies of vehicle maintenance;
-Determine necessary logistic and system support during vehicle maintenance (management of: spare parts, human resources, vehicles upon receipt in services (which depends of planned operations etc.));
-Solve practical problems regarding to the processes of vehicle maintenance;
-Recognize key performance indicators of maintenance;
-Design service for vehicle maintenance according to the planned maintenance operations and types and categories of vehicle which will be maintenance in that service, through determination of the following parameters: production program, number of workers and work places, number and types of service work spaces;
-Determine the technical equipment for designed vehicle service (diagnostic systems, tools etc.);

Theoretical teaching

Theoretical tuition is composed of four blocks each of them containing four thematic units with an overall number of 4x5 = 20 lecturing hours, with 4 x 2,5 = 10 additional hours for

working out on the teaching subjects and acquisition of new material.
Four basic theoretical tuition blocks contains (a)Maintenance - Life cycle, and investment effectiveness, Condition Time Sequence, Maintenance technological backgrounds, Variation of technological solutions, usage and maintenance in specific conditions, (b) Maintenance technologies (corrective, preventive, combined), Vehicle condition changes, Vehicle condition estimation methods, Technological procedures, (c) Project assignment, Number of vehicles to maintenance, Estimation of maintenance system capacity, Quality of Service, and (d) Kinds of maintenance technology processes, Maintenance Work place, Information systems, Logistics, Standardized and specialized service facilities.

Practical teaching

In the practical tuition part student has 30 hours of individual work to work out a seminar work and a project.
In the practical tuition part, following the aforementioned four main blocks, student works out more detailed thematic evaluation within the listening exercises followed by an individual seminar assignment about designing maintenance system for a given vehicle and an individual project assignment about maintenance system for a given service facility based on the knowledge acquired within the third and the fourth block. Student will also work out on a assignment considering maintenance logistics support as an integral part of the maintenance system, will deal with the selection and choice of garage equipment for a given work place, and will also deal with the dimensioning of maintenance capacities, in addition to some basic elements concerning an information system about operation and service of vehicles, and maintenance system specification.

Prerequisites

A B.Sc. diploma in automotive engineering is preference, and already passed exams in “Vehicle design 1” and “Vehicle design” are a must.

Learning resources

1. Class room
2. Subject teacher's book
3. Subject teacher's book
4. other literature type
5. IT Hardware
6. IT software

NUMBER OF HOURS

Total number of hours: 72

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**27**
auditory exercises	10
laboratory exercises	0
calculation tasks	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0

seminar works	5	final exam	5
project design	10		
discussion and workshop	2		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	20	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Vasic B., Jankovic D., Curovic, D.: Technology for vehicle maintenance, Faculty of Mechanical Engineering, Belgrade, 2000.

Vehicle Mechatronics

ID: 0873
Responsible/Holder professor VLADIMIR M. POPOVIĆ
Teaching profesor(s): POPOVIĆ VLADIMIR; STAMENKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

Course objectives are designed to meet the needs of the 21st century automotive industry for graduate students with the necessary skills and understanding in mechatronics. Students should be able to deal with a wide range of activities that include research, design, development and testing of mechatronic systems in motor vehicles.

Learning outcomes

Upon successful completion of this course, students should be able to:
- explain the concept of mechatronics and mechatronic systems, with respect to vehicles;
- describe in a nutshell the function of all components of vehicle mechatronic systems;
- analyse and explain the specificities of vehicle mechatronic systems (suspension systems, braking systems, power transmission systems, steering systems, integrated systems);
- analyze the problems when designing a vehicle mechatronic system;
- define the design process of a vehicle mechatronic systems (which includes the determination of future system goal and development of a functional mechatronic system scheme);
- simulate the operation of the designed mechatronic system, as well as to define the testing method for the system in question.

Theoretical teaching

Theoretical part of the course comprises following units: introduction to mechatronics, sensors and actuators, anti-lock braking systems, stability control systems, steer-by-wire steering systems, active suspension systems, advanced driver assistance systems (parts 1, 2 and 3), autonomous vehicles.

Practical teaching

Practical part of the course is focused on students's own mechatronic system project.

Prerequisites

No special requirements.

Learning resources

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NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	35	project design	20
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Handouts in digital form, 2023.
K. Reif (Ed.), Automotive Mechatronics - Automotive Networking, Driving Stability Systems, Electronics, Springer Vieweg,Wiesbaden, 2015.
B.T. Fijalkowski, Automotive Mechatronics: Operational and Practical Issues - Vol. 1, Springer Heidelberg, Dordrecht, 2011.
B.T. Fijalkowski, Automotive Mechatronics: Operational and Practical Issues - Vol. 2, Springer Heidelberg, Dordrecht, 2011.
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Vehicle Propulsion and Suspension Systems

ID: 1334
Responsible/Holder professor SAŠA R. MITIĆ
Teaching profesor(s): MITIĆ SAŠA; BLAGOJEVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: motor vehicles

Goals

Mastering the knowledge and skills necessary to perceive and understand the problems related to the design and calculation of vehicle transmission, suspension system and steering system and their impact on the characteristics and behavior of the vehicle.

Learning outcomes

Upon successful completion of this course, students should be able to: Explain the process of calculation of transmission, suspension system and steering system; Perform calculation of transmission, suspension system and steering system; Analyze the possibilities of predicting the impact of newly designed solutions of propulsion and suspension systems on the performance of the vehicle; Use modern engineering tools; Apply acquired logic through an independent calculation of an adequate system for a given project.

Theoretical teaching

Theoretical part of course consist of the following units: Design and calculation of transmission systems; Design and calculation of hydrodynamic and hydrostatic transmissions; Functional-constructive characteristics of suspension system and wheels; Characteristic performances and their specifics; The influence of suspension system and wheels on the longitudinal, lateral and vertical dynamics of the vehicle; Kinematic-geometric characteristics of suspension and steering system and its influence on the distribution of the relevant forces and vehicle behavior.

Practical teaching

Practical part of course consist of individual projects for all of the aforementioned units. Wherever feasible, individual projects are done on a computer, using appropriate software.

Prerequisites

No special requirements.

Learning resources

Computers with appropriate software tools, showpieces of systems, assemblies and vehicles, as well as their digital illustrations.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	3
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Mitic S.: handouts, 2023.
Rakicevic B.: handouts, 2023.
Blagojevic I.: Suspension and steering system design - handouts, 2023.

Vehicle Testing

ID: 1143
Responsible/Holder professor VLADIMIR M. POPOVIĆ
Teaching profesor(s): POPOVIĆ VLADIMIR; STAMENKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

The main objective of this course is to enable students to obtain objective information on the quality and performance of vehicles and their assemblies and parts at different stages of development, production and exploitation of vehicles using a series of procedures.

Learning outcomes

Upon successful completion of this course, students should be able to: 1. Explain how to measure physical quantities electrically while testing motor vehicles; 2. Select transducers and sensors, amplifiers, supplementary and auxiliary devices and devices for displaying vehicle test results; 3. Conduct different vehicle tests; 4. Analyze test results.

Theoretical teaching

Theoretical classes are focused on the following areas: basic concepts of vehicle testing; measurement of physical quantities by electrical means; strain gauges.

Practical teaching

Practical classes consist of the following laboratory exercises: testing by simulation in CarSim software; testing of completed vehicles; testing of vehicles for transport of perishable foodstuffs; testing of vehicles for transport of dangerous goods; testing of ambulance vehicles; testing of protective structures of agricultural tractors; testing of pedestrian warning sound system for installation on electric vehicles; measurement of chassis torsional rigidity, burning behavior of vehicle interior materials, noise measurement.

Prerequisites

No special requirements.

Learning resources

-

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0

elaboration and examples (revision)	0	check and assessment of lab reports	0
active teaching (practical)	**30**	check and assessment of seminar works	0
auditory exercises	0	check and assessment of projects	5
laboratory exercises	25	colloquium, with assessment	5
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	5		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Handouts in digital form, 2023.
J. Todorović, Motor Vehicle Testing (in Serbian), JUMV, Belgrade, 1995.

Vehicles and Environment

ID: 0874
Responsible/Holder professor IVAN A. BLAGOJEVIĆ
Teaching profesor(s): BLAGOJEVIĆ IVAN; MITIĆ SAŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: motor vehicles

Goals

The goal of this subject is to give the students an insight into effects vehicles have on the environment. Preservation of the environment and minimization of the negative impacts of driver-vehicle-environment system are the basis of modern vehicle development and exploitation. Therefore a more detailed analysis of these effects in this case are a prerequisite for creating a modern engineer, not only in the field of motor vehicles.

Learning outcomes

Upon successful completion of this course, students should be able to:
- Explain the concept of fuel consumption and the possibilities for its reduction;
- Analyze the impacts of driver on fuel consumption;
- Identify and explain the harmful elements of the exhaust emissions of motor vehicles, ways of their formation and effects, methods of measurement and legal constrain values per component;
- Identify alternative vehicle drives and fuels;
- Analyze working principles of hybrid and electric vehicles;
- Explain the impact of noise and vibration produced by vehicle;
- Recognize environmentally friendly and modern materials used in the design and manufacture of vehicles;
- Describe the recycling process and the life cycle of the vehicle.

Theoretical teaching

Introductory classes relate to the importance of the vehicle in production, transportation and traffic in contemporary economic and social environment.
They are followed by lectures that look back on the development of automotive technology that was largely affected by environmental conditions. The following lectures are divided into blocks according to a rough classification of basic elements of the impact of vehicles and drivers on the environment:
1. fuel consumption; 2. exhaust emission; 3. hybrid and electric vehicle drivetrain; 4. alternative fuels; 5. noise and vibration; 6. recycling and the use of modern materials.
The final lectures are planned to present the future trends in the design and exploitation of vehicles with the aim of improving environmental protection.

Practical teaching

By conducting the practical training, students should identify and analyze the impact of the vehicle-driver-environment system on the environment, primarily through fuel consumption

and exhaust emission. Through the laboratory classes, parameters of the vehicle engine for different driving modes (speed, acceleration and road conditions) are aquisited, providing the data for students to process in their reports and draw the conclusions.
In addition, students explore operating modes of hybrid and electric vehicles and effects of their.
Students are also required to write the essay on a given subject.

Prerequisites

No special requirements.

Learning resources

Motor vehicle;
Vehicle and engine parameters data acquisition system;
Hybrid vehicle;
Electric vehicle.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	15
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	3
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	4

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	30	project design	0
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

I. Blagojević, S. Mitić: Vehicles and the environment, Faculty of Mechanical Engineering, Belgrade, 2017.
I. Blagojević: Motor vehicle fuel consumption and saving, Faculty of Mechanical Engineering, Belgrade, 2016.

NAVAL SYSTEMS

Seakeeping

Ship buoyancy and stability 2

Ship design

Ship Equipment M

Ship Manoeuvring

Ship propulsion

Ship resistance

Ship strength 1

Ship strength 2

Ship structures 1M

Ship structures 2

Ship systems M

Skill Praxis M - BRO

Software application in Ship design

Seakeeping

ID: 1431
Responsible/Holder professor STEFAN S. RUDAKOVIĆ
Teaching profesor(s): RUDAKOVIĆ STEFAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: naval systems

Goals

To cover the basic knowledge of Naval Architecture connected to ship motion in waves.

Learning outcomes

1. The student will be able to apply comprehensive knowledge from fundamental natural and technical sciences to solve problems related to ship behaviour on waves – rolling, pitching, and heaving on regular and irregular waves. Additionally, the student will be familiar with the development of wave theory and seakeeping analysis, and their significance and application to modern ship stability regulations;
2. The student will be capable of formulating problems related to seakeeping and analysing the impacts of changes in various parameters, such as changes in metacentric height, hull form, and the distribution and shifting of cargo on the ship. This will include the analysis and qualitative assessment of available data during calculations, and using engineering judgement in cases of incomplete or unreliable information;
3. The student will be able to select and apply appropriate computational and analytical techniques to model problems related to seakeeping, considering the limitations of the applied techniques;
4. The student will be able to communicate effectively on complex engineering matters of the course subject with technical and non-technical audiences, evaluating the effectiveness of the methods used.

Theoretical teaching

Ship motion in calm water: rolling, heaving and pitching. Ship's natural periods. Added mass and damping – strip theory, the Lewis forms. Waves at sea surface: hydrodynamic theory, stochastic theory. Ship motion in regular waves: rolling, heaving and pitching. Ship motion in irregular waves: motion spectra, mean, significant and RMS values of ship motion. Displacement, velocity and acceleration of ship points. Probability of deck wetness, propeller emergence and slamming. Added resistance. Effects on passengers and crew. Dynamic loads. Seakeeping criteria. Improvement of ship seakeeping characteristics. Roll stabilization.

Practical teaching

Practical problems of seakeeping, illustrating the subjects lectured in the theoretical syllabus. In addition, students have to accomplish individually the project on ship rolling, heaving and pitching in irregular waves, for the ship already analyzed in projects of Buoyancy and Stability of Ship.

Prerequisites

Passed course Ship buoyancy and stability 2.

Learning resources

[1] M. Hofman: Extracts from lectures (handouts) /In Serbian/ [2] M. Hofman and I. Bačkalov: Exercises in Seakeeping. /In Serbian/

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 15

References

Hofman, M., Ponašanje broda na talasima, Mašinski fakulte u Beogradu, I izdanje, 2020
Lewis, Edward V. (editor), Principles of Naval Architecture, Part 3, SNAME, 1987
A.R.J.M.LLoyd: Seakeeping - Ship Behaviour in Rough Weather, 1998
Lewandowski, E., The Dynamics of Marine Craft, World Scientific, 2004.

Ship buoyancy and stability 2

ID: 1430
Responsible/Holder professor STEFAN S. RUDAKOVIĆ
Teaching profesor(s): RUDAKOVIĆ STEFAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: naval systems

Goals

To cover the advanced knowledge of Naval Architecture connected to ship buoyancy and stability: ship loading, flooding, damaged ship stability and grounding. It is a continuation of the course Ship buoyancy and stability 1.

Learning outcomes

1. The student will be able to apply comprehensive knowledge from fundamental natural and technical sciences to solve ship stability problems during loading/unloading, flooding, and grounding. Additionally, the student will be familiar with regulations on ship damage stability, understand their origin and development, and their relation to accidents. The student will be aware of examples of good engineering practice within the subject topics and the directions of future development in this field;
2. The student will be capable of formulating problems and analysing the impacts of loading/unloading, flooding, and grounding to reach well-founded conclusions about ship residual stability. This will include the analysis and qualitative assessment of available data during calculations, and using engineering judgement in cases of incomplete or unreliable information;
3. The student will be able to select and apply appropriate computational and analytical techniques to model ship stability problems during loading/unloading, flooding, and grounding, considering the limitations of the applied techniques;
4. The student will be able to communicate effectively on complex engineering matters of the course subject with technical and non-technical audiences, evaluating the effectiveness of the methods used.

Theoretical teaching

Loading/unloading of cargo: centric loading (small and large cargo, liquid cargo), eccentric loading. Flooding: alternative methods (added weight or lost buoyancy), centric and eccentric flooding, flooding of compartments with solid and liquid cargo. Damaged ship calculations: deterministic and probabilistic calculations, curve of floodable length, regulations. Ship grounding: bottom reaction (small and large), grounded ship stability, critical reaction, docking. Methods for improving ship stability.

Practical teaching

Practical problems of ship buoyancy and stability, illustrating the subjects lectured in theoretical syllabus. In addition, students have to accomplish individually the project: Flooding calculations (done in accordance to SOLAS regulations) for the ship already

analyzed in projects of Ship buoyancy and stability 1.

Prerequisites

There are no special requirements for attendance.

Learning resources

[1] M. Hofman: Extracts from lectures (handouts) /In Serbian/
[2] B. Ribar: The theory of ship /In Serbian/

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	0	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 15

References

Biran, A., Ship Hydrostatics and Stability, Butterworth Heinemann 2003
Lewis, E.V., (editor): Principles of Naval Architecture, Part 1, SNAME 1987
K.J. Rawson & E.C. Tupper, Basic Ship Theory, Longmans 1967

Ship design

ID: 1018
Responsible/Holder professor MILAN D. KALAJDŽIĆ
Teaching profesor(s): KALAJDŽIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: naval systems

Goals

Ship Design is a course that integrates all the knowledge of naval architecture and shipbuilding that a student has acquired during their studies. The goal is for the student, through classes and an independent project, to master the basic knowledge and skills of ship design and international regulations in shipbuilding, including their origin, development, and particularly their impact on ship design. The course also includes a critical analysis of existing regulations and methods applied in ship design.

Learning outcomes

Through classes and an independent project, student will master basic knowledge and skills of ship design and international regulations in shipbuilding, becoming familiar with their development and impact on safety, environment, and design process. They will be capable of applying comprehensive knowledge of mathematics, statistics, natural sciences, and engineering principles to solve complex problems, with a critical awareness of the broader engineering context. The student will be able to formulate and analyze complex problems, assess available data, and use engineering reasoning to work with uncertain or incomplete information, know how to select and apply appropriate computational and analytical techniques for modeling complex problems, considering limitations of applied techniques and recommendations. The student will be able to critically evaluate technical literature and other sources of information to solve complex problems, to design solutions for complex problems that demonstrate originality and meet social, user, business, and client requirements, considering health, safety, diversity, inclusion, cultural, social, environmental, and commercial issues. The student will apply an integrated or systemic approach to solving complex problems, will be able to evaluate the impact of solutions to complex problems on the environment and society and minimize their negative impacts. The student will identify and analyze ethical issues and make reasonable ethical choices based on professional codes of conduct. They will be able to select and apply appropriate materials, equipment, engineering technologies, and processes, considering their limitations. The student will effectively function as an individual, a member or leader of a team, and will evaluate the effectiveness of their own and team performance. They will be able to effectively communicate complex engineering issues to technical and non-technical audiences, assessing the effectiveness of the methods used.

Theoretical teaching

Basic principles of ship design. Rules, regulations, and conventions in the design, construction, and operation of ships. Types of regulations. Rules of classification societies,

international conventions, national regulations. Deterministic regulations. Probabilistic regulations. The design spiral. Weight, volume and area-based design. Weight groups. Statistic data on existing ships. Statistic data and prototype-based design. Statistics-based ship design: Formulas for main dimensions and their interrelations, ship-form coefficients, weight groups, centre of mass, power prediction. Effects of ship's dimensions and ship form on stability, resistance, strength, maneuvering and seakeeping. Ship calculations in the first approximation. Ship calculations in the second approximation. Design based on prototype: The choice of the prototype. Main dimensions, form coefficients, weight groups, centre of mass, power prediction. Lines drawing. General arrangement plan. Other technical documentation. Specifics in cargo ships design (multipurpose ships, container ships, bulk carriers, tankers), passenger ships, naval ship etc. Specifics in inland vessels design.

Practical teaching

Practical problems of ship design, illustrating the subjects lectured in theoretical syllabus. In addition, students have to develop individually the project of a cargo ship (preliminary ship design of a container ship, bulk carrier, multipurpose ship or a tanker), with all the necessary calculations, plans (including the general arrangement) and the technical documentation. Practical examples and application of regulations covered in theoretical syllabus. Some specifics of the regulations. Analysis of the impact of regulations on ship safety, the environment, and the design process.

Prerequisites

Exams passed in Buoyancy and Stability of Ship 2, Ship Resistance, Ship Propulsion, Ship Structures 2.

Learning resources

[1] M. Kalajdzic: Extracts from lectures (handouts). /In Serbian/
[2] I. Bačkalov: Instructions for project design. /In Serbian/
[3] Technical documentation of designed ships.
[4] The German Merchant Fleet, Seehafen Verlag, 2006
[5] Significant Ships, RINA Journals.
[6] Bačkalov, I., International Regulations in Shipbuilding: Ship Safety, Faculty of Mechanical Engineering, Belgrade, 1st Edition, 2017. /In Serbian/
[7] International Regulations: IMO Conventions (SOLAS, Tonnage, ICLL, MARPOL) and accompanying documents.
[8] Regulations for the Construction of Inland Waterway Vessels: ADN, ECE, Directive 2006/87/EC.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0

calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	25		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	50
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

H. Schneekluth, V. Bertram: Ship Design for Efficiency and Economy, Butterworth-Heinemann, 1998.
D.Watson: Practical Ship Design, Elsevier, 1998.
T. Lamb (editor): Ship Design and Construction, SNAME, 2003.
A. Papanikolaou: Ship Design - Methodologies of Preliminary Design, Springer, 2014
Bačkalov, I., International regulations in shipbuilding: ship safety, Faculty of Mechanical Engineering in Belgrade, 1st edition, 2017 on Serbian

Ship Equipment M

ID: 0975
Responsible/Holder professor ALEKSANDAR P. SIMIĆ
Teaching profesor(s): SIMIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: oral
Parent department: naval systems

Goals

Within the course, students are introduced to the basic characteristics of the most common types of marine displacement ships. Significant emphasis is placed on ship equipment, covering both mandatory components applicable to every vessel and the specific equipment required for certain ship types. Within this course, we explore the details of individual ship equipment elements, including their purpose, technical characteristics, operational principles, and the procedures for selecting appropriate equipment and determining its placement during the design phase. In addition, students are introduced to the regulations of various elements of ship equipment.

Learning outcomes

1. The student possesses in-depth knowledge of the fundamental features of typical displacement cargo ships, with a specific focus on ship equipment.
2. The student is able to apply comprehensive knowledge in the fundamental natural and technical sciences, as well as engineering principles to solving problems related to complex technical requirements in determining characteristics and deployment on board individual elements of required ship's equipment.
3. Depending on the type and purpose of the ship, the student is capable of formulating requirements for necessary equipment during the design process, considering relevant regulations, and critically analyzing available options. This includes critically considering various available technical solutions, guided by engineering judgment, taking into account the purpose of the equipment, the specifics of ship construction, and the available space.
4. The student is capable of selecting and applying appropriate computational methods to determine the basic characteristics of required ship equipment.
5. The student is qualified to select relevant technical literature and other sources of information when determining the basic technical characteristics of necessary equipment during ship design.
6. The student is capable of designing, selecting, and arranging the necessary equipment on the ship, considering both the functionality of the equipment and the safety of the crew during equipment handling. The arrangement of equipment affects accessibility and directly influences efficiency: cargo handling, anchoring, mooring, deployment of life-saving equipment, etc.

Theoretical teaching

In short, the course is focused on the following teaching units: 1) Most common types of marine displacement ships, 2) Deck equipment (anchoring equipment, mooring equipment,

and steering gear), 3) Cargo handling equipment (vertical and horizontal handling, ship cranes), and 4) Safety equipment (life-saving equipment, navigation and signalling equipment). The course gains significance because certain types of ships primarily differ from each other based on the installed equipment. The installed equipment significantly impacts the functionality of the ship, as well as its costs. On the other hand, ship equipment is often not manufactured in shipyards but is purchased from specialized manufacturers, which significantly affects the content of the subject. Within the subject, special attention is dedicated to regulations (rules of classification societies, resolutions, and conventions) that define the requirements which ship equipment must meet.

Practical teaching

Greater emphasis is placed on direct interaction with students within the practical part of the teaching. The focus is on applying knowledge necessary for everyday engineering practice, previously presented in theoretical teaching. Special attention is given to the rules of classification societies related to ship equipment. Through brochures provided by leading manufacturers of ship equipment, students are familiarized with the technical characteristics and installation specifics of the equipment, depending on the type of ship.

Prerequisites

There are no prerequisites.

Learning resources

Lectures are available in electronic form.
Various classification societies' rules.
Brochures of various equipment manufacturers.
Internet resources.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	2
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	1
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0

test/colloquium	55	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

D. J. House: Seamanship Techniques, Shipboard and Marine Operations, Elsevier, Oxford, 2004.
International Convention for The Safety of Life at Sea, Consolidated Edition, 2020.
IMO Life-Saving Appliances including LSA code, 2017.
OCIMF Anchoring System and Procedures, 2010.
OCIMF Mooring equipment guidelines 3rd Ed., 2008.

Ship Manoeuvring

ID: 1563
Responsible/Holder professor ALEKSANDAR P. SIMIĆ
Teaching profesor(s): SIMIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: naval systems

Goals

Within the course, students are introduced to the basic principles of ship manoeuvrability, in order to ensure safe control of the ship's trajectory during navigation. In this context, students are familiarized with standard procedures for assessment and criteria for evaluating the manoeuvrability of existing ships. Additionally, they become acquainted with the relevant regulations established by ITTC and IMO governing ship manoeuvrability. Students are comprehensively introduced to both theoretical and experimental methods utilized in ship design, with the aim of achieving the necessary manoeuvring characteristics. In addition, students acquire essential knowledge of the technical specifications of existing control devices utilized for steering the ship during navigation.

Learning outcomes

1. The student gains a comprehensive understanding of the fundamental challenges associated with ship manoeuvrability, along with the basic manoeuvring characteristics specific to seagoing displacement ships.
2. The student can effectively apply comprehensive knowledge in mathematics, rigid body dynamics, fluid mechanics and basic engineering principles to determine and analyze the manoeuvring performances of a ship.
3. The student is trained to critically assess how primary and secondary characteristics of hull form and control devices affect manoeuvrability, employing fundamental principles of natural sciences. This analysis aims to optimize ship design to enhance manoeuvrability.
4. The student is qualified to select and apply appropriate empirical, numerical, and experimental methods to assess the impact of basic parameters of hull form and control devices on the manoeuvring capabilities of the ship, considering the limitations of the waterway, as well as the constraints of the chosen methods.
5. The student can choose and critically evaluate relevant technical literature and other sources of information for solving complex problems in the field of marine hydrodynamics with a particular focus on ship manoeuvrability.
6. The acquired knowledge enables the student to address complex engineering challenges and meet specific design requirements imposed by contemporary trends in naval architecture, particularly those related to ship manoeuvrability. This is notably apparent in the case of full-form ships, which may lack directional stability, necessitating the implementation of innovative technical solutions within confined spaces to ensure the vessel's safety.

Theoretical teaching

The theoretical teaching emphasizes introducing students to the fundamental principles of ship manoeuvrability, along with essential mathematical formulations concerning: 1) basic principles of ship handling and manoeuvring; 2) theoretical approach – involves developing methods for numerical assessing ship manoeuvrability and analyzing the advantages and limitations of these methods; 3) experimental approach – involves discussing standard manoeuvrability tests, including model tests (free model tests and captive model tests), and full-scale tests of existing ships (such as spiral and reverse spiral tests, pull-out tests, Z tests, turning tests, etc.); Students are introduced to mandatory regulations concerning manoeuvrability, as well as to various technical solutions, i.e. control devices commonly used to regulate the ship's course during navigation.

Practical teaching

Within practical teaching, the emphasis is placed on applying theoretical knowledge to everyday engineering practice. Practical guidance is provided on conducting standard manoeuvrability tests for existing ships. Students are introduced to both active control devices (such as side jet propulsors, pump pushers, and steering propulsion devices) and passive control devices (including various types of rudders). Additionally, recommendations are provided for ship design and the selection of appropriate control devices to enhance manoeuvring characteristics and meet criteria outlined by IMO regulations. During practical teaching, various computational tasks are considered, to apply the theoretical concepts discussed.

Prerequisites

There are no prerequisites.

Learning resources

Extracts from lectures (handouts).
Detailed reports from measurements.
Manufacturer's product brochures.
Internet resources.
Relevant books and professional papers.
Relevant IMO documents.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	55	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Extracts from lectures (handouts)
E. Lewis, (editor): Principles of Naval Architecture (Chapter IX – Controllability), SNAME, Jersey City, 1988.
J. Brix: Maneuvering Technical Manual, Seehafen Verlag, Hamburg, 1993.
A.F. Molland, S.R. Turnock: Marine Rudders and Control Surfaces, Butterworth – Heinemann, 2007
Relevant IMO Documents

Ship propulsion

ID: 0956
Responsible/Holder professor ALEKSANDAR P. SIMIĆ
Teaching profesor(s): SIMIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: naval systems

Goals

Within the course, students are introduced to the fundamentals of ship propulsion. Special attention is paid to the physical phenomena that characterize the operation of propellers. The study focuses on the complex conditions under which propellers operate, specifically examining propeller-ship interaction and the influence of propeller geometry and ship stern form on hydrodynamic performance. Students are trained to independently determine the optimal propeller characteristics using common engineering methods while considering specific requirements and determining the necessary specifications of the main engine for propelling a typical seagoing cargo ship. Besides, students are introduced to a range of modern technical solutions aimed at enhancing the efficiency of a ship's propulsion system, as well as various regulations concerning technical and environmental requirements related to ship propulsion.

Learning outcomes

1. The student has developed a thorough understanding of the fundamental physical principles that underlie ship propulsion. Within this framework, both traditional and contemporary methodologies for addressing complex physical phenomena are explored, to determine the optimal characteristics of a propulsion system in alignment with design requirements. The student is acquainted with the model-scale experiments on propeller performance, as well as the procedures required to extrapolate and apply these findings to full-scale propellers.
2. The student adeptly applies a comprehensive understanding of mathematics, fluid mechanics, and fundamental engineering principles to assess the hydrodynamic performance of a propeller.
3. The student demonstrates the ability to critically analyze the impacts of both the basic geometric and hydrodynamic characteristics of propellers, taking into consideration the complex water inflow, particularly influenced by the stern design of typical seagoing vessels. This analysis aims to optimize ship propulsion.
4. The student can evaluate specific propeller characteristics to enhance the energy efficiency of the ship's propulsion system, leading to greater operational economy and minimized environmental impact.
5. The student is qualified to choose and apply appropriate empirical and numerical methods to determine the hydrodynamic characteristics of optimal propeller and required propulsive power while considering the design requirements and limitations of the methods employed.
6. The student can select and critically evaluate relevant technical literature and other sources of information to address complex problems in the field of ship hydrodynamics, with

a particular focus on determining ship propulsion performances.
7. The acquired knowledge enables the student to address complex engineering challenges and meet specific design requirements imposed by contemporary trends in naval architecture, particularly those related to ship propulsion.

Theoretical teaching

The student gains an understanding of the fundamental physical phenomena defining propeller operation, including the interaction between the ship's hull and the propeller, the coordinated functioning of the propeller and engine, and the processes involved in propeller selection and design using common engineering methods. Special emphasis is placed on both open-water propeller tests and self-propulsion tests, enabling students to acquire the essential skills to conduct, manage, or commission such tests and effectively analyze their outcomes. Detailed analysis is conducted on the transmission of power from the engine to the propeller, as it significantly influences the characteristics of the optimal propeller and the required power of the main engine. In addition, students are acquainted with a range of contemporary technical solutions aimed at enhancing the efficiency of ship propulsion systems, along with relevant regulations on technical and environmental requirements in ship propulsion. Lastly, students are introduced to a diverse range of propulsors, some of which are based on traditional propeller designs (such as propellers in nozzles, counter-rotating propellers, tandem propellers, etc.), while others represent more innovative designs found in relatively uncommon ship types or vessels (such as water-jet propulsors, propulsors with vertical wings, etc.). In addition, theoretical instruction covers the fundamental elements necessary for conducting sea trials, particularly concerning ship propulsion.

Practical teaching

As part of practical teaching, alongside the typical computational tasks accompanying theoretical chapters, there is a particular emphasis on the development of an individual and independent project (which continues on the project from the course Ship Resistance). Projekt se, ukratko, sastoji u sprovođenju proračuna primenom uobičajenih inženjerskih metoda (neki od njih i uz upotrebu računara), s ciljem da se odabere/projektuje optimalan propeler, odnosno odabere adekvatan brodski motor. In short, the project entails implementing calculations using standard engineering methods, including computer/software applications, to select or design an optimal propeller and determine the characteristics of an appropriate main engine. Special attention is paid to the energy efficiency of the adopted solution.

Prerequisites

Exam passed in Ship Resistance.

Learning resources

Extracts from lectures (handouts)/In Serbian
Instructions for project design /In Serbian
Additional literature obtained during lectures
Internet resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	OTHER

active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	10
discussion and workshop	0
research	**0**

knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5
test/colloquium	0
laboratory exercises	0
calculation tasks	0

seminar works	0
project design	35
final exam	60

Requirements to take the exam (number of points) 30

References

E. Lewis,(editor): Principles of Naval Architecture (Chapter VI – Propulsion), SNAME, Jersey City, 1988.
SNAME's Principles of Naval Architecture Series: Propulsion, Justin E. Kerwin and Jacques B. Hadler, 2010.
A. F. Molland, S. R. Turnock and D. A. Hudson, Ship resistance and propulsion, Cambridge University Press, 2017.
John Carlton, Marine Propellers and Propulsion, Butterworth-Heinemann, 2012.
Radojčić, D., Kalajdžić, M., Simić, A., Power Prediction Modeling of Conventional High-Speed Craft, Springer, 2019.

Ship resistance

ID: 0955
Responsible/Holder professor ALEKSANDAR P. SIMIĆ
Teaching profesor(s): SIMIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: naval systems

Goals

Within the course, students are introduced to the fundamentals of marine hydrodynamics and how the basic parameters of a ship's hull form influence ship resistance. They are trained to determine ship resistance for common types of seagoing ships by applying traditional engineering methods. Additionally, the course explores other conventional and unconventional types of ships from the perspective of ship resistance.

Learning outcomes

1. The student is thoroughly acquainted with the basic physical phenomena that characterize a ship's navigation. In this context, traditional, but also contemporary methods for solving complex physical phenomena, in order to determine a ship's calm water resistance, are considered. Special attention is given to conducting model-scale experiments and procedures involved in extrapolating and applying these findings to a full-scale ship.
2. The student is capable of applying comprehensive knowledge of mathematics, fluid mechanics, and basic engineering principles to determine the resistance of a ship during navigation.
3. The student demonstrates the ability to conduct a comprehensive analysis of the primary and secondary characteristics of a typical sea-going ship’s hull form. The purpose of this analysis is to optimize the hull form, with respect to ship resistance.
4. The student can assess the impact of selected ship design parameters on ship resistance to mitigate adverse environmental impacts.
5. The student is qualified to choose and apply appropriate empirical and numerical methods to determine ship resistance, considering both the limitations of the waterway and the methods applied.
6. The student can select and critically evaluate relevant technical literature and other sources of information to address complex problems in the field of ship hydrodynamics, with a particular focus on determining ship resistance.
7. The acquired knowledge enables the student to address complex engineering challenges and meet specific design requirements imposed by contemporary trends in naval architecture, particularly those related to ship resistance.

Theoretical teaching

To determine the ship’s main engine power, ship resistance must be determined first. It can be obtained by model tests or by other evaluation methods. Teaching is primarily oriented to the practical application of ship hydrodynamics in common engineering practice. Attention is particularly focused on model tests that are still the most reliable tool as well as on the

extrapolation of results from a model to a ship. Theoretical teaching is realized through the following teaching units: a) calculations of ship resistance components, resistance evaluation according to ITTC recommendations/method, b) effects of shallow and restricted water, c) model tests, model-ship correlation, standard methodical and statistical series, d) recommendations for the design of ship forms, and e) high-speed (unconventional) craft.

Practical teaching

The student should evaluate resistance for a usual sea-going ship (form) he/she was acquainted with within the subject Buoyancy and stability of ship 1. The obtained results will be used in the project that should be done within the Ship propulsion course. Thus, the student is enabled to perceive the ship as a whole, and resistance itself as a part of applied ship hydrodynamics that is unavoidable in the ship design process. Within the framework of practical teaching, the student is trained to do calculations using a computer i.e. to develop a mathematical model for resistance evaluation by himself. Moreover, some teaching units presented by theoretical teaching involve calculation examples too.

Prerequisites

It is necessary that the candidate: has 180 ECTS and has completed the project task in the subject Buoyancy and stability of ship 1

Learning resources

Extracts from lectures (handouts)/In Serbian.
Written instructions for project design /In Serbian.
Additional literature obtained during lectures.
Internet resources.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	8
laboratory exercises	0
calculation tasks	7
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0

test/colloquium	0	project design	35
laboratory exercises	0	final exam	60
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

E. Lewis (editor): Principles of Naval Architecture (Chapter V – Resistance), SNAME, Jersey City, 1988.
A. F. Molland, S. R. Turnock and D. A. Hudson, Ship resistance and propulsion, Cambridge University Press, 2017.
M. Hofman and D. Radojcic, Resistance and propulsion of High Speed Crafts in Shallow Water, MF Belgrade, (in serbian), 1997.
Radojčić, D., Kalajdžić, M., Simić, A., Power Prediction Modeling of Conventional High-Speed Craft, Springer, 2019.
Radojčić, D., Simić, A., Motok, M., Momcilovic, N., Friedhoff, B., Design of Contemporary Inland Waterway Vessels - The Case of the Danube River, Springer, 2021.

Ship strength 1

ID: 1015
Responsible/Holder professor NIKOLA V. MOMČILOVIĆ
Teaching profesor(s): MOMČILOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: naval systems

Goals

The course aims to prepare students with a comprehensive understanding, selection of appropriate methods for solving, and the direct resolution of fundamental ship strength problems. These include: basic modes of hull failure and limit states, hull responses, bending of stiffeners with and without attached plating, effective width of plating, geometrically similar sections, buckling of stiffeners, response of ship's transverse sections (frames), bending of plates (platings), buckling of unstiffened and stiffened plates (platings), effective width of plates.

Learning outcomes

1. Students will be able to apply comprehensive knowledge from fundamental natural and technical sciences (mainly: strength of materials, strength of structures, mechanical materials, mechanics) and engineering principles to solve fundamental ship strength problems such as: basic modes of hull failure and limit states, hull responses, bending of stiffeners with and without attached plating, effective width of plating, geometrically similar sections, buckling of stiffeners, response of ship's transverse sections (frames), bending of plates (platings), buckling of unstiffened and stiffened plates (platings), and effective width of plates.
2. Students will be capable of formulating and setting fundamental ship strength problems (abovementioned), using the foundations of natural sciences and engineering principles, to reach relevant conclusions while considering the limitations of methods and data incompleteness.
3. Students will be able to select and apply analytical and computational methods to model the fundamental ship strength problems (abovementioned), while considering the limitations of these methods.
4. Students will be capable of independently finding and critically using technical regulations (rules and regulations of classification societies and national registries, as well as other regulatory bodies), literature (papers, studies), and other information sources (data from shipowners, design offices, shipyards, estimated data, etc.) to solve the fundamental ship strength problems (abovementioned).
5. Students will be able to select and apply materials, consider shipbuilding technologies and processes, as well as their limits.
6. Students will be able to communicate complex engineering issues related to ship strength to both technical and non-technical audiences, evaluating the effectiveness of the methods used. This will be achieved by assigning ship strength topics for students to research and then present.

Theoretical teaching

Students are introduced to various types of ship strengths failures and their limit states. They study the basic loadings on a ship's hull, classified into static, quasi-static, and dynamic. Primary, secondary, and tertiary structural responses are analyzed, with conditional divisions into longitudinal, transverse, and local strength. Analytical and numerical methods for calculating the bending and buckling of beams, trusses, unstiffened, and stiffened plates in ship structures are explored.

Practical teaching

Students are acquainted with and independently perform calculations on: geometric characteristics of cross-section of stiffeners, bending of stiffeners with and without attached plating, effective width of attached plating, geometrically similar sections, buckling of stiffeners, responses of ship hull cross-sections (frames), bending of plates (platings), buckling of unstiffened and stiffened plates (platings), and effective width of plates. These skills are essential in modern engineering practice, both in direct calculations of hull strength and in creating semi-empirical formulas in rules of the classification societies.

Prerequisites

Defined by the Study Program Curriculum.

Learning resources

1. Theoretical lecture material (presentation).
2 Auditorial lecture material – tasks solutions (presentation).
3. Book: M. Motok, Čvrstoća broda (in Serbian), FME Belgrade, 2005.
4. Rules and regulations for ships of the classification societies.
5. Strength of materials – tables of geometrical characteristics.
6. Computer room.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	17
laboratory exercises	0
calculation tasks	10
seminar works	3
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	25
test/colloquium	0	project design	0
laboratory exercises	0	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 15

References

M. Motok: Ship Strength /In Serbian/, MF, Beograd, 2005.
J. K. Paik: Ultimate Limit State Analysis and Design of Plated Structures, John Wiley & Sons, 2018.
O. F. Hughes and J. K. Paik: Ship Structural Analysis and Design, SNAME, 2010.
SNAME: Ship Design and Construction, Vol I, SNAME, 2003.
M. Milovančević, N. Anđelić, V. Milošević-Mitić, M. Dunjić, D. Ružić, R. Čukić: Otpornost materijala – tablice (in Serbian), FME Belgrade, 2021

Ship strength 2

ID: 1017
Responsible/Holder professor NIKOLA V. MOMČILOVIĆ
Teaching profesor(s): MOMČILOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: naval systems

Goals

The objective of the course is to enable students to have a basic understanding of the theory of the finite element method, a comprehensive understanding of the engineering approach and the concept of using this method in shipbuilding, as well as to equip them for solving basic ship strength problems at the level of stiffeners, stiffened plates, frames, unstiffened plates, stiffened plates, or any other local part of the structure.

Learning outcomes

1. Students will be capable of applying knowledge from fundamental natural sciences and technical disciplines (notably: strength of material, strength of structures, materials, mechanics) and engineering principles in understanding the finite element method in shipbuilding, as well as in understanding and solving specific ship strength problems using this method, such as responses of: stiffeners, stiffened plates, frames, unstiffened plates, stiffened plates, or any other local part of the structure.
2. Students will be able to, based on the use of fundamentals of natural sciences and engineering principles, formulate and pose fundamental problems (as mentioned above) in the analysis of ship strength using the finite element method to produce conclusions, while taking into account the limitations of the method and the incompleteness of data.
3. Students will be capable of selecting and applying computational methods based on the finite element method to model fundamental ship strength problems (as mentioned above), bearing in mind the method's limitations. Additionally, students will compare those results with existing analytical solutions.
4. Students will be capable of independently finding and critically using technical regulations (rules and regulations of classification societies and national registers, as well as other regulatory bodies for analysis using the finite element method), literature (papers, studies), and other information sources (data obtained from shipowners, design offices, shipyards, estimated data, etc.) to solve fundamental ship strength problems (as mentioned above) using the finite element method.
5. Students will be able to apply a systematic approach to solving complex structural problems of ship strength using the finite element method.
6. Students will know how to select and apply appropriate materials, consider shipbuilding technologies and processes, and their limitations, in the analysis of structures using finite elements.

Theoretical teaching

Students are introduced to the application of the finite element method in engineering

analyses. They become familiar with the basics of theory of elasticity, and then with the fundamentals of the finite element method theory in the context of linear-elastic analyses of ship structures. This includes: stiffness matrices of elements (rods, beams, and plates), stiffness matrices of structures, preprocessor modeling of ship structures, and similar topics. They are also explained the broader context of this method in shipbuilding and structural safety of ships, especially through the requirements and rules of classification societies regarding direct calculations of this type.

Practical teaching

Students are introduced to and independently perform calculations of ship strength using the finite element method. Such calculations include responses: stiffeners, stiffened plates, frames, unstiffened plates, stiffened plates, or any other local part of the structure.

Prerequisites

Defined by the curriculum of the study program.

Learning resources

1. Theoretical lecture material (presentation).
2 Auditorial lecture material – tasks solutions.
3. Book: M. Motok, Čvrstoća broda (in Serbian), FME Belgrade, 2005.
4. Rules and regulations for ships of the classification societies.
5. Strength of materials – tables of geometrical characteristics.
6. Computer room.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	20
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	10
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	0	final exam	45

calculation tasks	0

Requirements to take the exam (number of points) 30

References

M. Motok: :Ship Strength (In Serbian), FME Belgrade, 2005.
O. F. Hughes, J. K. Paik: Ship Structural Analysis and Design, SNAME, 2010.
LR: Rules and regulations for the classification of ships, 2020.

Ship structures 1M

ID: 1459
Responsible/Holder professor NIKOLA V. MOMČILOVIĆ
Teaching profesor(s): MOMČILOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: naval systems

Goals

The course aims to equip students with the understanding and ability to design ship structures using the rules and regulations of classification societies. Additionally, it seeks to thoroughly acquaint students with all elements of ship structures and their roles within the ship's hull.

Learning outcomes

1. Students will be capable of applying knowledge from fundamental natural, technical sciences (primarily: strength of materials, strength of structures, engineering materials) and engineering principles to the scantling determination and optimization of ship structural elements.
2. Students will be able to formulate the roles of ship structural elements within the hull, by optimizing and designing them, based on the principles of natural sciences and engineering, considering method limitations and data incompleteness.
3. Students will select and apply analytical and computational methods to model ship structural elements through their scantling determinations and optimization.
4. Students will independently find and critically use technical regulations (rules and regulations of classification societies and national registries, among other regulatory bodies), literature (papers, studies), and other information sources (data from shipowners, design offices, shipyards, estimated data, etc.) for the scantling determination and optimization of ship structural elements.
5. Students will apply a systematic approach to solving complex problems in the scantling determination and optimization of ship structures.
6. Students will choose and apply appropriate materials, consider shipbuilding technologies and processes, and their limitations.

Theoretical teaching

Students learn about the concept of ship structures and all the elements within a ship. They will discover their roles, appearance, technology, the loads they undergo throughout their lifespan, construction systems, and the design of the mid, fore, and aft parts of the ship, as well as other regions on the ship. The role of regulatory bodies and their regulations in ship constructions is thoroughly explained, as well as the methodology for scantling determination, optimizing, and designing ship structures, especially from the perspective of structural safety (ship strength).

Practical teaching

Students are introduced in detail to the project of ship structures scantling determination using a specific given ship as an example. They then create this project, which consists of technical drawings and reports. In this part of the course, students choose a construction system, learn how to dimension elements using standards and regulations, and ultimately complete this project, which includes the scantling determination (and optimization) of all elements of the ship's midsection hull.

Prerequisites

Defined by the curriculum of the study program.

Learning resources

1. Theoretical lecture material (presentation).
2 Auditorial lecture material – task solution.
3. Rules and regulations for ships of the classification societies.
4. Computer room.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	18
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	7
colloquium, with assessment	0
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	20	project design	45
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 60

References

LR: Rules and regulations for the classification of ships, 2020.
BV, Rules for the classification of steel ships, 2021.
D.J. Eyres: Ship Construction, London, 1972.

Ship structures 2

ID: 1477
Responsible/Holder professor NIKOLA V. MOMČILOVIĆ
Teaching profesor(s): MOMČILOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: naval systems

Goals

The objective of the course is to enable students to understand and create projects related to the longitudinal strength of ships. Additionally, students should be equipped to understand and analyze the problem of a ship's ultimate strength. Students need to understand, identify differences and requirements, as well as to be capable of designing the structure of various types of ships (general cargo ships, container ships, bulk carriers, and others).

Learning outcomes

1. Students will be capable of applying comprehensive knowledge from fundamental natural, technical sciences (notably: strength of materials, strength of structures, engineering materials) and engineering principles to solving and analyzing global ship strength problems (longitudinal, ultimate, structural).
2. Students will be capable, based on the use of fundamentals of natural sciences and engineering principles, to formulate and set fundamental problems of global ship strength (longitudinal, ultimate, structural), to reach relevant conclusions, keeping in mind the limitations of the methods and the incompleteness of data.
3. Students will be able to select and apply analytical and computational methods to model fundamental problems of global ship strength (longitudinal, ultimate), considering the limitations of these methods.
4. Students will be capable of independently finding and critically using technical regulations (rules and regulations of classification societies and national registers, as well as other regulatory bodies), literature (papers, studies), and other sources of information (data obtained from shipowners, design offices, shipyards, estimated data, etc.) to solve fundamental problems of global ship strength (longitudinal, ultimate, structural).
5. Students will know how to apply a systematic approach in solving complex problems of global ship strength and ship structures.
6. Students will know how to select and apply appropriate materials, consider shipbuilding technologies and processes, and their limitations.
7. Students will be capable of communicating complex engineering issues in the context of global ship strength (longitudinal, ultimate, structural) with both technical and non-technical audiences, evaluating the effectiveness of the methods used.

Theoretical teaching

Students are introduced to the concept of global ship strength through explanations of the ship's longitudinal strength and ultimate strength, including both global and local loads acting on the ship's hull (static and dynamic). Additionally, the specificities of constructions

for different types of ships (general cargo ships, container ships, bulk carriers, and others) are explained.

Practical teaching

Students are thoroughly introduced to the project of longitudinal strength of a ship. They then independently conduct direct calculations of the longitudinal strength of a specific ship, considering all relevant loads (static and dynamic), while using the rules and regulations of classification societies. Additionally, students are introduced in more detail (compared to the theoretical part of the course) to the methods of calculating the ultimate strength of a ship.

Prerequisites

Defined by the curriculum of the study program.

Learning resources

1. Theoretical lecture material (presentation). 2 Auditorial lecture material – tasks solutions. 3. Book: M. Motok, Čvrstoća broda (in Serbian), FME Belgrade, 2005. 4. Rules and regulations for ships of the classification societies. 5. Strength of materials – tables of geometrical characteristics. 6. Computer room.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	9
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	21
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	0	project design	65
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 60

References

M. Motok: Ship Strength (in Serbian), FME Belgrade, 2005.
O.F. Hughes, J. K. Paik: Ship Structural Analysis and Design, SNAME, 2010.
J. K. Paik: Ultimate Limit State Analysis and Design of Plated Structures, Wiley, 2018.
SNAME: Ship Design and Construction, Vol I, SNAME, 2003.
M. Milovančević, N. Anđelić, V. Milošević-Mitić, M. Dunjić, D. Ružić, R. Čukić: Otpornost materijala – tablice (in Serbian), FME Belgrade, 2021.

Ship systems M

ID: 1016
Responsible/Holder professor MILAN D. KALAJDŽIĆ
Teaching profesor(s): KALAJDŽIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written+oral
Parent department: naval systems

Goals

To cover the basic knowledge of Marine Engineering connected to ship piping and pumping systems, to become familiar with ship systems (bilge, ballast, sanitary, tanker systems, fire-fighting systems, etc.) and learn the basics of their calculation and design.

Learning outcomes

The outcome of the course is to familiarize students with ship systems and the basics of their calculation and design. Students will be capable of applying comprehensive knowledge from mathematics, statistics, fluid mechanics, natural sciences, and engineering principles to solve complex problems, with a critical awareness of engineering development and broader context. They will also be able to formulate and analyze complex problems, assessing available data and using engineering reasoning to work with uncertain or incomplete information, considering the constraints of applied techniques. Moreover, students will know how to select and apply appropriate computer and analytical techniques for modeling complex problems, as well as choose and apply suitable materials, equipment, engineering technologies, and processes, respecting their limitations.

Theoretical teaching

Ship piping systems: pressure diagram, piping characteristics, characteristics of marine pumps, joint operation of pumps and a piping, suction head problems. Piping armature. Types of marine pumps. Individual ship systems: Bilge system, emergency system, rescue system; Ballast system; Heeling and trim system; Sanitary systems: system of fresh and sea water, system of waste water. Drainage system. Tanker systems: cargo system, stripping system, tank ventilation, tank cleaning, cargo circulation, cargo heating system. MARPOL Regulations. Firefighting systems: fire detection, fire-fighting systems (water, inert gases, foam, halons).

Practical teaching

Principle design and calculations of various ship piping and pumping systems. Practical examples of ship systems, illustrating the subjects lectured in theoretical syllabus.

Prerequisites

Exams passed in Fluid mechanics B or M.

Learning resources

[1] Extracts from lectures (handouts) /In Serbian/.

[2] Instructions for making tasks from ship systems /In Serbian/.
[3] Technical documentation: Examples of ship systems. Catalogues of marine pumps and armature.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	18
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 10

References

R.L. Harrington: Marine Engineering, SNAME 1992
A. Rowen et al: Introduction to Practical Marine Engineering, SNAME 2005

Skill Praxis M - BRO

ID: 1220
Responsible/Holder professor MILAN D. KALAJDŽIĆ
Teaching profesor(s): KALAJDŽIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: naval systems

Goals

The student gains practical experience in the occupational environment where he will pursue his future career. He identifies essential functions of the business system in the domain of design, development and manufacturing as well as the role and tasks of a naval architect within such business system.

Learning outcomes

The student should gain practical experience in the way of organizing and functioning of the environment where he will apply the acquired expert knowledge, identify models of communication with his colleagues and business information flows, identify fundamental processes in design, manufacturing, maintenance within the context of his future competence, establish personal contacts and acquaintances he will make use of during his schooling, or when applying for job in the future.

Theoretical teaching

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Practical teaching

Practical teaching involves work in organizations where various activities are performed that have to do with naval architecture. The student chooses thematic unit and manufacturing company or research institution after consulting the Professor. In general, the student is allowed to conduct skill praxis in: shipyards, design and consulting agencies, companies dealing with ship and machinery maintenance, or one of the laboratories at the Faculty of Mechanical Engineering. Skill praxis can be done abroad as well. The student is obliged to keep a diary of skill praxis, where he will describe jobs he is doing, record his conclusions and remarks. After he completes the skill praxis, the student makes a report and provides explanations to the Professor. The report is handed over in the form of a seminar work.

Prerequisites

It is only recommended to students MODULE OF NAVAL ARCHITECTURE

Learning resources

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	60	seminar works	10
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 10

References

M.Kalajdžić - Skill Praxis M-BRO - Electronical publication, Faculty of Mechanical Engineering, Belgrade 2021

Software application in Ship design

ID: 1564
Responsible/Holder professor MILAN D. KALAJDŽIĆ
Teaching profesor(s): KALAJDŽIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: naval systems

Goals

The aim of the course is to cover the application of software packages for ship design and basic calculations in shipbuilding. With the help of software packages, the student should analyze and optimize the ship from the perspectives of safety, efficiency, and environmental acceptability.

Learning outcomes

Acquisition of practical knowledge in the application of computer programs for ship form development, hydrostatic and hydrodynamic calculations, optimization of ship form using CFD, prediction of ship engine power, selection of ship construction elements, ship behavior in waves, and ship design.
The student will be equipped to apply comprehensive knowledge from mathematics, statistics, natural sciences, and engineering principles to solve complex problems, supplemented by critical awareness of engineering development and broader engineering context, including formulating, analyzing, and evaluating available data to draw informed conclusions and applying engineering reasoning when dealing with uncertain or incomplete information in ship design.
The student will be able to choose and apply appropriate computational and analytical techniques for modeling complex problems, apply an integrated or systemic approach to problem-solving, and use practical laboratory and workshop skills for problem investigation, considering constraints of applied techniques in the domain of shipbuilding.

Theoretical teaching

Concepts and fundamental aspects of applying computer programs and commercial software packages for shipbuilding. During the course, the application and demonstration of the use of some basic and advanced software packages related to ship geometry, ship lines, hydrostatic and hydrodynamic calculations, optimization of ship form using CFD, prediction of engine power, construction, maneuvering, and ship behavior in waves are explained and demonstrated.

Practical teaching

Students are trained to work with existing software packages in order to solve practical engineering problems related to ship geometry, ship lines, hydrostatic and hydrodynamic calculations, optimization of ship form using CFD, prediction of engine power, construction, maneuvering, and ship behavior in waves. The instruction takes place concurrently with the Ship Design course, allowing students to apply software in their project tasks.

Prerequisites

Exams passed in Buoyancy and Stability of Ship 2, Ship Resistance, Ship Propulsion, Ship Structures 2.

Learning resources

[1] Extracts from lectures (handouts) and prepared instructions for software usage /In Serbian/
[2] Support for software packages: STAR CCM+, AutoCAD, Rhinoceros, DelftSHIP, AutoShip (ModelMaker, AutoHydro), HydroComp.
[3] Internet resources.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	10
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	50
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

M. Kalajdžić - Written Lecture Notes and Prepared Software Usage Instructions - Electronic Edition, Faculty of Mechanical Engineering, University of Belgrade, 2022
DELFTshipTM user manual, 2023.
AutoCAD user manual, 2023.

PHYSICS AND ELECTRICAL ENGINEERING

Biomedical instrumentation and equipment

Electric Machinery

Electronics

Biomedical instrumentation and equipment

ID: 1323
Responsible/Holder professor TOMISLAV M. STOJIĆ
Teaching profesor(s): LUKIĆ PETAR; STOJIĆ TOMISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: physics and electrical engineering

Goals

Introducing to standard measuring and diagnostically medical methods and implementation of electron devices in medicine. The focus is on the principles and operation methods of the biomedical equipment with brief description of device construction and function of some devices. The subject educates engineers to work together with other experts to improve existing and develop new biomedical equipment.

Learning outcomes

By attending the course, students will be educated to understand and analyze problems concerned with operation and usage of biomedical instrumentation and equipment. This course educate students to connect basic principals of electronics, physics and medicine and to practically implement them into modern medical equipment.

Theoretical teaching

Principles of medical measurements and instrumentation. Sensors for biomedical measurements. Electric and magnetic stimulators. Ultrasound in medicine - overview of the diagnostically methods: tomography, cardiosonography, measurement of blood flow (Doppler). Methods based on medical imaging - Rontgen, computer tomography, Anger camera, nuclear magnetic resonance, positron emitting tomography, thermograph. Medical image processing. Medical image generation: digital and digitalized image. Basic methods for image processing.

Practical teaching

Basic principles of medical measurements and instrumentation. Overview of the sensors and their characteristics that are used for biomedical measurements. Basic modules of the electric muscle stimulator - presentation. Ultrasound in medicine - overview of the diagnostically methods: tomography, cardiosonography, measurement of blood flow (Doppler). Generating of the medical image - examples. Digitalization of analogous image. Medical image processing. Basic methods for image processing. Basic methods for digital medical image improving. Morphology methods for image processing. Practical examples from clinical practice.

Prerequisites

mandatory Electrical engineering and preferably Electronics

Learning resources

Printed excerpts from lectures (handouts) /In Serbian/

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	25
laboratory exercises	0
calculation tasks	0
seminar works	3
project design	0
discussion and workshop	2
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	15	seminar works	15
test/colloquium	35	project design	0
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

P. Lukić, Analog electronics fundamentals, Faculty of Mechanical Engineering, University of Belgrade, 2015, ISBN 978-86-7083-855-0, /In Serbian/
Mirjana Popović, Milica Janković, Dejan Popović: Biomedical measurements and instrumentation, Akademska misao, Beograd, 2009., ISBN: 978-86-7466-371-4, /In Serbian/
Joseph D. Bronzino (editor): The Biomedical Engineering - Handbook, CRC Press, IEEE Press, USA, 1995.
D. B. Kandić: Electro technique, Faculty of Mechanical Engineering, Belgrade,2002.
D. M. Škatarić, N. V. Ratković, T. M. Stojić, P. M. Lukić: Solved Numerical Problems in Electro technique, Faculty of Mechanical Engineering, Belgrade, 2000.

Electric Machinery

ID: 0401
Responsible/Holder professor DOBRILA M. ŠKATARIĆ
Teaching profesor(s): ŠKATARIĆ DOBRILA; STOJIĆ TOMISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: physics and electrical engineering

Goals

Understanding and accepting basic laws in electric machinery; according to this knowledge students will be able to describe and recognize some important problems in many engineering fields: mechanical engineering, bio-medicine, food processing industry, and power engineering. The students will meet during the course different types of electric machines.

Learning outcomes

Upon successful completion of this course, students should be able to:
1) adequately recognize, mathematically describe and understand the most important types of electrical machinery and processes in them;
2) adequate mathematical express and quantify different physical quantities that describe the operation of electrical machines;
3) recognize the need for the application of appropriate electrical machine to the requirements of real engineering problems; define the basic data required to communicate with other professions;
4) recognize on the basis of the acquired knowledge the actual existing electrical drives and perform elementary diagnostics of possible failures of electrical machines.
Checking outcomes listed under items 1) and 2) is done via computational tests and exam, as well as via student answers to the questions.
Checking outcomes cited under 3) and 4) is based on individual problems addressed to each student to be solved.

Theoretical teaching

Magnetic circuits: Intro,basic components, permeability and hysteresis.
Transformers: power transformers, autotransformers, measuring transformers; basic equations, measurements, connections.
Electro- mechanical systems; energy conversion principles; force and torque equations.
Dc Machines: motors and generators; basic equations, moment characteristics, efficiency.
Induction motors (3 phase): principles and equations; construction; implementation.
Synchronous machines: types, construction, equations, principle of operation, implementation.
Single phase induction motors : specifics in construction and operation
Step motors: construction and principles of work; implementation.
Control of electric machinery: classical and modern control principles(electronic, frequency, PLC application etc)

Practical teaching

Practical lessons include: 1) exercises on the blackboard (numerical examples and problems in general numbers) and 2) labs. Practical classes follow the curriculum of lectures, particularly transformers, polyphase induction motors, motors and direct current generators and a combination of electromechanical coupling. The making of homework is scheduled. Laboratory exercises are: 1) Measurement power of three-phase motors, 2) Demonstration of a three-phase synchronous generator, 3) Operation of three-phase asynchronous motors: basic quantities measurement, change the direction of rotation; 4) DC motor, regulation, demonstration of work.

Prerequisites

no specific conditions

Learning resources

1. Handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	5
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	15	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 35

References

Fitzgerald, Kingsley, ELEctric machinery, Naučna knjiga, 1962.
G. Dotlić, ELEKTROENERGETIKA KROZ STANDARDE ZAKONE I PROPISE, SMEITS, 2001.
Del Toro V., Electrical Engineering Findamentals, Prentice-Hall, New Jersey, 1986;

T.Stojic, D.Skataric, Electrical machines for mechanical engineering students /in Serbian/, Faculty of Mechanical engineering, Belgrade, 2015.
Nasar S., Electric Machines and Electromechanics, Schaum's Outline Series, McGraw-Hill, 1998.

Electronics

ID: 1324
Responsible/Holder professor PETAR M. LUKIĆ
Teaching profesor(s): LUKIĆ PETAR; STOJIĆ TOMISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: physics and electrical engineering

Goals

Understanding the fundamental laws of the Electronics and the attainment of competencies for the further development of the academic knowledge and skills in scientific, professional and applied engineering areas and mechanical engineering that rely on Electronics. Understanding the fundamental components and circuits that are used in Electronics and methods for their analysis, simulation and design.

Learning outcomes

Staying in the program, students acquire the ability to carry out scientific and technical activities. Mastered the methods of analysis, measurements and design, predictions and solutions consideration of consequences. Acquire an understanding of research and practical methods in the field of electronics that would adequately be able to apply in resolving concrete problems in mechanical engineering.

Theoretical teaching

Place and Role of Electronics; object of study; a brief history; electronic components and electronic circuits - some basic share; signals in electronic circuits. Fundamentals of semiconductor physics: structure of crystals, pure and doped semiconductors,electrical properties, transport processes; p-n junction: directly and inversely polarized. Semiconductor diodes: structure, role and working principle, static and approximate static characteristics, models for small and large signals, temperature effects, polarization, specific types of diodes. Bipolar transistors: structure, roles and working principle, static characteristics, polarization, models for large and small signals, Darlington configuration. Unipolar
transistors - FETs, JFET and MOSFET: structure and functioning, role and working principle, static characteristics, polarization, models for large and small signals, SiC and heterostructure based transistors. Basic circuits with diodes: half-wave and full-wave rectifiers, diode clipping and clamping circuits. Basic amplifier configurations, types and specifications, common emitter, common base and common collector amplifiers, operation analysis. Current sources: current mirror, Wilson and Widlar current source. Two-stage and multi-stage amplifiers, the designe principles and operation analysis. Negative feedback: concept, role and types; amplifier with negative feedback amplification and its impact on the characteristics of amplifiers, design principles. Circuits with operational amplifier: operational, differential, inverting, non-inverting amplifier, differentiator, integrator, voltage to current and current to voltage converters, precision rectifiers. Complex circuits - design principles. Linear oscillators roles and types, operation principles, the condition of

oscillation,Wien bridge oscillator, Hartley and Colpitts oscillator.

Practical teaching

For auditory exercises are being selected numerical examples that follow the curriculum of lectures. Special attention is paid to the analysis of the work of individual electronic circuits, the roles of the individual components in circuits, reviewing of electronic circuits as functional units, but also recognizing the individual characteristic assemblies inside the circuit. The starting point is the easiest circuits, and then tends that students independently, combining smaller units, designed more complex circuits. There is a possibility of laboratory exercises: basic applications of diodes (rectifiers, limiters);common emitter amplifier (adjusting setpoints and recording frequency characteristics); selected circuits with operational amplifiers.

Prerequisites

Defined by study program curriculum.

Learning resources

1. Petar M. Lukić: "Fundamentals of Analog Electronics", Faculty of Mechnaical Engineering, University of Belgrade, Belgrade, 2015, ISBN 978-86-7083-855-0

2. Jacob Millman, Arvin Grabel:"Microelectronics", Second Edition, McGraw-Hill Book Company, 1987.
3. Rifat M. Ramović, Rajko M. šašić: "Analysis and modeling of Small Dimensiones Unipolar Transistors", DINEX, Belgrade, 1999.
4. Dejan B. Živković, Miodrag V. Popović: "Impulse and Digital Electronics", Faculty of Electrical Engineering, Nauka, Belgrade, 1992.
5. Slavoljub Marjanović: "Electronics - Discrete and Integrated Analog Circuits", 5th Edition, Faculty of Electrical Engineering, Nauka, Belgrade, 1992.
6. Spasoje Tešić, Dragan Vasiljević: "Fundamentals of Electronics", Građevinska knjiga, Belgrade, 2009., ISBN 978-86-395-0572-1
7. A. Sedra, K. C. Smith: "Microelectronic circuits", 6th Edition, Oxford University Press, NY, 2011, ISBN 978-019-973851-9
8. Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	8
calculation tasks	0
seminar works	2
project design	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	9
test, with assessment	3
final exam	3

discussion and workshop	0
research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	65
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Petar M. Lukić: "Fundamentals of Analog Electronics", Faculty of Mechnaical Engineering, BU, Belgrade, 2015, ISBN 978-86-7083-855-0
Jacob Millman, Arvin Grabel:"Microelectronics", Second Edition, McGraw-Hill Book Company, 1987.
Spasoje Tešić, Dragan Vasiljević: "Fundamentals of Electronics", Građevinska knjiga, Belgrade, 2009., ISBN 978-86-395-0572-1
Rifat M. Ramović, Rajko M. šašić: "Analysis and modeling of Small Dimensiones Unipolar Transistors", DINEX, Belgrade, 1999.
A. Sedra, K. C. Smith: "Microelectronic circuits", 6th Edition, Oxford University Press, NY, 2011, ISBN 978-019-973851-9

PROCESS AND ENVIRONMENTAL PROTECTION ENGINEERING

Air Pollution Control

Analysis and risk management in process industries

Biotechnology

Chemical and Biochemical Operations and Reactors

Combustible, technical and medical gases

Design of fire protection systms

Design, construction and operation of processing systems

Draying and drayers

Economic analysis in process engineering

Energy in process engineering

Furnaces and boilers in industry

Heat exchangers

Heat transfer operations and equipment

Maintenance in process industry

Mass transfer and equipment

Measurements and Control in Process Industry

Mechanical and hydromechanical Operations and Equipment

Principles of environmental and work space protection

Processes and Equipment for water treatment

Skill praxis M-PTH

Technical legislation

Transport phenomena in process industry

Waste and wastewater management

Air Pollution Control

ID: 0124
Responsible/Holder professor DEJAN B. RADIĆ
Teaching profesor(s): RADIĆ DEJAN; OBRADOVIĆ MARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

The goal of course is a review of basic design devices used in facilities whose purpose is the air pollution control. This is achieved through a review of the basic construction of apparatus for the purification of gases and review of methofdology for calculations commonly used types of these devices. In this way the student masters the skills of designing these facilities and individual devices.

Learning outcomes

Upon completion of the course is expected that the candidate has mastered the skills related to analysis and evaluation of application of air pollution control devices for a particular purpose. The knowledge that the student acquire the specific technical solutions, selection of treatment methods and equipment enabling the understanding of basic principles essential for the design of air pollution control installations and calculation of particular devices.

Theoretical teaching

Apparatus for particulate emission reduction – Inertial and gravitational devices, centrifugal separators, electrostatic precipitators, fabric filters.
Apparatus for wet particulate and gas emission reduction – Spray towers, scrubbers (spray, cyclone, baffle, impigment etc), venturi scrubber.
Dry, wet and semidry gas emission control – wet scrubbers, absorbers, adsorbers, packed bed absorbers, condensers.
SOx, NOx and VOC control.

Practical teaching

Design of settling chambers.
Design of centrifugal separators.
Design of fabric filters.
Design of wet scrubbers.
Desing of Venturi scrubbers.
Material balances of air pollution control devices.
Design od apsorbers for gas cleaning.
NOx removal devices.
VOC removal devices.
Laboratory – measurement of particulate and gas emission.

Prerequisites

Defined by curriculum of study program/module.

Learning resources

1. Experimental installation for air emission measurements, Laboratory for process engineering (room 6) EOP-LPI
2. Devices and apparatus for for air emission measurements, Laboratory for process engineering (room 6) EOP-LPI

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	11
laboratory exercises	1
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	15	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	15	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

S.Calvert, H.M.Englund, Handbook of Air POLUUTION Technology, John Wiley & Sons, 1984.
C.C.Lee, S. D. Lin, Handbook of Environmental Engineering Calculations, Second Editions, Mc Graw Hill, 2007.
Kuburović, M., Jovović A., Stanojević, M., Karan, M., Radić, D., Petrov, A.: Environmental protection (Chapter 15), Termotehničar, Interklima – V. Banja, SMEITS–Belgrade, 2004.
Vuković, D, Bogner, M.: Cleaning technique, SMEITS, Belgrade, 1996.

Analysis and risk management in process industries

ID: 1180
Responsible/Holder professor SRBISLAV B. GENIĆ
Teaching profesor(s): GENIĆ SRBISLAV; ARANĐELOVIĆ IVAN; IVOŠEVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: process and environmental protection engineering

Goals

Introducing students with risk analysis, risk management and risk engineering in the field of process industries

Learning outcomes

Students will overcome the basic concepts in the field of risk analysis, as well as the engineering approach to risk management

Theoretical teaching

1 Classification of industrial risks
2 Basic elements of risk in process plants
3 The physical quantities on the basis of which the risk is assessed: temperature, pressure, concentration
4 Classification of hazardous materials and processes
5 HAZOP and DOW procedures for risk assessment
6 Zone of danger of fire and explosions

Practical teaching

1 Auditorial exercises
2 Development of study on hazard area
3 Creating a HAZOP or DOW elaborate for risk assessment

Prerequisites

-

Learning resources

-

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	10
elaboration and examples (revision)	2

OTHER	
knowledge checks	**6**
assessment of calculation tasks	2
check and assessment of lab reports	0

active teaching (practical)	**12**	check and assessment of seminar works	0
auditory exercises	8	check and assessment of projects	0
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	4	test, with assessment	2
seminar works	0	final exam	2
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 0

References

Towler G., Sinnott R. K., Chemical Engineering Design, Elsevier, 2008.

Biotechnology

ID: 1264
Responsible/Holder professor NIKOLA V. KARLIČIĆ
Teaching profesor(s): KARLIČIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

The purpose of subject is for students to get knowledge about basic processes and equipment, which is used in biotechnology. Through the semester students' projects, students get creative and specific practical skills for construction of process equipment. The laboratory exercises have the aim to give appropriate knowledge to students about examination of process equipment during the production as well as the exploitation process.

Learning outcomes

After successful course attending students get ability for: analysis, synthesis and predicting solutions and consequences; developing of critic and self critic thinking and approach; practical knowledge implementation; professional ethic; connecting knowledge from different subjects and their implementation; developing skills and abilities for knowledge implementation in adequate area.

Theoretical teaching

1. Basics of biotechnology (definitions, products and raw materials), 2. Basics processes and designing of biotechnology, 3. Bioreactors (continuous, batch), 4. Processes and equipment of biotechnology, 5. Processes, equipment and materials for sterilization processes (thermal and mechanical processes), 6. Mathematical modeling of fermentation processes (Monod equation, stoichiometry of bioprocess), 7. Biotechnological processes for waste materials treatment (waste water: bioaeration tanks, biofilters, biodiscs; solid waste: composting, landfills), 8. Treatment of waste materials in anaerobic processes (digesters, landfills), 9. Biotechnological processes for gas cleaning.

Practical teaching

1. Basic products of biotechnology, 2. Raw materials in biotechnological processes, 3. Selection of bioreactors construction, 4. Construction characteristics of bioreactors, 5. Laboratory exercise: Determination of aerator characteristics in bioreactors with aeration agitation, 6. Determination of thermal sterilization process parameters, 7. Equipment for sterilization processes, 8. Biological treatment methods of domestic, industrial and agricultural waste, 9. Biotechnological equipment for waste water treatment, 10. Design of bioreactors – anaerobic digesters.

Prerequisites

Compulsory course. There is no specific requirement for course attending.

Learning resources

Laboratory facility for determination of aerator characteristics in bubble aeration bioreactors, Laboratory of process technique (room 6), LPT

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	19
laboratory exercises	6
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10
test/colloquium	10	project design	0
laboratory exercises	5	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 16

References

Kuburović, M., Stanojević, M.: Biotechnology – processes and equipment, Edition "Process technique", SMEITS, Belgrade, 1997., KPN
Bogner, M. at all.: Handbook of thermal technique, Interklima grafika, Vrnjačka Banja, 2003
Rehm, H. J., Reed, G., Brauer, H.: Biotechnology, Vol. 2, Fundamentals of Biochemical Engineering, VCH Verlagsgesellschaft, mbH, Weingeim, 1985.
Jackson, A. T.: Proces Engineering in Biotechnology, Open University Press, Buckingham, 1990.
Veljković, V.: Basics of biochemical engineering, Faculty of technology, Leskovac, 1994.

Chemical and Biochemical Operations and Reactors

ID: 0301
Responsible/Holder professor DEJAN B. RADIĆ
Teaching profesor(s): RADIĆ DEJAN; OBRADOVIĆ MARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

The purpose of subject is for students to get knowledge about theories of kinetic and dynamic of physical-chemical transformations in various technological processes. Influence of process parameters to gaining conditions for physical and chemical equilibrium is separately considered. Getting knowledge about basic models of chemical reactors, types of chemical reactions, rules used for qualitative and quantitative description of complex physical-chemical phenomenon and mass and heat balance equation, gives students basic for independent projecting of technologies and systems of process industry.

Learning outcomes

Successful completion of the study program the student acquires the knowledge necessary to understand the kinetics of chemical reactions and to master the methodology of calculation of chemical processes and reactors. Introduction to basic models of chemical reactors and material equations and thermal balance should allow students to independently analyze the real process, that the application of engineering and scientific methods to be able to design processes and systems.

Theoretical teaching

Classification of chemical reactions. Mechanism of complex chemical reactions. Chemical equilibrium. Chemical equilibrium constant. Influence of process parameters on chemical equilibrium and chemical reaction. Material and heat balance of chemical reactions. Heats and free energies of formation. Enthalpy, entropy and free energy. Half life. Degree of conversion.
Kinetic equation of chemical reaction. Rate of chemical reaction. Order of chemical reaction. Basic principles of design of heterogeneous systems. Rate constants of complex reactions. Classification and models of chemical reactors. Ideal chemical reactors. Material and heat balance of reactor. Batch reactors. Continuous stirred-tank reactors. Plug flow reactors. Cascade of continuous ideal reactors. Analysis of rate equations. Analysis and modeling of chemical reactors. Design of chemical reactors and processes.

Practical teaching

Calculations of multicomponent and multiphase systems. Determination of chemical equilibrium constant.
Basic principles of thermodynamic for chemical reactions. Heat effect of chemical reactions. Exothermic and endothermic chemical reactions.
Analysis of complex chemical reactions.

Calculation of the rate of chemical reaction. Order of chemical reactions.
Design of chemical reactors and processes – material and heat balances.
Calculations of ideal reactors (batch reactors, continuous stirred-tank reactors, plug flow reactors, cascade of continuous ideal reactors).
Comparation and selection of type of reactor.
Chemical reactor plant. Process optimization.

Prerequisites

Defined by curriculum of study program/module

Learning resources

1. Levenspeil, O.: Chemical reaction engineering, serbian translation, Belgrade, 1991.
2. Ворошец, Д., Кубуровић, М.: Thermodynamics of multicomponent systems and chemical thermodynamics, Faculty of mechanical engineering, Belgrade, 1991.
3. Perry's Chemical Engineering Handbook, Mc-Graw Hill, 1999.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	2
calculation tasks	8
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	7
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	25	project design	0
laboratory exercises	5	final exam	50
calculation tasks	10		

Requirements to take the exam (number of points) 28

References

Смирнов, Н.Н., Волжинскии, А.И., Химические реактори в примерах и задачах, Химија, Ленинград, 1986.
Coulson, J. M., Richardson, J. F.: Chemical Engineering, Vol. 3: Chemical Reactor Design, Biochemical Reaction Engineering including Computational Techniques and Control,

Pergamon Press, Oxford, 1982.
Smith, J.M., Van Ness, H.C., Addott, M.M.: Chemical Engineering Thermodinamics, McGraw International Edition, ISBN: 0-07-240296-2, 2001.
Walas S. M.: Chemical Process Equipment, Selection and Design, Butterworth-Heinemann, 1990.

Combustible, technical and medical gases

ID: 0511
Responsible/Holder professor DEJAN B. RADIĆ
Teaching profesor(s): RADIĆ DEJAN; KARLIČIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

The aim of this course is to familiarize students with the fuel characteristics, technical and medical gases, and to acquire academic skills and competencies for selection and calculation of equipment of gas installations. Through this course student mastery specific practical skills for work in the design and calculation of pipelines and fittings, storage tanks and other equipment for gas. Through laboratory student acquire knowledge related to testing of equipment for gas.

Learning outcomes

Successful completion of the study program the student receives the following general skills: analysis, synthesis and forecasting solutions and consequences, and develop critical thinking and self-critical approach, application of knowledge in practice, professional ethics, linking knowledge from different fields and their applications, development of skill and dexterity in the use of knowledge in the field of distribution and transportation of natural gas storage and technical gases.

Theoretical teaching

Natural gas, LPG, other fuel gases. Types and equipment for Gas Pressure Regulating Stations and Gas Pressure Regulating and Metering Stations. Types of devices for inner gas installations, safety equipment, removal of combustion products. Technical gases: air, atmospheric gases, hydrogen, chlorine… – characteristics and applications. Equipment of installations for storage and distribution. Production of atmospheric gases. Cleaning and preparation of installations. Gas bottles an tanks for gas storage, pilot regulators, gas pressure regulators, safety blow – off and relief valves, check valves, gas filters, heat exchangers, pipe insulating connections, control device accessories , odorizers , ball valves , electromagnetic valves, flow rate regulators, gas regulating and metering stations.

Practical teaching

Gas composition, pressure drops, odorisation. Pipe sizing, level of security, material characteristics. Classification and elements of gas pipelines. Hydraulic calculation of gas pipelines. Gas pipeline equipment. Testing of installation of natural gas, LPG, other fuel gases and technical (industrial) gases. Calculation and sizing of equipment (pressure regulators, safety valves, apparatus…). Capacity of Gas Pressure Regulating Stations and Gas Pressure Regulating and Metering Stations. EN and ISO standards. Gas purification. Danger zones.

Prerequisites

Defined by curriculum of study program/module.

Learning resources

Given that for the subject has not yet completed a textbook, materials for lectures in printed and electronic form are given to students.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	7
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	25	project design	15
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 28

References

M. Šunic, N. Dujmović: Gas and gas technique, 1981
S. Raketić: Gases, Technical gases – fuel gases, regulations and security measures, 1985.
Strelec, V: Gas manual, Nafta – Poslovna zajednica, Zagreb, 1982.
Bogner, M. i dr.: Termotehničar, part 2, Interklima-Grafika, Vrnjačka Banja, SMEITS, Belgrade, 2004.
Tanasković, P.: Crude oil and gas transport, part III – LPG, Nafta-Gas, Novi Sad, 1976.

Design of fire protection systms

ID: 1373
Responsible/Holder professor MILOŠ M. IVOŠEVIĆ
Teaching profesor(s): IVOŠEVIĆ MILOŠ; ARANĐELOVIĆ IVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: process and environmental protection engineering

Goals

Introducing students with fire safety analyzes, preventive regulations on fire protection, fire characteristics of industrial objects and buildings, fire extinguishers and installations for smoke ventilation

Learning outcomes

Students will be able to overcome the basis of fire safety analyzes, preventive regulations on fire protection, fire characteristics of industrial objects and buildings, fire extinguishers and installations for smoke ventilation

Theoretical teaching

1 Overview of technical regulations in the field of fire protection
2 Fire characteristics of industrial objects and buildings
3 Fire extinguishers
4 Stable and mobile fire extinguishing systems
5 Installations for smoke and heat removal

Practical teaching

1 Practical exercises
2 Calculation of the fire characteristics of industrial objects and buildings
3 Fire risk assessment
4 Design of fire extinguishing installations
5 Design of installation of smoke and heat

Prerequisites

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Learning resources

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NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING		OTHER	
active teaching (theoretical)	18	knowledge checks	9

lectures	10	assessment of calculation tasks	0
elaboration and examples (revision)	8	check and assessment of lab reports	1
active teaching (practical)	**18**	check and assessment of seminar works	0
auditory exercises	1	check and assessment of projects	3
laboratory exercises	2	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	15		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Erić M., Fire and preventive technical protection (In Serbian), Jel & Mil, Čačak, 2003.

Design, construction and operation of processing systems

ID: 0363
Responsible/Holder professor ALEKSANDAR L. PETROVIĆ
Teaching profesor(s): PETROVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

Objective of the course is to introduce students to different stages of construction, from technical documentation preparation and obtaining the necessary approvals to construction and exploitation. Students learn about with the contents of the project. In the second part of the course acquire basic knowledge related to activities that follow design of processing industry facilities (power supply, operating fluids, transport, water flow etc.). Part of the course deals with the economic evaluation of investments.

Learning outcomes

Main outcome of the course is to teach students to independently run object construction. This includes project documentation preparation and object construction. After successful completion of the study program, student is capable to foresee the extent of necessary design work in processing industry, as well as to plan necessary installation for production plants.

Theoretical teaching

Legal framework for building facilities. Planning and Construction Law. Aim of design. Building capital investment facilities. Types of mechanical engineering projects. Content of a mechanical engineering project. Workplace safety. Fire protection. Environment protection. Assessment of impact on environment. Design of technology supported production line. Drawing schemes of technology systems and production systems. Marking of apparatus, valves, fittings and equipment for measuring and regulation on technological schemes. Technology warehouses and transport systems. Plants for energy supply. Basic forms of energy: heat (thermal), electrical and mechanical (potential and kinetic energy). Power systems. Operating fluids (water, air, technical gases).Distribution of water vapor. Compressed air and technical gases. Heating, air-conditioning and ventilation. Maintenance of production and technology systems. Assessment of services in building capital investment facilities. Investment costs. Feasibility study. Exploitation costs.

Practical teaching

Introduction to the investment technical documentation. Introduction to the format of mechanical engineering projects. Examples of calculation of technology supported production lines. Examples of drawing technology systems schemes. Designing warehouses and transport systems. Power supply systems. Compressed air supply. Design of facilities for energy supply. Distribution of operative fluids. Budget and validation of investment. Exploitation and investment costs of facility operation. Independent realization of the main machine engineering project according to the predefined project task.

Prerequisites

Defined with curriculum of study program / module

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	5
calculation tasks	5
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	3
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	5	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Handouts
Perry's Chemical Engineering Handbook, Mc-Graw Hill, 1999.
Bogner M.: Design of thermotechnical and process systems, Third revised edition, Belgrade, 2007., KDA.

Draying and drayers

ID: 1063
Responsible/Holder professor MARKO O. OBRADOVIĆ
Teaching profesor(s): OBRADOVIĆ MARKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

Students will be introduced to technical bases of materials drying process. The goal of this course is a review of the dryers basic constructions. Through this course students acquire skills and knowledge to recognize problems that occur in complex drying processes.

Learning outcomes

Successful completion of the study program student acquires specific skills in function of quality performance of professional activities. It is anticipated that students acquire knowledge on specific technical solutions in the fields of drying materials, as well as being able to analyze complex technical solutions.

Theoretical teaching

The definition of the drying process, classification, application and importance of processes and equipment for drying, the definition of basic parameters, measuring of mass moisture content.
Statics of the drying process,
Kinetics of the drying process,
Kinetics of convective drying of wet materials. The curves of drying kinetics, Experimental determination and aproach. The drying speed curves,
Design of dryers,
General settings in the design of drying, basic requirements for drying, dryers constructions and selection of accessories for drying; choice of drying agent and the heat carrier,
Balancing processes,
Material and energy balance of dryer, Theoretical and real drying, Graphical presentation of process in a dryer,
Heat balance calculaton of dryers,
Heat balance calculation of dryers using the "enthalpy-composition" and "enthalpy-temperature" diagrams; hot air and diluted exhaust gas drying and convective dryers efficiency,
Types and classification of dryers constructions,
Auxiliary dryers equipment,
Techno-economic indicators of dryers operation.

Practical teaching

Basic terms and parameters,
Basic calculations in the drying processes,

The calculation of basic characteristics of wet air,
Calculation of material and energy balance,
Calculation of material and energy balance of theoretical and real dryer in hot air and diluted exhaust gas drying processes (drying agent flow, heat consumption, the coefficient of heat transfer, consumption of heated steam, plant efficiency)
Calculation of material and energy balance of theoretical and real dryier during the process of air preheating as a drying agent, as well as drying agent recirculating,
Selection and dimensioning of dryers,
Determination of drying thermograms (convective drying kinetics) in static-layer,
Determination of moisture adsorption of silica gel,
Determining the proportion of moisture in the exhaust flue gas ducts,
Development of technical documentation,
Preparation for development of technical documentation, Development of technical, (constructional) documentation: Selection and sizing dryers, equipment specifications and graphic documentation.

Prerequisites

There are no requirements to attend courses, in terms of the previously passed courses.

Learning resources

Obradović M, Jovović A, Karan M, Đurić S, Radić D, Stanojević M, Todorović D, Karličić N, Kuburović M: Dryers – Theory and practice, Union of Mechanical and Electrotechnical Engineers and Technicians of Serbia (SMEITS) and University of Belgrade, Faculty of Mechanical Engineering, 2019. (ISBN 978-86-81505-95-3)
Laboratory facility / installation / machine (LFI):
Laboratory dryer with auxiliary equipment,
Laboratory measurement system (LMS),
Equipment for determining proportion of moisture in the air,
Equipment for determining proportion of moisture in the flue and waste gases.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	11
laboratory exercises	3
calculation tasks	4
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	20	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

Обрадовић М. и др: Сушаре - Теорија и задаци, Машински факултет у Београду и СМЕИТС, 2019.
Владимир Валент: Сушење у процесној индустрији, Технолошко-металуршки факултет, Београд, 2001.
Димитрије Ворошец, Ђорђе Козић: Влажан ваздух - термодинамичке особине и примена, СМЕИТС, Београд, 2002.
Радивоје Топић: Основе пројектовања, прорачуна и конструисања сушара, Научна књига, Београд, 1989.
Robert E. Treybal: Mass-transfer operations, third edition, McGraw-Hill International book company, 1981.

Economic analysis in process engineering

ID: 1061
Responsible/Holder professor SRBISLAV B. GENIĆ
Teaching profesor(s): GENIĆ SRBISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: process and environmental protection engineering

Goals

Familiarize students with the basic concepts of economic analysis, through the study of the capital and operating costs, shortcut methods of economic optimization and economic analysis of investment.

Learning outcomes

Students will be able to:
* calculate the investment costs
* calculate the operating costs
* determine the economic parameters of investment profitability
* use the shortcut procedures for determining of the optimal pipeline diameter and optimal insulation thickness

Theoretical teaching

Types of design documentation and typical economic analysis
The basic functions of the equipment in process facilities
Capital costs
Operating costs
Economic analysis of investment
Shortcut economic evaluations: optimal diameter of pipeline, optimal thickness of insulation

Practical teaching

Practical examples of calculation of:
* capital costs
* operating costs
* economic parameters for investment analysis
* the optimal diameter of pipeline and the optimal insulation thickness using shortcut methods.

Prerequisites

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Learning resources

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	10
elaboration and examples (revision)	2
active teaching (practical)	**12**
auditory exercises	7
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	2
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Genić S., Jaćimović B., Mitić S., Kolendić P., Economic analysis for process engineering (in Serbian), SMEITS, Beograd, 2014.

Energy in process engineering

ID: 1059
Responsible/Holder professor MIRJANA S. STAMENIĆ
Teaching profesor(s): STAMENIĆ MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: process and environmental protection engineering

Goals

Mastering the basic knowledge and skills of using the energy in process industry in order to adequately deal with the practical matters of rational use of energy and maintenance of energy equipment and systems in industrial companies. In addition, basic knowledge of the transformation and energy use are essential for the understanding of matter from other subjects of process engineering and environmental protection.

Learning outcomes

Understanding the operation of energy equipment and technologies and principles of their rational use. Preparation of the energy balance of industrial companies; implementation of energy auditing procedure, energy data collection and implementation of methodology for defining the energy losses of equipment and installations in industrial plants.Understanding basic terms within Energy Management System (ISO 50001:2011). Basic concept of BAT (Best Available Techniques) in energy efficiency in industrial plants.

Theoretical teaching

1. Energy, energy transformation and utilization of energy in production processes in industry (general concepts on energy sources and energy reserves; an overview of energy consumption and energy systems in industrial plants, energy balances of industrial companies).
2. Energy sources in industrial companies (power supply of industrial plants, boilers and boiler rooms, the combined heat and power production in industry, energy requirements for production processes).
3. Utilization of fuels in industry (distribution of fuels, combustion systems, combustion and basics of combustion efficiency).
4. Steam as energy carrier (steam characteristics, processes and equipment that uses steam in the process industry; characteristics of distribution systems for steam and condensate return).
5. Compressed air (systems for compressed air supply in industrial companies, distribution of compressed air, quality and preparation of compressed air, energy efficiency improvements in compressed air system).
6. Energy efficiency in lighting systems in industrial companies.
7. Financial analysis of energy efficiency measures for energy utilities in industrial companies.

Practical teaching

1. Preparation of energy balance (methodology of collecting data on energy consumption in

industrial companies; examples of energy balance of selected companies).
2. Review of energy systems in process engineering and calculation of coefficient of efficiency (power supply of industrial plants; boilers and boiler rooms, the combined heat and power production in industry, energy requirements of production processes).
3. Calculation of energy losses in distribution systems for steam and condensate return (steam quantity used for the production process; calculation of energy losses through the pipeline walls; calculations of energy losses in case of improper drainage of condensate).
4. Calculations of energy losses in industrial equipment that use the fuel (e.g. calculation of the combustion process, calculation of flue gas waste heat).
5. Calculation of energy losses of compressed air system.
6. Possible energy savings within lighting system.
7. Financial analysis of proposed energy efficiency measures in energy utilities in industrial companies.
8. Preparation of the seminar work - Energy Audit in selected industrial company (students doing their paper work and calculations, with the help of teaching assistant; they are obliged to prepare written report on energy audit within one selected industrial company as well as power point presentation). Seminar work will be done in teams.

Prerequisites

Defined in curriculum of the module

Learning resources

Selected chapters form Industrial furnaces and boilers - manual with solved examples(chapters 1, 2 and 3),
Lecture layouts,
Guidelines for solving problems, guidelines for preparation of reports on laboratory work, guidelines for preparation of seminar work,
Additional literature - Brochures and Newsletters in edition of Serbian Industrial Energy Efficiency Network (SIEEN); Manual for training of energy managers within industrial energy systems.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	14
elaboration and examples (revision)	4
active teaching (practical)	**18**
auditory exercises	0
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	13
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	10	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Jankes, G., Stanojević, M., Karan, M., Stamenić, M.: Industrial furnaces and boilers – manual with solved calculation problems, Faculty of Mechanical Engineering, Belgrade, 2001.
Jankes, G., Stamenić, M. et al.: Manual for energy efficiency improvements and energy conservation in industry, Innovative Center of Faculty of Mechanical Engineering – SIEEN, Belgrade, 2009.
Genić, S., Stamenić, M., Nikolić, A., Živković, B., Čantrak, Đ., Brdarević, Lj., Manual for energy managers training in the field of industrial energy, Faculty of Mechanical Engineering, Belgrade,2016
Jaćimović, B., Genić, S., Stamenić, M., Aranđelović, I. et al: Methods and Examples of Experimental Research in Process Engineering and Thermotehnic, Faculty of Mechanical Engineering, Belgrade, 2022

Furnaces and boilers in industry

ID: 0993
Responsible/Holder professor MIRJANA S. STAMENIĆ
Teaching profesor(s): STAMENIĆ MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

In this course students will acquire necessary knowledge and skills for designing, maintenance and operation of industrial furnaces, and basic skills required for the maintenance and operation of industrial boilers. Additionally, students will learn about methodology on energy balances and the basic principles of efficient use of energy in industrial furnaces and boilers.

Learning outcomes

Students will gain necessary skills to work on design and the organization of maintenance in industrial furnaces, and the planning of maintenance and operation of industrial boilers. Students will be trained for work on the projects for energy efficiency in industrial furnaces and boilers.

Theoretical teaching

1. Basics of combustion theory (solid, liquid and gaseous fuels).
2. Basics of heat radiation.
3. Definition and classification of industrial furnaces and boilers.
4. Elements of construction and equipment of industrial furnaces.
5. Energy balances of industrial furnaces.
6. Characteristics and specification of industrial furnaces construction (furnaces for heating and melting of metals, nonmetals industrial furnaces, ovens in the food industry, etc).
7. Application and specification of industrial boilers construction .
8. Characteristics of steam and hot water industrial boilers, boiler outlines, overview of the boilers construction, boiler furnaces and reheating surfaces, energy balance and definition of coefficient of efficiency, procedures for boiler testing.

Practical teaching

1. Examples of selected types of industrial furnaces.
2. The elements of construction and equipment of industrial furnaces.
3. Examples of material and energy balances in combustion of gaseous, liquid and solid fuels.
4. Examples of heat radiation regarding calculation of heat transfer within kiln and boiler furnaces.
5. Examples of material and energy balances of industrial furnaces.
6. Examples of energy balances of industrial boilers.
7. Calculation problems: Preparation and assignment of calculation problems; students will solve problems in classes with help of teaching assistant.

8. Description and preparation of laboratory exercises: measurement instruments and methodology, study the structure, organization of work on laboratory exercises.
9. Laboratory: measurement of energy losses in industrial furnaces in real operation: Students divided in groups will measure the parameters necessary for the calculation of energy losses in industrial furnaces in a selected company.

Prerequisites

Defined by curriculum of study program/module.

Learning resources

Material from lecture – handouts.
Solution manuals, manuals for laboratory exercises, manuals for homeworks and seminar work.
Software for the calculation of the combustion process and the development of energy balance of industrial furnaces and boilers.
Supplementary literature - Termotehničar, volume 1 and 2, Poslovna politika, Belgrade, 1992. (volume 1 - chapters 3, 5 and 6, volume 2 - chapter 4)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	24
elaboration and examples (revision)	6
active teaching (practical)	**30**
auditory exercises	8
laboratory exercises	7
calculation tasks	15
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	10	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 45

References

Termotehnicar, chapter 1 and 2, Poslovna politika, Beograd, 1992.
Jankes, G., Stanojević, M., Karan, M., Stamenić, M.: Industrial furnaces and boilers – manual

with solved calculation problems, Faculty of Mechanical Engineering, Belgrade, 2001.
Baukal, C.: The John Yink Combustion handbook, CRC company, 2001.
Ан. Л. Бергауз и др.: Справочник конструктора печеи прокатного производства, Том I и II, Металлургија. Москва, 1970.
STEAM its generation and use, 41st Edition, Babcock and Wilcox, 2005.

Heat exchangers

ID: 1549
Responsible/Holder professor SRBISLAV B. GENIĆ
Teaching profesor(s): GENIĆ SRBISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: process and environmental protection engineering

Goals

Analysis of heat transfer operations and apparatus and their role in modern industry. Getting to know the most commonly used types of heat transfer apparatuses - their construction and calculation procedures.

Learning outcomes

Mastering the calculation procedures required for the analysis of heat transfer operations - creating a heat balance, determining the operating line and driving force. Mastering the calculation procedures required for sizing the most commonly used heat exchangers.

Theoretical teaching

Classification of heat transfer operations and apparatus. General methodology for the calculation of stationary heat transfer operations and apparatus. Operational and equilibrium line, driving force of heat transfer process, number of transfer units. Stationary recuperative heat exchangers: double pipe, shell-and-tube, plate, finned tube. General methodology for calculating non-stationary heat transfer operations. Types of batch heat exchangers. Contact heat exchangers for heat transfer operations in the vapor-liquid (barometric condensers) and gas-liquid (water cooling tower) system.

Practical teaching

Examples from the field of heat transfer operations. Creation of the heat balance and determination of the operating line, the driving force of the heat exchange process, and the number of transfer units.
Dimensioning examples of the most commonly used heat exchangers: double pipe, shell-and-tube, plate, finned tube, batch exchangers, barometric condensers and water-cooling tower.

Prerequisites

-

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	OTHER

active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10
test/colloquium	30
laboratory exercises	0
calculation tasks	0

seminar works	0
project design	30
final exam	30

Requirements to take the exam (number of points) 0

References

Jaćimović B., Genić S., heat transfer operations and apparatuses, Part 1: Recuperative heat exchangers, Mašinski fakultet, Beograd, 2022.
Genić S., Jaćimović B., Jarić M., Budimir N., Properties of process fluids, Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije, Beograd, 2014.

Heat transfer operations and equipment

ID: 1057
Responsible/Holder professor SRBISLAV B. GENIĆ
Teaching profesor(s): GENIĆ SRBISLAV; IVOŠEVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

Analysis of the mass transfer operations and apparatuses and assessment of their role in modern industry.
Understanding the most commonly used types of mass transfer apparatuses - their design and calculation procedures.

Learning outcomes

The mastery of calculation procedures needed to analyze the heat transfer operations - the balance of energy, determination of the operational line and driving force.
The mastery of calculation procedures for sizing of the most commonly used heat transfer apparatuses.

Theoretical teaching

Classification of mass transfer operations and basics principles of heat-transfer operations
General calculation procedure for mass transfer operations. Operation and equilibrium line, mass transfer driving force, number of transfer units.
Stationary recuperative heat exchangers: double pipe, shell-and-tube, plate, finned tube.
General methodology for the calculation of non-stationary heat transfer operations and apparatus. Types of batch heat exchangers.
Contact heat exchangers for operations in the vapor-liquid (barometric condensers) and gas-liquid (water cooling tower) systems.
Evaporation and evaporators.

Practical teaching

Examples of mass transfer operations.
Preparation of the heat balance and determination of the operating line, the driving force of the heat exchange process, and the number of transfer units.
Dimensioning examples of the most commonly used heat exchangers: double pipe, shell-and-tube, plate, finned tube, batch, barometric condensers, water cooling tower.
Dimensioning examples of evaporators.

Prerequisites

Defined in curriculum of the study program of the module.

Learning resources

Jaćimović B., Genić S., Heat Transfer Operations And Equaipment, Part 1: Recuperative Heat

Exchangers, Mašinski Fakultet Beograd, 2016.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	24
elaboration and examples (revision)	6
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	6
calculation tasks	0
seminar works	0
project design	24
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Jaćimović B., Genić S., Heat Transfer Operations And Equaipment, Part 1: Recuperative Heat Exchangers, Mašinski Fakultet Beograd, 2016.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.
Genić S., Jaćimović B., Jarić M., Budimir N., Properties of process fluida, Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije, Beograd, 2014.

Maintenance in process industry

ID: 1062
Responsible/Holder professor NENAD R. MITROVIĆ
Teaching profesor(s): MITROVIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: process and environmental protection engineering

Goals

The objective of the course is that students acquire theoretical and practical knowledge in the field of maintenance of technical systems (concept, technology...). Through teaching activities, students acquire creative and specific practical skills that qualify them to work in the field of maintenance of equipment, machines and systems in process industry.

Learning outcomes

By successful completion of the study program student acquires the following skills: analysis, synthesis and prediction of solutions and consequences in the field of maintenance in process industry; development of critical thinking and self-critical approach; application of knowledge in practice; professional ethics; correlation of knowledge from different fields and their applications; involvement in the activities related to maintenance in the company.

Theoretical teaching

Introduction. Technical system. Maintenance of technical systems. Maintenance engineering. Basic concepts of probability and statistics. Life cycle of technical system. Maintenance process. Maintenance systems. Concept of maintenance. Modelling and optimization of maintenance system. Characteristics of maintenance system. Analysis and evaluation of maintenance system. Designing systems in terms of maintenance. Inventory management. Maintenance Management.

Practical teaching

Systematic approach to maintenance. Basic concepts of probability and statistics - examples. Maintenance technology. Maintenance procedures. Logistics. Maintenance examples of process equipment in operation (pressure vessels, heat exchangers, filters...). Examples of pipeline construction and maintenance. Writing a seminar paper.

Prerequisites

No requirements.

Learning resources

Available faculty resources (classrooms, laboratories and library) will be used for the course. Literature for the course is in the professor's cabinet, as well as at faculty's library.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	18
elaboration and examples (revision)	0
active teaching (practical)	**18**
auditory exercises	9
laboratory exercises	0
calculation tasks	0
seminar works	9
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	20	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Тодоровић Ј.: Инжењерство одржавања техничких система, Југословенско друштво за моторе и возила, Београд, 1993
Isailović M., Petrović A., Bogner M., Balać M., Mitrović N.: Propisi o opremi pod pritiskom, Eta Beograd, Beograd, 2013
Група аутора: Методи и примери експерименталног рада у процесном инжењерству и термотехници, Машински факултет, Београд, 2022

Mass transfer and equipment

ID: 1372
Responsible/Holder professor MILOŠ M. IVOŠEVIĆ
Teaching profesor(s): IVOŠEVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: process and environmental protection engineering

Goals

Analysis of the mass transfer operations and apparatuses and assessment of their role in modern industry.
Understanding the most commonly used types of mass transfer apparatuses - their design and calculation procedures.

Learning outcomes

The mastery of calculation procedures needed to analyze the mass transfer operations - the material balance, determination of the operational line and driving force.
The mastery of calculation procedures for sizing of the most commonly used mass transfer apparatuses.

Theoretical teaching

Classification of mass transfer operations and basics principles of mass-transfer operations
General calculation procedure for mass transfer operations. Operation and equilibrium line, mass transfer driving force, number of transfer units, theoretical stage.
Mass transfer operations: distillation (continuous evaporation, single stage distillation, continuous condensation, distillation with deflegmation, differential distillation, fractional distillation, differential condensation), rectification, absorption, extraction, leaching, adsorption, drying.
Mass transfer apparatuses for gas-liquid systems, liquid-liquid and solid phase - fluid. Trayed and packed columns, drying chambers, etc.
Membrane mass transfer operations and and apparatuses.
Development trends in the field of mass transfer operations and apparatuses.

Practical teaching

Examples of mass transfer operations. Mass and heat balancing. Determination of the operating line, driving force, the number of transfer units, the number of theoretical stages.
Examples of sizing of most commonly used mass transfer apparatuses: distillation column (with packing and with trays), extraction columns (with packing and with trays), adsorber (with a fixed layer of adsorbent), dryers (continuous and periodical).
Design procedures for membrane mass transfer operations and and apparatuses.

Prerequisites

Defined in curriculum of the study program of the module.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	2
laboratory exercises	2
calculation tasks	10
seminar works	0
project design	16
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	2
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Mašinski Fakultet Beograd, 2010.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Mašinski Fakultet Beograd, 2007.
Jaćimović B., Genić S., Heat Transfer Operations And Equaipment, Part 1: Recuperative Heat Exchangers, Mašinski Fakultet Beograd, 2016.

Measurements and Control in Process Industry

ID: 0477
Responsible/Holder professor DEJAN B. RADIĆ
Teaching profesor(s): RADIĆ DEJAN; TODOROVIĆ DUŠAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

Introducing the candidate with the principles of process measurement and control of the process using the measured values. After the course candidates will be capable to independently perform statistical processing of measurement results and evaluation of measurement uncertainty. The process of accreditation of laboratories and regulatory organizations.

Learning outcomes

Upon completion of the course is expected that the candidate is familiar with the basic measurements and instruments used in measurement and control in process systems. Also it is expected that the student is able to independently plan experimental measurements and work in laboratory and also to evaluate the measurement uncertainty. Basic knowledge about the accreditation of laboratories candidate receives through the consideration of the basic requirements of relevant standards.

Theoretical teaching

Basic concepts of measurement and control in the process industry. Basic measurements in the process industry. Temperature measurements. Measurement of pressure and pressure differences. Measurement of fluid flow. Types and operating principles of sensors. Other measurements in process industry: weight, level, concentration, humidity, fluid physical properties (density and viscosity). Determination of the composition of gases and concentration of particulate matter. Complex measurement systems with data acquisition. Analog and digital signals. Transferring data to a computer. The formation of the control algorithm. Basic principles of operation of the SCADA software. Application of PLC's control. Measurement error. Statistical analysis of measurement results. Traceability of measurements. Calibration of measuring instruments. The concept and method for determining measurement uncertainty. Metrology laboratories and laboratories for testing and calibration. Methods and requirements for achieving the technical competence of laboratories accredited according to SRPS ISO/IEC 17025:2006 and SRPS ISO/IEC 17020:2002

Practical teaching

Examples of certain measuring devices, devices for data acquisition and control. The realization of individual measurements in the laboratory (practical laboratory work). Processing of measured data and values and estimation of measurement uncertainty. The physical basis of determination of the measured values. Mathematical expressions that

describe the phenomena that are used to process measurements. Methods of temperature measurements, pressure and pressure difference, flow metering using orifice plate, speed measurements of gases analysis. Complex systems of measurement and control of process systems. Methods for determining the measurement uncertainty. The process of laboratory accreditation.

Prerequisites

The subject is optional. No special requirements for attending the case.

Learning resources

1. Laboratory installation for pressure and temperature measurements (manometers, inclined manemoter, pressure transmitters, U-tube, thermocouples, thermometers, acquisition system), Laboratory for Process engineering (room 6).
2. Apparatus for flow measurement (orifice plate, Pitot tube, anemometers), Laboratory for Process engineering (room 6).
3. Analysers for emission monitoring (gas analysers and equipment for emission measurements of particulate matter), Laboratory for Process engineering (room 6).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	17
laboratory exercises	13
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	0
laboratory exercises	30	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Jones, B.: Instrument technology, Volume 1, Newnes-Butterworths, London, 1976.
Boyer, S.: Supervisory Control and Data Acquisition, 2nd Edition, Instrument Society of

America, USA, 1999.
Jankes, G., Stanojević, M., Karan, M.: Industrial fournaces and boilers-Measurements in process, Mechanical faculty Belgrade, 1996.
Vušković, I.: Principles of measurements technics, Mechanical faculty Belgrade, 1977.

Mechanical and hydromechanical Operations and Equipment

ID: 0991
Responsible/Holder professor MARKO O. OBRADOVIĆ
Teaching profesor(s): OBRADOVIĆ MARKO; KARLIČIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

The objective of the course is to students get theoretical and practical knowledge of common mechanical and hydromechanical processes and the associated equipment utilized in mineral processing. Course acquaints the students with characteristics of bulk solid materials and the basics techniques for bulk solid characterization. Mechanisms and basic principles of size reduction are covered. Subject gives overview of the main unit operations with respect to comminution (crushing and grinding) and screening/classification met in nowadays practice as well as equipment used in the unit operations. The combination of unit operations and equipment into circuits is also covered, as well the calculation of the basics characteristics of the equipment used.

Learning outcomes

After completing the course the students are expected to able to calculate and use the curves for particle size distribution. Students shall know the most important unit operations in mineral processing, the mechanisms and principles of size reduction and methods used to classify particles according to their size and their characteristics. Student will be able to identify and select the equipment involved in a comminution circuit and calculate basics characteristics of the equipment. The students should know the principles for designing mineral processing circuits.
After completing the course students will be capable to apply their knowledge in the real case studies of mineral processing and will have required background knowledge for mineral concentration processes.

Theoretical teaching

1. Introduction to mechanical and hydromechanical operations, 2. Characteristics of size reduction processes, particle size and shape estimation, 3. Particle size analysis, sieve analysis, 4. Principles of comminution, comminution theory, 5. Crushing (basic principles, reduction ratio, crushers – types, constructions and operating principles, nip angle, critical operating speed, capacity, power consumption), 6. Grinding (basic principles, reduction ratio, types and construction of mills, operating principles, charge of mills – volume, types, wear etc, mill rotation and critical speed, mill capacity, mill power), 7. Comminution circuits (circulation load ratio, influence of circulation load ration on mill capacity, optimal value of circulation load ratio), 8. Screening (performance of screens, efficiency of screening, screening surfaces, probability of particle passage, kinetics of screening, screen types, factors affecting screen performance, screen capacity), 9. Classification (principles of classification, free settling, hindered settling, efficiency of separation, partition curve, air classifiers,

cyclones, hydraulic classifiers – horizontal current classifiers, vertical current classifiers, centrifugal current classifiers (hydrocyclones), 10. Mixing

Practical teaching

1. Characterization of particle size and shape, 2. Particle size distribution and sieve analysis, 3. Crushing – practical problems, 4. Grinding – practical problems, 5. Laboratory – sieve analysis, 6. Bulk material handling – transportation and feeding, 7. Screening – practical problems, 8. Classification – practical problems (air classifiers, cyclones, hydraulic classifiers), 9. Practical problem – calculation of industrial venting system (selection and cyclone dimensioning, pipeline calculation), 10. Mixing – practical problems

Prerequisites

Obligatory subject of elective module Process engineering and environment protection.

Learning resources

1. Bogner Martin: Mechanical operations, Naučna knjiga, Belgrade, 1987.
2. Bogner M, Stanojević M, Livo L: Cleaning and filtration of gasses and liquids, ETA, Belgrade, 2006.
3. Knežević Dinko: Mineral processing, University of Belgrade, Faculty of Mining and Geology, Belgrade, 2012.
4. Ćalić Nadežda: Principles of mineral processing, University of Belgrade, Faculty of Mining and Geology, Belgrade, 1990.
5. Magdalinović Nedeljko: Size reduction and classification, Nauka, Belgrade, 1999.
6. Laboratory installation for coal grindability testing and particle size distribution, Laboratory for Process Engineering

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	19
laboratory exercises	2
calculation tasks	0
seminar works	0
project design	9
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0

test/colloquium	10	project design	10
laboratory exercises	5	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 16

References

Barry A. Wills, Tim Napier-Munn: Mineral Processing Technology, Elsevier Science & Technology Books, 2006.
A. Gupta, D.S. Van: Mineral Processing Design and Operations - An Introduction, Elsevier, 2006.
R.P. King: Modeling and Simulation of Mineral Processing Systems, 2nd edition, Society for Mining, Metallurgy, and Exploration, Inc, 2012.
Warren McCabe, Julian Smith, Peter Harriot: Unit operations of chemical engineering, fifth edition, McGraw-Hill, 1993.
***: Basics in Minerals Processing, Metso Corporation, 2015.

Principles of environmental and work space protection

ID: 1124
Responsible/Holder professor DUŠAN M. TODOROVIĆ
Teaching profesor(s): TODOROVIĆ DUŠAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: process and environmental protection engineering

Goals

The main course objectives are related to introduce students to environmental problems, natural hazards and human impact on the environment. In order to solve problems, students will be acquainted with the physics and chemistry of the environment, atmospheric phenomena, the basics of microbiology and ecology.

Learning outcomes

Based on lessons envisaged to overcome the students will be able to make independent decisions related to environmental management, sustainable development, impact assessment of projects and facilities on the environment. Especially important is the knowledge that students acquire in terms of life cycle analysis of products and processes.

Theoretical teaching

Introduction, The changing role of technology, legislation and regulation; Technical basis-JUS ISO 14000; Importance and influence of public
The dilemma of industrialization and urbanization, The growth of the energy impact on the environment, Energy source impact on the environment
Classification and measurement of natural hazards, Greenhouse effect and ozone depletion, Acid rain;
Physics and chemistry of the environment, Particulate matter distribution, Solutions and solubility, Gases, gas mixtures, transport in the system of "gas-liquid" Material balance, Reaction, Reaction kinetics and reactors
Atmospheric science, Basic characteristics and balance, Air flow, atmospheric stability, turbulence, Water in the atmosphere, Climate; Prediction of air pollution concentrations
Microbiology and Ecology, Basic and applied microbiology, Epidemiology and disease, energy flows in ecosystems, food chains and trophic levels, Nutrient cycles, Elements of limnology, Eutrophication
Sustainable Development, EIA, RA and LCA; The strategy, Plans and Programs, Ethics.

Practical teaching

The basic calculation of the positions of legislation, norms and standards,
The calculation of risk and hazard installations,
Calculation of episodic air pollution, Sample of inventory/cadastre of gases,
Example of impact assessment and risk assessment strategies, plans and programs, Elements of the product life cycle,
Modeling of particulate matter distribution, Solutions and solubility, Gases, gas mixtures,

transport in the system "gas-liquid", Calculation of material balance,
Basic calculations of chemical reactions, reaction kinetics and reactors,
Calculating the energy balance of the atmosphere, basic concepts and calculations related to air flow, atmospheric stability, turbulence, water circulation in the atmosphere, meteorology, dispersion models, plume model,
The basic concept of ecology, energy flows in ecosystems, the basic calculations in microbiology,
Development of simplified impact assessment study or preparation of LEAP,
Consultations during the project development,
Public presentation of papers and discussion.

Prerequisites

There are no requirements to attend courses, in terms of the previously passed courses.

Learning resources

Considering that for the course is not yet completed a textbook, materials for lectures are submitted to students in printed and electronic form.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	12
elaboration and examples (revision)	0
active teaching (practical)	**12**
auditory exercises	8
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	4
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	0
test, with assessment	0
final exam	4

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	10	project design	10
laboratory exercises	0	final exam	70
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

Kuburovic, M., Jovovic, A., et al., Zastita zivotne sredine (Chapter 15), p. 644-856., Termotehnicar, tom 2, 2004., ISBN 86-82685-03-5

Kiely, G., Environmental Engineering, McGraw-Hill, 1997.

Processes and Equipment for water treatment

ID: 1123
Responsible/Holder professor DUŠAN M. TODOROVIĆ
Teaching profesor(s): TODOROVIĆ DUŠAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

The aim of the course is to give students the academic skills and competencies to monitor the process as well as the selection and designing appliances and devices used for water treatment. Through the term paper students acquire creative ability and specific practical skills for performing tasks within their profession, process monitoring and design of process equipment.

Learning outcomes

After successful course attending students get ability for: analysis, synthesis and predicting solutions and consequences; developing of critic and self-critic judgment and approach; practical implementation of knowledge; professional ethic; connecting knowledge from different areas and their implementation; developing skills and abilities for knowledge implementation in adequate area.

Theoretical teaching

1.Basic characteristics of water, 2. Chemical composition of water, Problems of water pollution, 3. Methods of coagulation and flocculation of water, 4. Methods of sedimentation, flotation and filtration, 5. Water chlorination, 6. Use of ozone in water purification, 7. Activated carbon water treatment , 8. Water softening, 9. Industrial water, 10. Membrane water treatment.

Practical teaching

1.Practical examples of basic characteristics of water, 2. Practical examples of chemical composition of water and problems of water pollution, 3. Practical examples of methods of coagulation and flocculation of water, 4.Practical examples of methods of sedimentation, flotation and filtration, 5. Practical examples of water chlorination, 6. Practical examples of use of ozone in water purification, 7. Practical examples of activated carbon water treatment, 8. Practical examples of water softening, 9. Practical examples of industrial water, 10. Practical examples of membrane and membrane modules, use of membrane processes for various purposes.

Prerequisites

Elective course. There is no specific requirement for course attending.

Learning resources

D. Todorovic: Lecture handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	30	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 28

References

Stanojević, M., Simić, S. Radić, D., Jovović, A .: Use of gases in water treatment, University of East Sarajevo, Faculty of Mechanical Engineering, BiH, 2013.
Kuburović, M., A. Petrov: Environmental Protection, SMEITS and Faculty of Mechanical Engineering Belgrade, Belgrade, in 1994.
Bogner, M., Stanojević M .: About water, ETA Belgrade 2006.
Degremont, G .: Technique of water purification, Translated from the French, Građevinska knjiga, Belgrade, 1976.

Skill praxis M - PTH

ID: 1550
Responsible/Holder professor DEJAN B. RADIĆ
Teaching profesor(s): RADIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: process and environmental protection engineering

Goals

The goal of course is to acquaint students with the resources, machines and devices used in various industries, especially in the food and pharmaceutical industry, chemical industry, oil refining, gas, non-metals and building materials, metallurgy, energy, communal activity. The practice should enable students to easily master the subject matter of vocational subjects.

Learning outcomes

The successful completion of course students are introduced to: 1. processes and equipment used in the processing industry, 2. designing methods of processing plants, 3. test methods of processing plants and equipment, and others.

Theoretical teaching

The role and importance of professional practice - process engineering, engineering in environmental protection. Basic principles of devices and machines of process equipment. Fundamentals of technological processes in the field of process engineering. The basics of designing process systems. The basics of distributions main and auxiliary fluids.

Practical teaching

Organization and visits to factories of process industries. Understanding the specific technological processes and equipment in process industries through a review of technical documents and examining the situation in the factories. Analysis of technical documents (project and technical documentation) in the process industries. Technical control (audit) of technical documents - from compliance with documentation requirements of regulations and standards in the field of process industries. Introduce students to the measuring equipment used in the process industry by direct insight into condition of this equipment in factories and laboratories at its disposal department. The role of process engineers in the design and implementation of systems management processes and technologies.

Prerequisites

Obligatory subject of elective module Process engineering and environment protection.

Learning resources

Literature published by members of the Department of Process Engineering. Technical documentation. Cataloging documentation.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	80
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Technical legislation

ID: 0997
Responsible/Holder professor NENAD R. MITROVIĆ
Teaching profesor(s): MITROVIĆ NENAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: process and environmental protection engineering

Goals

Objective of the course is that students acquire academic skills and academic competencies for
application of technical legislation. Through teaching activities, students acquire creative and specific practical skills that qualify them to work in their professional field - design.

Learning outcomes

By successful completion of the study program student acquires the following skills: analysis, synthesis and prediction of solutions and consequences; development of critical thinking and self-critical approach; application of knowledge in practice; professional ethics; correlation of knowledge from different fields and their applications; development of skill and proficiency in the use of knowledge in field of technical documentation preparation.

Theoretical teaching

1. Technical regulations - laws, directives and standards. Project types as part of technical documentation. 2. Construction stages from building permits, preparation, construction, supervision and use permit. 3. Accreditation. Testing laboratories, control organizations and certification bodies. Quality system. 4. Basis for development of directives and standards in terms of content and responsibilities for implementation. Adoption of European and international standards (EN, ISO). Inspection bodies and their expertise.

Practical teaching

1. Legal obligations on the content of main projects - the elaboration of certain chapters. 2. The formation and content of the general and technical conditions by project type and content. 3. Designer obligations during preparation of technical documentation regarding the fire and explosion protection. Development of appropriate annexes required in the technical documentation. 4. Creating and changing directives. General directives that apply to all professions (supervision, construction, inspection). Conformity assessment. 5. Examples of directives related to technical questions. 6. CE marking. 7. Presentation preparation and public presentation. Content of the documents (letters, proposals, contracts...).

Prerequisites

No requirements.

Learning resources

Available faculty resources (classrooms, laboratories and library) will be used for the course.

Literature for the course is in the professor's cabinet, as well as at faculty's library.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	12
elaboration and examples (revision)	0
active teaching (practical)	**12**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	2
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	20
test/colloquium	20	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Група аутора: Методи и примери експерименталног рада у процесном инжењерству и термотехници, Машински факултет, Београд, 2022
Богнер, М.; П.Зекоња, Д. Ивановић: Приручник за израду пројектне документације, ЕТА, Београд, 2007.
Mitrovic, N., Balac, M., Petrovic, A., Milosevic, M.: Primena metode korelacije digitalnih slika (Digital Image Correlation - DIC) na opremu pod pritiskom, Mašinski fakultet Beograd, Beograd, 2017
Isailović M., Petrović A., Bogner M., Balać M., Mitrović N.: Propisi o opremi pod pritiskom, Eta Beograd, Beograd, 2013
Mitrović, N. i grupa autora: „Ocenjivanje usaglašenosti proizvoda – razvoj infrastrukture", Institut za nuklearne nauke Vinča, Mašinski fakultet Beograd, Beograd, 2009.

Transport phenomena in process industry

ID: 1056
Responsible/Holder professor MIRJANA S. STAMENIĆ
Teaching profesor(s): STAMENIĆ MIRJANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: process and environmental protection engineering

Goals

Acquiring the necessary knowledge to understand the transport phenomena of heat and mass transfer in the process industry. Application of steady and unsteady heat and mass transfer in phases (two or more component fluids) in process equipment.

Learning outcomes

The understanding of fundamentals of heat and mass transfer processes accompanied with multi-phase fluid flow. Estimation procedures for the intensity of heat and mass transport and pressure drop in chemical engineering.

Theoretical teaching

Molecular transport phenomena. Newtons law of fluid friction, Fouriers law of heat conduction, Ficks law of molecular diffusion.
Steady and unsteady state heat and mass transfer in fluids.
Differential equations of of momentum, heat and mass convective transport. Laminar and turbulent flow.
Simplified models of convective transport. Analysis of heat and mass transfer resistances.Coefficients of Heat and mass transfer.
Similarity theory. Analogies between mass, heat and momentum transfer.
Mass transfer across a phase boundary. Inter-phase turbulence.
Simultaneous mass and heat transfer. Wet-bulb temperatures.
Boiling, condensation and thermal radiation. Typical cases in process equipment (heat exchangers, columns, furnaces).
Unsteady heat and mass transfer in solid phase.
Heat radiation.

Practical teaching

Examples of steady and unsteady state molecular transport in fluids and solids
Examples of convective transfer.
Examples of application of the similarity theory - criterial equations
Examples of heat and mass transfer across a phase boundary.
Examples of simultaneous heat and mass transfer.
Laboratory: Wet-bulb temperature, coefficient of molecular diffusion
Examples of heat transfer with phase change: boiling, condensation
Examples of thermal radiation.
Examples of the unsteady heat and mass transfer in solid phase.

Examples of heat radiation.

Prerequisites

Defined in curriculum of the module

Learning resources

Resources are books listed within chapter - Literature

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	22
elaboration and examples (revision)	8
active teaching (practical)	**30**
auditory exercises	13
laboratory exercises	5
calculation tasks	12
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	5	final exam	30
calculation tasks	15		

Requirements to take the exam (number of points) 31

References

Jaćimović B., Genić S., Heat Transfer Operations And Equipment, Part 1: Recuperative Heat Exchangers, Faculty of Mechanical Engineering, Belgrade, 2022.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 1: Mass Transfer Basics, Faculty of Mechanical Engineering, Belgrade, Second Edition, 2019.
Jaćimović B., Genić S., Mass Transfer Operations And Equipment, Part 2: Mass Transfer Operations, Faculty of Mechanical Engineering, Belgrade, 2010.
Genić, S., Jaćimović, B., Jarić, M., Budimir, N., Process Fluid Properties, SMEITS, 2014.
Jaćimović, B., Genić, S., Stamenić, M., Aranđelović, I. et al: Methods and Examples of Experimental Research in Process Engineering and Thermotehnic, Faculty of Mechanical Engineering, Belgrade, 2022

Waste and wastewater management

ID: 0125
Responsible/Holder professor ALEKSANDAR M. JOVOVIĆ
Teaching profesor(s): JOVOVIĆ ALEKSANDAR; TODOROVIĆ DUŠAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written+oral
Parent department: process and environmental protection engineering

Goals

In this course, students will gain a solid basic and specific knowledge in the field of waste management and wastewater management. Laboratory exercises give students the opportunity to solve the various practical problems and perceive gained theoretical knowledge.

Learning outcomes

Knowledge that students acquired about the specific technical solutions, the choice of methods of use waste and wastewater treatment equipment enabling the assessment of basic principles relevant for the design of these plants.

Theoretical teaching

Characteristics, management, Legal basis and strategy, Systems of collection, Separation and treatment, Incidence and equipment for waste collection, transfer stations, transport, separation at source, recycling,
Thermal processing procedures, a biological waste treatment products using waste processing,
Criteria for disposal, problems, control and treatment of leachate, generation and use of landfill gas, waste management future - legislation, collection, incineration, disposal,
Hazardous waste, remediation of contaminated soil,
Water resource management, Technological (process) characteristics, Planning, Legislation, Political influences, Future challenges,
Water demands, Requirements for water quality, Sources of water supply, Water treatment, Transfer (transport), distribution and storage of water, needs and future development,
Water pollution, Waste water collection, Treatment principles, Treatment plants,
Role of public and government in controlling pollution, Trends in controlling water pollution.

Practical teaching

Calculation of the waste growth, determining the required capacity for the collection, calculation of waste composition,
Selection and sizing of equipment for waste treatment,
Selection and sizing of equipment for the factory for processing of municipal solid waste,
Determining the basic size of the landfille and landfill gas generation calculations and possibility of its using,
Calculation of concentration and flow of pollutants in and efficiency of equipment for the wastewater treatment,

Calculation of material and heat balance of devices for wastewater treatment and calculation of characteristic values,
Selection and sizing of equipment for wastewater treatment,
Examples of plants for biological wastewater treatment,
Experimental determination of heat and material balance of devices for pyrolysis of waste,
Determining the effectiveness of the air distributor in the aeration devices for biological wastewater treatment.

Prerequisites

There are no requirements to attend courses, in terms of the previously passed courses.

Learning resources

Considering that for the course is not yet completed a textbook, materials for lectures are submitted to students in printed and electronic form.
Laboratory facility / installation / machine (LFI):
1. Laboratory testing facility for wastewater treatment
2. Laboratory plant for thermal waste treatment

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	13
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	2
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	20	final exam	50
calculation tasks	20		

Requirements to take the exam (number of points) 27

References

Kuburovic, M., Jovovic, A., et al., Zastita zivotne sredine, chapter 15, p. 644-856., Termotehnicar, tom 2, Interklima, SMEITS, 2004., ISBN 86-82685-03-5

Jovovic, A., Karan, M., Petrovic, A.: Process and equipment in waste treatment systems, in: Developments of equipment in process and environmental engineering, 2000., p. 97-122, ISBN 86-7083-385-9
Stanojevic, M., Simic, S., Radic, D.,Jovovic, A, Аерација отпадних вода, теорија и прорачуни, ETA, Beograd, 2006., ISBN 86-85361-07-9

PRODUCTION ENGINEERING

Additive Manufacturing Technologies

Assembly Technology

Computer control and monitoring in manufacturing automation

Computer Integrated Manufacturing Systems and Technology

Computer Simulation in Manufacturing Automation

Coordinate Measuring Machines

Decision-making methods

Industrial robots

Intelligent manufacturing systems

Machine tools M

Manufacturing Automation

Manufacturing Systems Design

Mechatronics Systems

Micro Manufacturing and Characterization

New generation of machine tools and robots

New Technologies

PRODUCTION INFORMATION SYSTEMS

Quality Management

Sheet-Metal Processing Tools

Skill Praxis M - PRO

Additive Manufacturing Technologies

ID: 1314
Responsible/Holder professor MIHAJLO D. POPOVIĆ
Teaching profesor(s): POPOVIĆ MIHAJLO; PJEVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

Introduction to theoretical principles and practical skills in the field of designing technologies based on the adding material - additive technologies and their application to metal and polymeric materials. Furthermore, achievement of theoretical and practical knowledge from the design, calculation and construction of machining systems for additive manufacturing technologies based on modern technologies and optimal solution - natural construction methods and generative design.

Learning outcomes

Upon successful completion of this course, students should be able to: • Recognize the basic differences between methods of material removal, material shaping and adding material (additive technologies) • Distinguish methods of additive manufacturing • Compare methods of additive manufacturing • Analyze the possibility of using additive technologies • Depending on the load of the structure and its purpose, they prescribe the appropriate type if additive technology, as well as modes of manufacturing • Generate a computer model of the work: CAD and scanning • Use generative methods (approaches) of designing based on natural method of construction • Optimize the geometry of the structure according to the conditions of additive technologies • Prepare for manufacturing • Design and calculate a processing system intended for additive manufacturing technologies.

Theoretical teaching

Division of technologies; Basic concepts; The importance of Additive Manufacturing Technologies in modern development and production; Division of Additive Manufacturing Technologies; Additive production processes; 3D printing; Application (Production of prototypes, functional parts and tools); Techniques for forming 3D models using CAD tools and scanning; Natural construction method and generative design methods; Examples from industry, future directions of Additive Manufacturing Technologies development.

Practical teaching

Laboratory practices with laboratory equipment in which the student gets acquainted with the practically realized processing systems for additive technologies. Introduction to the process of production of functional parts through the development of the project task. Computer simulations: Optimization of geometry, prescribing manufacturing technology base od additive manufacturing technologies, design of subsystems for the accompanying type of additive technology. Workshops: scanning of parts and processing in CAD packages. 3D printing. Rapid prototyping and rapid production of tools and accessories.

Prerequisites

Defined by the study program / module curriculum.

Learning resources

Filament extruder for 3D printer, 3D pen, FFF 3D printer, mSLA Creality LD-002R 3D printer, 3D scanner; Lectures in electronic form; Instructions for performing exercises in the laboratory; Instructions for project design; CAx workstations with appropriate software packages.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Gibson I, Rosen W.D, Stucker B, Additive Manufacturing Technologies - Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010.
Gebhardt A, Heotter J.S, Additive Manufacturing, 3D Printing for Prototyping and Manufacturing, Hanser Gardner Publications, 2016.
Stritesky O, Prusa J, Bach M, Basics of 3D Printing with Josef Prusa, Prusa REsearch, Prague 2019.

Assembly Technology

ID: 1535
Responsible/Holder professor ŽIVANA B. JAKOVLJEVIĆ
Teaching profesor(s): JAKOVLJEVIĆ ŽIVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

1. Learning of systematic approach to the design and production of mechanical assemblies;
2. Understanding assembly process and basic assembly operations;
3. Impact of assembly process on product development – product structure and Design For Assembly techniques;
4. Part mating process, modeling and understanding relationships between precision, sensitivity and flexibility;
5. Basic concepts of assembly systems – manual, automatic and robotic systems; Assembly system design; Assembly workstation design issues;
6. Performance and Economics of Assembly Systems;
7. Product lifecycle and product disassembly.

Learning outcomes

After successfully completing course, student is capable to:
1. Analyze assembly and carry out its optimal sequencing into basic assembly operations for the given set of criteria;
2. Design a system for automatic assembly that includes parts feeding, orientation, separation and geometry control;
3. Design systems for manual assembly with all sub-systems including sequencing;
4. Design systems for automatic and robotized assembly including work stations, as well as peripherals for parts feeding;
5. Optimize assembly design with respect to its assemblability using qualitative and quantitative Design for Assembly techniques

Theoretical teaching

Theoretical background of industrial assembly systems is given through 10 lectures + introductory lecture:
0. What is industrial assembly and its role in production systems,
1. Assembly system structure and assembly process,
2. Part mating theory of compliantly supported rigid parts,
3. Joining techniques and processes,
4. Feeding and material flow in assembly system,
5. Assembly structure, sequencing and Design For Assembly,
6. Manual assembly systems,
7. Automatic assembly systems – rigid transfer lines,
8. Automatic assembly systems – flexible assembly lines and robotic assembly cells,

9. Performance and Economics of Assembly Systems, and
10. Product lifecycle and disassembly technology.

Practical teaching

Practical training is organized through laboratory exercises and project (team work) of assembly system design for selected product.
LAB 1: Quasi-static part mating – demonstration of passive compliant device RCC, demonstration of 6 DOF force/torque sensor, force sensor calibration, robot motion programming, measurement of part mating forces and identification of contact situations, comparison of experimentally evaluated results with theory.
LAB 2: Passive systems for feeding and orienting – vibratory bowl feeder and linear feeding tracks demonstration, part geometry analysis and identification of basic natural resting states, design and obstacles optimization of passive orienting system for selected class of headed cylindrical parts, tuning the system, measurement and efficiency estimation of configured orienting system, estimating of mean feeding capacity.
LAB 3: Vision systems for part feeding - demonstration of vision system configuration and its use in part feeding, image analysis and identification of paths contours and its locations, identification of system performances and optimization.

Project covers the following topics: 1. Assembly design and product design for assembly (DFA), 2. Parts presenting systems - orientation, separation and positioning task, 3. Working heads for part mating, part joining and other assembly operations, and 4. Transfer systems - assembly conveying, manipulation operations, line balancing and control.

Prerequisites

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Learning resources

1. Jakovljević Ž., Petrović P. B., Contact states recognition in robotized assembly, FME, Belgrade 2011 /In Serbian/
2. Jakovljević Ž., Assembly technology - Handouts, FME, Belgrade, 2024
3. Robotic cell equipped with sensory and acquisition system for demonstration of compliant part mating and RCC working principle;
4. Experimental system based on linear vibratory conveyor for demonstration and students training in design of passive part presenting systems;
5. Vision system for demonstration and students training in designing of flexible robotic part presentation systems;

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING		**OTHER**	
active teaching (theoretical)	**30**	**knowledge checks**	**15**
lectures	20	assessment of calculation tasks	0
elaboration and examples (revision)	10	check and assessment of lab reports	2
active teaching (practical)	**30**	check and assessment of seminar works	0
auditory exercises	6	check and assessment of projects	2
laboratory exercises	12	colloquium, with assessment	0

calculation tasks	0	test, with assessment	6
seminar works	0	final exam	5
project design	12		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Ćosić., I., Assembly Systems, IP Nauka, Beograd, 1991, ISBN: 86-7621-045-4. /In Serbian/
Boothroyd, G. 1983. Design for Assembly Handbook, Design project, Dep. Of Mechanical Eng., University of Massachusetts, Amherst, Massachusetts, USA.
Bothroyd, G., Poli, C. and Murch, L. E. 1982. Automatic Assembly, Marcel Dekker Inc., New York, USA, ISBN 0-8427-1531-4.
Whitney, E., D., Mechanical Assemblies: their Design, Manufacture, and Role in Product Development, Massachusetts Inst. of Techn, New York Oxford, OXFORD UNI PRESS, 2004, ISBN 0-19-515782-6
Groover, M., Automation, Production Systems and Computer Integrated Manufacturing, Prentice-Hall, Inc. 1987.

Computer control and monitoring in manufacturing automation

ID: 1537
Responsible/Holder professor NIKOLA R. SLAVKOVIĆ
Teaching profesor(s): SLAVKOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The goal of the course is for students to acquire the necessary knowledge in the application, design, and implementation of modern computer control and monitoring systems in manufacturing automation, as well as to get skills for solving practical problems of computer control and monitoring in automation.

Learning outcomes

After completing this course the students should be able to: 1. Apply a stepper motor to actuate a mechanical system within the manufacturing process, including designing the hardware architecture and control system based on integrated microcontrollers; 2. Implement a system for moving two or more controlled axes using interpolation algorithms based on the direct search method; 3. Physically realize the task of multi-axis movement defined in G-code on a microcontroller platform with interpolation algorithms based on direct search methods; 4. Generate a program for the movement of anthropomorphic robots and achieve their integration with the sensor environment by including real-time signal processing; 5. Conceptualize a system for computer monitoring of the manufacturing process.

Theoretical teaching

1. Computer control systems in manufacturing automation. CNC control, robot controllers, and programmable controllers. 2. CNC control. Functions, hardware, software, mathematical models. Main and auxiliary motion control, interpolation, and internal calculations. Control panel and programming. Communication functions. 3. Programmable controllers. Functions, hardware, software, input/output modules. 4. SCADA systems. Functions, hardware, software. Data acquisition, human-machine interface, programming, and control and monitoring algorithms. 5. Sensors and actuators for control and monitoring. Remote and intelligent terminal units. 6. Modern computer control systems and open-architecture control systems. Communication networks.

Practical teaching

1. Calculation exercises: Tasks in control design and monitoring in manufacturing automation with programming and control scheme design. 2. Laboratory exercises: Practical realization of examples of control and monitoring in manufacturing automation in laboratory conditions using a computer-based control system, CNC control, and robots. 3. Project: Designing examples of control and monitoring in automation.

Prerequisites

Defined by the Study Program Curriculum.

Learning resources

N. Slavković, Lectures for each lesson (handouts). L. Matijašević, B. Momčilović, Instructions for laboratory exercises (handouts). Course site containing essential information for students and a list of reference books. Resources of the Robotics & AI Laboratory and the Cybernetics and Mechatronic Systems Laboratory with industrial robots, microcontrollers, and sensors.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	8
laboratory exercises	15
calculation tasks	2
seminar works	0
project design	5
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	0
test, with assessment	6
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Suh Suk-Hwan, Seong Kyoon Kang, Dae-Hyuk Chung, Ian Stroud, Theory and design of CNC systems, Springer, 2008.
Mikell P. Groover, Automation, Production Systems, and Computer Integrated Manufacturing, Prentice-Hall, Inc. 1987.
Yoram Koren, Computer Control of Manufacturing Systems, McGraw-Hill Book Company, 1983.
David Bailey, Edwin Wright, Practical Scada for Industry, Esevier, 2003.

Computer Integrated Manufacturing Systems and Technology

ID: 1529
Responsible/Holder professor GORAN M. MLADENOVIĆ
Teaching profesor(s): MLADENOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: production engineering

Goals

A detailed study of the principles and application of computer integrated manufacturing. Advanced concepts and models related to computer-aided design, computer-aided process planning, computer aided manufacturing, production planning and scheduling.

Learning outcomes

This course will enable the student to:
• apply knowledge of modeling, simulation and visualization in industrial applications,
• design CIM systems that satisfy the given conditions,
• identify and solve problems in the operation of the CIM system,
• improve the performance of manufacturing systems using different CIM concepts and tools,
• handle production data and the different software used in production.

Theoretical teaching

1. Introduction to CIM
2. Computer-aided Design
3. Automated Manufacturing Equipment
4. Group Technology And Computer-aided Process Planning
5. Shop Floor Control and Introduction of FMS
6. Production Planning and Control
7. Cim Implementation and Data Communication

Practical teaching

Laboratory work includes computer-aided applications and programming of automated production equipment.

Prerequisites

Defined by curriculum of study programme/module.

Learning resources

(1) B. Babic, Computer integrated systems and technologies, University of Belgrade, Faculty of Mechanical Engineering, 2017
(2) B. Babic, Software "Moodle" for distance learning (http://147.91.26.15/moodle/), University of Belgrade, Faculty of Mechanical Engineering, 2012
(3) AnyLogic simulation software
(4) B. Babic, Software packages for process planning

(5) B. Babic, Process planning, University of Belgrade, Faculty of Mechanical Engineering, 2006

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	40
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

B. Babic, Computer Integrated Systems and Technology, University of Belgrade - Faculty of Mechanical Engineering, ISBN: 978-86-7083-960-1, 2017. (in Serbian)
Б.Бабић, FLEXY–INTELLIGENT EXPERT SYSTEM FOR FTS DESIGN, Series ITS, Book 5, University of Belgrade - Faculty of Mechanical Engineering, ISBN:86-7083-250-X,1994. (in Serbian)
Groover, M. P., Automation, Production Systems, and Computer-Integrated Manufacturing, 3rd Ed. Pearson Education, 2008.

Computer Simulation in Manufacturing Automation

ID: 0722
Responsible/Holder professor ŽIVANA B. JAKOVLJEVIĆ
Teaching profesor(s): JAKOVLJEVIĆ ŽIVANA; NEDELJKOVIĆ DUŠAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The objective of this course is that students: acquire knowledge and skills necessary for practical problems solving in manufacturing automation using computer simulation; to master the methods used for computer simulation modeling and implementation in manufacturing automation; to obtain the knowledge about the systematic approach to the project of computer simulation in manufacturing automation; to develop critical approach to the effects of computer simulation application in automation; to get familiar with the role of computer simulation within digital factory.

Learning outcomes

After successfully completing this course, the students should be capable to:
- Create and implement stochastic simulation;
- Create conceptual model for discrete event simulation;
- Create and implement discrete event simulation within fixed and flexible automation framework;
- Create conceptual and computer model for continuous simulation of various processes;
- Integrate continuous and discrete event simulation;
- Manage discrete event simulation project.

Theoretical teaching

1. Introduction to computer simulation: simulation objectives; advantages and disadvantages of simulation; phases of computer simulation development; computer simulation in manufacturing automation; a variety of simulation models: continuous and discrete models, deterministic and stochastic simulation
2. Stochastic simulation: sampling methods, random numbers, random number generators, Monte Carlo simulation
3. Discrete event simulation: elements of discrete event simulation, conceptual modeling of discrete event simulation, activity cycle diagram
4. Computer models for discrete event simulation: approaches in model coding: activity based approach, event based approach, process based approach, the three phase approach; comparative analysis of different approaches
5. Discrete event simulation software: general purpose programming languages, application oriented simulation software; definition of simulation model in programming languages and simulation software packages; simulation outputs and results presentation; application of computer graphics and animation in simulation; application examples of simulation software
6. Discrete event simulation application in automation: generation of conceptual and

computer models of fixed, programmable and flexible automation
7. Discrete event simulation project: system definition, generation of simulation model, model verification and validation, simulation experiments, results presentation and documentation
8. Continuous system simulation: continuous systems modeling, basic principles of numerical integration, modeling of the examples of continuous systems in manufacturing automation, programming languages and software for continuous system simulation, integration of continuous simulation into discrete event simulation
9. Digital factory and simulation: concept and models of digital factory; the role of simulation in digital factory: plant design and optimization, operational management and optimization

Practical teaching

Laboratory exercises:
1. Monte Carlo simulation
2. Discrete event simulation software: ARENA – basic functioning principles and simulation examples
3. Discrete event modeling and simulation: examples of fixed and flexible automation
4. Continuous systems simulation: modeling and simulation of specific examples in the area of manufacturing automation using general purpose programming language and in application oriented simulation software – ARENA
Discrete event simulation project:
Students work on project dealing with the development of a simulation of a chosen flexible manufacturing system. During project realization students systematically implement all phases of discrete event simulation project: conceptual modeling, model coding, animation generation, model verification and validation, experimentation, analysis of the simulation results. The output is the report and project presentation at the end of semester.

Prerequisites

none

Learning resources

Jakovljevic, Z., Computer simulation in manufacturing automation – lecture handouts
Computer classroom – each student individually works on a computer
Arena Simulation Software by Rockwell Automation
General purpose programming language

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	20
calculation tasks	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	1
colloquium, with assessment	0
test, with assessment	8

seminar works	0
project design	10
discussion and workshop	0
research	**0**

final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5
test/colloquium	30
laboratory exercises	15
calculation tasks	0

seminar works	0
project design	20
final exam	30

Requirements to take the exam (number of points) 30

References

Carrie, A., Simulation of Manufacturing Systems, John Willey and Sons, New York, 1988
Robinson, S., Simulation: The Practice of Model Development and Use, John Willey and Sons, New York, 2004
Pidd, M., Computer Simulation in Management Science, John Willey and Sons, New York, 2004
Kelton, D., V., et al., Simulation with Arena, McGraw-Hill, 2009
Cellier, F., E., Kofman, E., Continuous System Simulation, Springer, New York, 2006

Coordinate Measuring Machines

ID: 1166
Responsible/Holder professor SLAVENKO M. STOJADINOVIĆ
Teaching profesor(s): STOJADINOVIĆ SLAVENKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The objective of the course is acquire of knowledge and skills in the field of coordinate metrology and flexible metrological automation for solving metrological problems in production engineering. Students should acquire and to master new knowledge and skills about: basic terms in production metrology, development and application of coordinate measuring machine (CMM) in engineering practice; subsystems of CMM; accuracy and methods of accuracy testing; measuring and inspecting all types of tolerances through the definition of the measurement protocol, the configuration and calibration of measuring sensors; methods of automatic inspection planning and simulation of inspection and measurement.

Learning outcomes

After successfully completion of this course, the students should be capable to: recognize the structure and characteristics of the CMM subsystem with their functions; determine the CMM coordinate systems and define the inspection and measurement plan; determine the sequence of metrological tasks with the configuration of the measurement sensor and perform the analysis from the geometric-metrological aspect; determine the CMM error budget and perform its analysis; take tolerances from the CAD geometric model, simulate measurement and output from the simulation used in the CMM programming system (geometric-metrological identification); analyze the report on the results of measurement and inspection; make CMM selection for the conditions of use (group of metrology tasks) in the production organization.

Theoretical teaching

Theoretical teaching embraces ten units: 1. Introduction to measuring machines. Basic characteristics. Development and application of CMM. Presentation of measuring machines of the latest-fifth generation. 2. Hardware structure of CMM. 3. Software for general and special purpose, its characteristic and applications. 4. Programming CMM. Off / on - line programming. 5. Accuracy and accuracy testing of CMM. Standards for accuracy testing of CMM. 6. Automatic inspection planning on CMM. Metrological model of part and metrological features. 7. Optimization of the planned measuring path. 8. Configuring measuring probes and analyzing the setup of measuring parts. 9. Measurement and inspection planning . Measuring protocol. 10. Simulation of measurement and generation of a control data list.

Practical teaching

Practical teaching embraces ten units: seven auditory and three laboratory exercises, as well

as seminar work. The content of the auditory exercises is as follows: 1. Measurement and inspection. Determination of the coordinate measurement system. 2. Definition of geometric and metrological features. 3. Distribution of measuring points by metrological features depending on the type of tolerance. 4. The principle of the collision avoidance. 5. Generating the initial path of the measurement sensor during inspection of prismatic parts on CMM. 6. Generating the optimal path of the measuring sensor on the base an ants colony optimization technique. 7. Analysis of setup of measuring parts and measuring bases.
Laboratory exercises are realized by factory visit and work in the PTC-Creo (CMM-module) software for modeling and simulation, as a followed: 1. Visit to the factory that owns CMM and get familiar about its work and technical characteristics. 2. Modeling and simulation of measurements in the software system PTC Creo - CMM module. 3. Inspection planning in PTC Creo - CMM module for a concrete measuring part. Generating CL files of a measuring sensor.

Prerequisites

Defined by curriculum of study programme.

Learning resources

1. Stojadinovic, S. (2022), Coordinate measuring machine, handouts for each lecture. 2. The instruction for doing laboratory exercises, tasks and seminar work. 3. The monograph in the field of quality and production metrology. 4. The web site of the course. 5. Facility and technical equipment: Laboratory for production metrology and TQM.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	9
calculation tasks	3
seminar works	4
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	1
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	20		

Requirements to take the exam (number of points) 30

References

Stojadinovic, M.S., Majstorovic, D. V. (2019), An Intelligent Inspection Planning System for Prismatic Parts on CMMs, Springer International Publishing, 978-3-030-12806-7.
Majstorovic, V., Hodolic, J. (1998), Coordinate Measuring Machine, FTN Novi Sad /in Serbian/
Sladek, A. J. (2016), Coordinate Metrology - Accuracy of Systems and Measurements, Springer Verlag Berlin Heidelberg
Smith, G. T. (2013). Industrial metrology: surfaces and roundness. Springer Science & Business Media.
Durakbasa, M.N. (2004). Geometrical product specification and verification for the analytical description of technical and non-technical structures, TU Wienna, Austria.

Decision-making methods

ID: 0302
Responsible/Holder professor ZORAN Đ. MILJKOVIĆ
Teaching profesor(s): MILJKOVIĆ ZORAN; PETROVIĆ MILICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: production engineering

Goals

The aim of the course is to train the students to make decisions in the process of product development and design by using mathematical-algorithm-based procedures and artificial intelligence techniques. Development of students' creative abilities in improving technical/technological characteristics of a product using methods based on conceptual design points out the optimum decision function based on intelligent agents.

Learning outcomes

Students' learning outcomes of this course are:
• The complex use of IC technologies in decision-making.
• The implementation of developed software (MATLAB, BPnet, ART Simulator, AnyLogic, TRIZ, Flexy) in solving typical technological problems within decision-making methods based on paradigms of artificial intelligence.
• Autonomous selection of the methods based on application of artificial neural networks and genetic algorithms in seeking the optimal solution in the process of product development.
• Understanding the interaction of soft and hard real-time subsystems of mobile robot in decision-making during exploring by using reconfiguration of physical structure and intelligent behaviour programming in MATLAB.

Theoretical teaching

Introduction to the theory of decision-making; intelligent systems. Systems for design and selection of solutions. Hybrid intelligent manufacturing systems; decision-making methods based on intelligent agents. Decision-making based on paradigms of artificial intelligence. Artificial neural networks; neuron - a processing element, transfer function (activation), architecture, learning algorithms. Application of artificial neural networks in decision-making. Genetic algorithms. Manufacturability of the product, process planning optimization. Intelligent machines and decision-making. Development of advanced technologies for the 21st century.

Practical teaching

Conceptual design and decision-making variables (selected examples). Analysis of typical manufacturing problems in domain of decision-making (laboratory work). Algorithms of machine learning and knowledge-based presentation - decision tree induction. Software for simulation of artificial neural networks (laboratory work). Manufacturability of the product - design parameters based on material flow for chosen manufacturing process (programming

in MATLAB); application of genetic algorithms in optimization (selected examples). Machine learning of material flow for chosen manufacturing process. Intelligent machines and decision-making (programming in MATLAB) - reconfigurable mobile robots and machine learning (laboratory work). Examples of conceptual designed products with optimal performances, pointing out the application of advanced production technologies (project activities). Project design (design parameters, searching performances, and defining of a decision matrix and decision function).

Prerequisites

Defined by Curriculum.

Learning resources

[1] Z. Miljković, M.M. Petrović, INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and artificial intelligence, Textbook, XXVIII+409 p., Univ. of Belgrade - Faculty of Mechanical Engineering, 2021 (I edition), 18.1 /In Serbian/
[2] Z. Miljković, D. Aleksendrić, ARTIFICIAL NEURAL NETWORKS – solved examples with theoretical background (2nd ed.), Textbook, Univ. of Belgrade - Faculty of Mechanical Engineering, 2018, 18.1 /In Serbian/
[3] Z. Miljković, SYSTEMS OF ARTIFICIAL NEURAL NETWORKS IN PRODUCTION TECHNOLOGIES, Monograph book within the Series Intelligent Manufacturing Systems, Vol. 8, Univ. of Belgrade - Faculty of Mechanical Engineering, 2003, 18.1 /In Serbian/
[4] V.R. Milačić, MANUFACTURING SYSTEMS DESIGN THEORY, Monograph book within the Series Intelligent Manufacturing Systems, Vol. 2, Univ. of Belgrade - Faculty of Mechanical Engineering, 1987, 18.1 /In Serbian/
[5] Z. Miljković, M.M.Petrović, Handouts, Univ. of Belgrade - Faculty of Mechanical Engineering, 2022, 18.1 /In Serbian/
[6] Z. Miljković, M.M.Petrović, Software "Moodle" for distance learning (http://147.91.26.15/moodle/), Univ. of Belgrade - Faculty of Mechanical Engineering, 2022, 18.13
[7] Z. Miljković, M.M.Petrović, Website for Decision-making methods (http://cent.mas.bg.ac.rs/), Univ. of Belgrade - Faculty of Mechanical Engineering, 2022, 18.13
[8] Z. Miljković, Software packages for simulation of artificial neural networks - BPnet, ART Simulator, MATLAB; Laboratory CeNT website: http://cent.mas.bg.ac.rs/, Univ. of Belgrade - Faculty of Mechanical Engineering, 18.13
[9] Laboratory mobile robot prototype (Khepera II mobile robot with gripper and camera; LEGO Mindstorms NXT and EV3 Sets of reconfigurable mobile robots equipped with sensors and microcontrollers), Laboratory CeNT, Univ. of Belgrade - Faculty of Mechanical Engineering, 18.12
[10] Laboratory model of designed manufacturing system, Laboratory CeNT, Univ. of Belgrade - Faculty of Mechanical Engineering, 18.12

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING		**OTHER**	
active teaching (theoretical)	**30**	**knowledge checks**	**15**
lectures	20	assessment of calculation tasks	0

lectures	20	assessment of calculation tasks	0
elaboration and examples (revision)	10	check and assessment of lab reports	0
active teaching (practical)	**30**	check and assessment of seminar works	0
auditory exercises	2	check and assessment of projects	4
laboratory exercises	16	colloquium, with assessment	2
calculation tasks	0	test, with assessment	4
seminar works	0	final exam	5
project design	12		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	25	project design	35
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Y. Hatamura, (2006) DECISION-MAKING IN ENGINEERING DESIGN, Springer-Verlag London Limited, Printed in Germany.
J. N. Siddall, (1972) ANALYTICAL DECISION-MAKING IN ENGINEERING DESIGN, Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
Z. Miljković, M.M. Petrović, (2021) INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and AI, Textbook (In Serbian), XXVIII+409 p., Univ. of Belgrade - Faculty of Mechanical Eng.
E. Alpaydin, (2010) INTRODUCTION TO MACHINE LEARNING, 2nd Edition, The MIT Press, Cambridge, England.;E. Alpaydin, (2004) INTRODUCTION TO MACHINE LEARNING, The MIT Press, Cambridge, England.
R. R. Murphy, (2000) INTRODUCTION TO AI ROBOTICS, A Bradford Book, The MIT Press, Cambridge, Massachusetts London, England.

Industrial robots

ID: 1106
Responsible/Holder professor ZORAN Đ. MILJKOVIĆ
Teaching profesor(s): MILJKOVIĆ ZORAN; SLAVKOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The student should acquire fundamental knowledge of industrial robots (basic subsystems, their functioning variants and realization), knowledge needed for robot design, robotized workplaces design, robot programming, intelligent behaviour as well as develop capability for further dealing with subject matter in domain of robotics.

Learning outcomes

After completed this course the students should be able to:
• Understand the role and importance of industrial robots application (effects on productivity, flexibility, product quality and humanization of work).
• Solve the problem of robot introducing to the plant/factory.
• Select appropriate robot configuration, end-effector and peripheral equipment for given technological task.
• Design robotized workplace taking into account cycle time analysis as well as techno-economic analysis (pay back analysis).
• Programming the robots as well as robotized cell.
• Design the basic manipulator mechanical subsystems as well as select the appropriate components.

Theoretical teaching

New teaching contents:
1. Definitions, functional structure of a robot with subsystem description, classification.
2. Robot kinematics: spatial descriptions and transformations, direct and inverse kinematics problem.
3. Robot control. Control system structure. Single axis control (drive and measuring system, transmission system). Industrial robot control system (PTP and CP). Intelligent control of industrial robots.
4. Sensors, internal and external. End effectors, grippers and tools.
5. Robot programming, methods. Robot programming languages.
6. Robot application. Robot cell layouts and cycle time analysis. Manipulation and processing tasks, assembly, techno-economic analysis.

Explanations of new teaching contents:
1. Robot mechanical structure – manipulator. Mobile robots - specifications and types.
2. Description of orientation. Algorithm of associating coordinate systems to robot segments.

The Jacobian.
3. Recognition systems.
4. Artificial intelligence within advanced robotic systems.

Practical teaching

Practical teaching involves all necessary types of exercises.
1. Five auditory exercises: Kinematics of manipulators. Analysis of drive systems, measuring systems, transmission systems. End effectors. Robot programming. Robot application.
2. Four calculation tasks: Spatial relations and transformations. Robot kinematics and cycle time analysis. Three home-works relates to all these areas.
3. Three laboratory exercises: Robot kinematic (mechanical) structure – manipulator. Drive systems, measuring systems and transmission systems. Robot programming.
4. Seminar work: robot kinematics, programming, cycle time analysis.

Prerequisites

Study curriculum and student motivation for knowledge acquisition in domain of industrial robots according to the goals set and outcomes offered.

Learning resources

1. Textbook: (2021) Z. Miljković, M.M. Petrović, INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and artificial intelligence, (I edition), XXVIII+409 p., /In Serbian/ University of Belgrade - Faculty of Mechanical Engineering.
2. Additional textbook: (2024) D. Milutinović, INDUSTRIAL ROBOTS, (I edition), XII+761 p., /In Serbian/ University of Belgrade - Faculty of Mechanical Engineering.
3. Z. Miljković, N. Slavković, Handouts for each lecture. /In Serbian and English/
4. Z. Miljković, N. Slavković, Instructions for doing students' tasks, laboratory exercises and seminar work. /In Serbian and English/
5. Z. Miljković, N. Slavković, The Course site (http://cent.mas.bg.ac.rs/nastava/ir_msc/index.htm) containing relevant information for students, book references as well as addresses of robot manufacturers and respective institutions (IFR, RIA, JARA, CIRP, etc.).
6. Facility: Laboratory for industrial robotics and artificial intelligence with four industrial robots, fifteen mobile robots equipped with sensors and microcontrollers, twelve cameras, computer platform under Linux operating system, software for simulation and programming WORKSPACE 5, 3D printer as well as educational means.
7. Craig J.J. (1989) Introduction to Robotics: Mechanics and Control, Addison Wesley.
8. Sciavicco L., Siciliano B., (2005) Modelling and Control of Robot Manipulators, Springer.
9. Dudek G., Jenkin M., (2010) Computational Principles of Mobile Robotics, 2nd ed., Cambridge University Press.
10. Connell J.H., (1990) Minimalist Mobile Robotics - A Colony-style Architecture for an Artificial Creature, Academic Press.
11. Angeles J., (2007) Fundamentals of Robotic Mechanical Systems, 3rd ed., Springer.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3

elaboration and examples (revision)	10	check and assessment of lab reports	0
active teaching (practical)	**30**	check and assessment of seminar works	1
auditory exercises	13	check and assessment of projects	0
laboratory exercises	8	colloquium, with assessment	2
calculation tasks	8	test, with assessment	4
seminar works	1	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	5
test/colloquium	60	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Z. Miljković, M.M. Petrović, (2021) INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and AI, Textbook (In Serbian), XXVIII+409 p., Univ. of Belgrade - Faculty of Mechanical Eng.
D. Milutinović, (2024) INDUSTRIAL ROBOTS, (I edition), Additional textbook (In Serbian), XII+761 p., University of Belgrade - Faculty of Mechanical Engineering.
Groover P.M., Weiss M., Nagel R.N., Odrey N.G. (1987) Industrial Robotics: Technology, Programming and Applications, 2nd Ed., McGraw-Hill, New York.
Pires M.J. (2007) Industrial Robot Programming, Springer.
McKerrow P.J. (1991) Introduction to Robotics, Addison Wesley.

Intelligent manufacturing systems

ID: 0131
Responsible/Holder professor ZORAN Đ. MILJKOVIĆ
Teaching profesor(s): MILJKOVIĆ ZORAN; PETROVIĆ MILICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: project design
Parent department: production engineering

Goals

The aim of the course is to develop students' ability for conceptual design and implementation of intelligent manufacturing systems and processes by using the design theory, machine learning and evolutiveness, based on paradigms of artificial intelligence (AI). After he/she becomes familiar with the structure of intelligent manufacturing system based on multi-agent methodology (agents: robot, machine tool, machine learning, process planning, optimization, software, etc.) using laboratory equipment like reconfigurable mobile robots with sensors and laboratory model of designed manufacturing system as well as simulation by applying specialized software tools, the student will acquire knowledge necessary for the development of advanced production technologies.

Learning outcomes

Students' learning outcomes of this course are:
• Implementation of developed software tools (e.g. TRIZ, Flexy) for modelling and analysis of intelligent manufacturing systems and processes.
• Selection of methods based on the application of artificial neural networks (by using software packages MATLAB, BPnet, ART Simulator) and other computational intelligence techniques in designing and building intelligence of artefacts (autonomous mobile robots can thus be observed interacting with their manufacturing environment) as well as scheduling of manufacturing entities.
• Advanced utilization of the software for discrete event simulation (AnyLogic, Flexy) with analysis and presentation of the experimental results obtained.
• Understanding the interaction of soft and hard real-time subsystems of autonomous mobile robot through reconfiguration and advanced programming in MATLAB.
• Capability for team work.

Theoretical teaching

Introduction to knowledge and machine learning-based intelligent systems. Machine learning models; deduction, induction and analogy. Machine learning as a basis of intelligent systems and processes. Paradigms of AI; decision tree induction, artificial neural networks, genetic algorithms, case-based reasoning-CBR (learning from experience), etc. Evolutiveness and intelligent systems based on Multi-agent Systems Engineering (MaSE) methodology. Agents work autonomously; basic concepts and importance. Autonomous mobile robots; target cognitive capabilities of mobile robots including perception processing, collision avoidance, anticipation, path planning, complex motor coordination, reasoning about other agents, etc.

Mobile robot localization and navigation (pose estimation) as well as characteristic objects detection in robotic exploration within the manufacturing environment. The design theory and development of intelligent manufacturing systems. Scheduling of manufacturing entities. Software tools for modelling and analysis of intelligent manufacturing systems. Conceptual design of typical FMS lay-out configurations (FMS-Flexible Manufacturing System). Examples of developed Intelligent Manufacturing Systems (IMS).

Practical teaching

Modelling and analysis of intelligent manufacturing systems and processes (laboratory work). Exemplified application of developed intelligent systems (laboratory work). Software for simulation of artificial neural networks (laboratory work). Software architectures for machine learning of intelligent systems. Intelligent behaviour of manufacturing system agents based on empirical control algorithm. Subsumption architecture for intelligent control based on achieving increasing pre-specified levels of competence in an intelligent robotic system (intelligent behaviour design of an autonomous mobile robot interacting with detected objects - programming in MATLAB). Scheduling plans optimization using genetic algorithms (programming in MATLAB). Software tools for conceptual design of FMS lay-out configurations (laboratory work). Project design (Material handling; Intelligent control of autonomous mobile robot; Scheduling of indoor transportation equipment).

Prerequisites

Defined by Curriculum.

Learning resources

[1] Z. Miljković, M.M. Petrović, INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and artificial intelligence, Textbook, XXVIII+409 p., University of Belgrade - Faculty of Mechanical Engineering, 2021 (I edition), 18.1 /In Serbian/
[2] Z. Miljković, D. Aleksendrić, ARTIFICIAL NEURAL NETWORKS – solved examples with theoretical background (2nd ed.), Textbook, University of Belgrade - Faculty of Mechanical Engineering, 2018, 18.1 /In Serbian/
[3] M. Kalajdžić (editor), Lj. Tanović, B. Babić, M. Glavonjić, Z. Miljković, et al., CUTTING TECHNOLOGY (9th ed.), Handbook, University of Belgrade - Faculty of Mechanical Engineering, 2021, 18.1 /In Serbian/
[4] Z. Miljković, Systems of artificial neural networks in production technologies, Monograph book within the Series Intelligent Manufacturing Systems, Vol. 8, University of Belgrade - Faculty of Mechanical Engineering, 2003, 18.1 /In Serbian/
[5] Z. Miljković, M.M. Petrović, Handouts, University of Belgrade, Faculty of Mechanical Engineering, 2022, 18.1 /In Serbian/
[6] Z. Miljković, M.M. Petrović, Software "Moodle" for distance learning (http://147.91.26.15/moodle/), University of Belgrade - Faculty of Mechanical Engineering, 2022, 18.13
[7] Z. Miljković, M.M. Petrović, Website for IMS (http://cent.mas.bg.ac.rs/), University of Belgrade - Faculty of Mechanical Engineering, 2022, 18.13
[8] Laboratory mobile robot prototype (Khepera II mobile robot with gripper and camera; LEGO Mindstorms NXT and LEGO Mindstorms EV3 Sets of reconfigurable mobile robots equipped with sensors and microcontrollers), Laboratory CeNT, University of Belgrade - Faculty of Mechanical Engineering, 18.12
[9] Laboratory model of designed manufacturing system, Laboratory CeNT, University of Belgrade - Faculty of Mechanical Engineering, 18.12

[10] Software packages (MATLAB, BPnet, ART Simulator, AnyLogic, TRIZ, Flexy), Laboratory CeNT, University of Belgrade, Faculty of Mechanical Engineering, 18.13

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	2
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	20	project design	35
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Z. Miljković, M.M. Petrović, (2021) INTELLIGENT MANUFACTURING SYSTEMS – with excerpts from robotics and AI, Textbook (In Serbian), XXVIII+409 p., Univ. of Belgrade - Faculty of Mechanical Eng.
R.Siegwart,I.R.Nourbakhsh,D.Scaramuzza, (2011) INTRODUCTION TO AUTONOMOUS MOBILE ROBOTS, 2nd Edition, The MIT Press; R.Siegwart,I.R.Nourbakhsh, (2004) INTR. TO AUTONOMOUS MOBILE ROBOTS, The MIT Press.
N.P. Suh, (2001) AXIOMATIC DESIGN - ADVANCES AND APPLICATIONS. New York.:Oxford University Press; N.P. Suh, (1990) THE PRINCIPLES OF DESIGN, Oxford University Press.
E. Alpaydin, (2010) INTRODUCTION TO MACHINE LEARNING, 2nd Edition, The MIT Press, Cambridge, England.; E. Alpaydin, (2004) INTRODUCTION TO MACHINE LEARNING, The MIT Press, Cambridge, England.
R.R. Murphy, (2000) INTRODUCTION TO AI ROBOTICS, The MIT Press, Cambridge, England.

Machine tools M

ID: 0920
Responsible/Holder professor BRANKO M. KOKOTOVIĆ
Teaching profesor(s): KOKOTOVIĆ BRANKO; ŽIVANOVIĆ SAŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

1. To develop ability to perceive typical missions of machining systems.
2. To study machine tools mechanisms and systems for their control and programming.
3. To receive training in testing procedures for machine tools.
4. To develop ability to analyze complex machine tools and machining systems equipment.
5. The develop ability to analyze the resources for machine tools development.
6. To study configuring and/or building of machine tools for planned mission.
7. To receive training for realization of one mission of machine tools through writing the seminar work.
8. To know how to make technical projects.

Learning outcomes

Upon successful completion of this course students should be able to:

1. Recognize typical missions of manufacturing systems.
2. Apply basic types of machine tool mechanisms in their design.
3. Configure the control of CNC machine tools based on systems with open architecture.
4. Program new generation machine tools using different programming methods.
5. Evaluate the quality of machine tools and machining system based on applied standard test procedures.
6. Configure mechine tool for their own needs.
7. Apply the acquired knowledge on the available resource for the development and / or improvement of machine tools and manufacturing systems.
8. Prepare Technical Elaborate and reports about testing and programming of machine tools.

Theoretical teaching

New teaching contents:
1. AH-1 Machine tools mechanisms.
2. AN-2 Hydraulic installations of machine tools
3. AN-3 Configuring machine tools.
4. AN-4 Open-architecture machine tools control.
5. AN-5 Object programming of machine tools.
6. AN-6 Testing of machine tools and machining systems.
7. AN-7 Complex machine tools.
8. AN-8 Machine tools and machining systems equipment.

9. AN-9 Resources for machine tools and machining systems development.
Extension:
1. AR-1 Extension of the theme AN-1 using the examples of support structures, guides, leading spindle etc.
2. AR-2 Extension of the theme AN-3: Methods of configuring new machine tools.
3. AR-3 Extension of the theme AN-4: The EMC2 System for machine tools control.
4. AR-4 Extension of the theme AN-5: The STEP-NC Protocol for programming machine tools.
5. AR-5 Extension of the theme AN-6: Examples of complete procedures for testing machine tools.

Practical teaching

1.Auditorial exercises:
(1)Resources for studying machine tolls. (2)Plan and program of laboratory exercises.
2. Laboratory exercises:
(1)Machining system static stiffness. (2)Testing lathe accuracy. (3)Working accuracy of numerically-controlled milling machines. (4)Circular interpolation test, or, One combined testing of machining system.
3. Seminar work.

Prerequisites

Study curriculum and student motivation for learning about machine tools and machining systems according to the goals set and outcomes offered.

Learning resources

1. N.N, Visionary Manufacturing Challenges for 2020, National Academy Press, Washington, D.C. 1998, ISBN 0-309-06182-2.
2. W. R. Moore, Foundations of Mechanical Accuracy, The Moore Special Tool Company, First Edition, Third Printing, 1999.
3. X. Xu, A.Y.C. Nee, Advanced Design and Manufacturing Based on STEP, Springer, 2009, ISBN 978-1-84882-738-7.
4. D. Zhang, Parallel Robotic Machine Tools, Springer, 2010, ISBN 978-1-4419-1116-2.
5. W. A. Khan, A. Raouf, K. Cheng, Virtual Manufacturing, Springer, 2011, ISBN 978-0-85729-185-1.
6. H. A. ElMaraghy (Ed), Changeable and Reconfigurable Manufacturing Systems, Springer,2009, ISBN: 978-1-84882-066-1.
7. K. Apro, Secrets ot 5-Axis Machining, Industrial Press, 2008, ISBN 978-0-8311-3375.
8. M. Weck, C. Brecher, Werkzeugmaschinen 1, Maschinenarten und Anwendungsbereiche, Springer, 2005, ISBN 10 3-540-22504-8.
9. M. Weck, C. Brecher, Werkzeugmaschinen 2, Konstruktion und Berechnung, Springer 2006, ISBN 10 3-540-22502-1.
10. R. Neugebauer (Hrsg.), Parallelkinematische Maschinen Entwurf, Konstruktion, Anwendung, Springer, 2006, ISBN 10 3-540-20991-3.
11. LPI-1: Three work places with manually controlled machine tools.
12. LPI-2: Three work places with numerically controlled machine tools.
13. LMS-1: The system for circular interpolation test.
14. LMS-2: The system for laboratory testing of machine tools accuracy.
15. LRS-1: One developmental work place with machine tool of the MOMA type.
16. LRS-2: One work place for testing machine tools mechanisms.
17. LPS-1: Work places for programming machine tool of the MOMA type.

18. APS-1: The system for experimental data acquisition and processing.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	3
laboratory exercises	17
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	7
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	20
test/colloquium	35	project design	0
laboratory exercises	15	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Glavonjic, M., Kokotovic, B., Zivanovic, S., MACHINE TOOLS - PRACTICUM, /in Serbian/, ISBN: 978-86-6060-163-8, University of Belgrade, Faculty of Mechanical Engineering, 2023.
M. Mitsuishi, K. Ueda, F. Kimura (Eds.), Manufacturing Systems and Technologies for the New Frontier, Springer, 2008, ISBN 978-1-84800-266-1.
M. Weck, C. Brecher, Werkzeugmaschinen 3, Mechatronische Systeme, Vorschubantriebe, Prozessdiagnose, Springer, 2006, ISBN 10 3-540-22506-4.
M. Weck, C. Brecher, Werkzeugmaschinen 4, Automatisierung von Maschinen und Anlagen, Springer, 2006, ISBN 10 3-540-22507-2.
M. Weck, C. Brecher, Werkzeugmaschinen 5, Messtechnische Untersuchung und Beurteilung, dynamische Stabilität, Springer, 2006, ISBN 10 3-540-22505-6.

Manufacturing Automation

ID: 0785
Responsible/Holder professor ŽIVANA B. JAKOVLJEVIĆ
Teaching profesor(s): JAKOVLJEVIĆ ŽIVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: production engineering

Goals

The objective of this course is that students: acquire knowledge of the application, design and implementation of contemporary manufacturing automation; master the skills of practical problem-solving in the domain of automation by using computer, information, control, manufacturing, and other technologies and appropriate scientific methods.

Learning outcomes

After successfully completing this course, the students should be capable to:
- Analyze social, economic, production and other effects of automation;
- Integrate knowledge in related subjects and implement them in automation;
- Analyze and synthesize combinational automata;
- Synthesize sequential automata;
- Carry out pneumatic and electro-pneumatic realization of combinational and sequential automata;
- Program programmable logic controllers according to IEC 61131-3.

Theoretical teaching

1. Introduction to manufacturing automation: definition of automation; types of production systems automation; fixed, flexible, programmable and intelligent automation; advantages and disadvantages of automation
2. Number systems: additive number systems; positional number systems (decimal, binary, octal, hexadecimal); conversion of numbers between positional number systems
3. Codes and coding: binary coded decimal; conversion between binary coded decimal and binary number system; Gray code; alphanumerical codes
4. Switching algebra: axioms of Boolean algebra; elementary operations of switching algebra; theorems of switching algebra; logic functions; canonical forms of logic functions (sum of minterms and product of maxterms); minimization of logic functions
5. Technologies and components for realization of control tasks in manufacturing automation: the structure of control system - subsystems for information acquisition, information processing and command execution; pneumatic and electro-pneumatic realization; sensors, actuators, logical and memory elements.
6. Combinational and sequential automata: Definition, models, synthesis and analysis; Pneumatic and electro-pneumatic realization
7. Programmable controllers: functions, hardware, software, input-output modules; programming languages and programming according to IEC 61131-3.
8. Examples of manufacturing automation

Practical teaching

1. Auditory exercises: examples in automation design, with control system analysis and synthesis, programmable controllers programming, and control scheme design.
2. Laboratory exercises:
PL1 Control of pneumatic actuators
PL2 Analysis of combinational automaton (pneumatic realization)
PL3 Synthesis of combinational automaton (pneumatic realization)
PL4 Synthesis of combinational automaton (electro-pneumatic realization using PLC)
PL5 Synthesis of sequential automaton (electro-pneumatic realization using PLC)
PL6 Synthesis of sequential automaton (electro-pneumatic realization using PLC- timers and counters)
PL7 Synthesis of sequential automaton (electro-pneumatic realization using PLC and programming in sequential function charts)

3. Seminar work: examples of automation design with control system synthesis, programmable controllers programming and control scheme design.

Prerequisites

none

Learning resources

1. Pilipović M., Jakovljevic, Z, Manufacturing automation, FME, Belgrade, 2017 /In Serbian/
2. Pilipović M., Manufacting processes automation: Laboratory. FME, Belgrade, 2006 /In Serbian/
3. Jakovljevic, Z., Manufacturing automation, lecture handouts
4. Laboratory desk with electro-pneumatic components and programmable controllers, Laboratory for manufacturing automation.
5. Pick and place modular robots, Laboratory for manufacturing automation.
6. Programming computers, Laboratory for manufacturing automation.
7. Software for programmable controller programming, Laboratory for manufacturing automation
8. Network of computers and PLCs, Laboratory for manufacturing automation

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	14
calculation tasks	0
seminar works	6
project design	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	4
final exam	5

discussion and workshop	0
research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	20	project design	0
laboratory exercises	10	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Pilipović M., Jakovljević, Ž, Manufacturing automation, ISBN: 978-86-7083-927-4, FME, Belgrade, 2017 (in Serbian)
Pilipović M., Manufacting processes automation: Laboratory, ISBN 978-86-7083-561-4, FME, Belgrade, 2006 (in Serbian)
Holdsworth, B., Woods, C., Digital Logic Design, ISBN: 9780750645829, Newnes, 2002
John, K. H., Tiegelkamp, M., IEC 61131-3: Programming Industrial Automation Systems, ISBN: 3-540-67752-6, Springer-Verlag, 2001
Lazic, B. Z., Computer technology basics, ISBN: 86-7466-234-X, Akademska misao, Belgrade, 2006 (in Serbian)

Manufacturing Systems Design

ID: 1534
Responsible/Holder professor BRANKO M. KOKOTOVIĆ
Teaching profesor(s): KOKOTOVIĆ BRANKO; ŽIVANOVIĆ SAŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

1. Understanding the structure of the modern machining systems, the functions of the basic subsystems and their interactions.
2. Application of methodological frameworks of developed design theories.
3. Study of static and dynamic properties of the machining system and optimization methodology of its mechanical structures
4. Application of modern CAD/CAM/CAE systems for simulating static and dynamic behavior of mechanical structures of machining systems
5. Gaining practical experience in experimental identification of static and dynamic properties of supporting structures
6. Application of modern software environments in the creation of a virtual prototype of a machine system
7. Practical experience in drafting technical reports.

Learning outcomes

Upon successful completion of this course, students should be able to:
1. Within the methodological framework of the design theory formulates functional requirements, design parameters and the design matrix at all levels of the design process of one product and implements the necessary corrections that lead to the optimization of the design solution.
2. Set up the concept of a static model of the concrete supporting structure of the machining system, with the necessary simplifications of the real model, define the model of the support system and external load, generate a discretized model using the finite element method (FEM), perform simulation in the selected program environment for FEM analysis and explain the obtained results: displacements, stresses and reactions of supports;
3. Set up the concept of a dynamic model of the concrete supporting structure of the processing system, define a model of the support system, define a simplified model, mass characteristics and generate a discretized model using the finite element method (FEM), calculate the natural frequencies and forms of oscillation using a computer and explain the results obtained;
4. Creating a setup for experimental identification of parameters of static and dynamic behavior of a mechanical structure;
5. Possesses the necessary knowledge for designing a machine system (transmission for spindle system, transmissions for feed drives, main spindles of machine tools), in the form of analytical models, standards, market of specialized components, and already realized design solutions.

6. Uses modern software environments in creating a virtual prototype of a machine system or its subsystem;
7. Conceptualizes a technical elaboration, which refers to the considered design solution or performed tests, in the field of processing systems.

Theoretical teaching

Theoretical teaching is organized through the following teaching units:
AT-1 Developed design theories and methodologies for developing and constructing technical systems and products
AT-2 Processing system - statics
AT-3 Dynamics of processing systems (models of supporting structures with concentrated masses, regenerative effect, position coupling, damping and dampers)
AT-4 Bearing structures of machine tools (morphology, materials, topology, optimization)
AT-5 Finite element method in the analysis of the static behavior of the supporting structure
AT-6 Finite element method in the analysis of the dynamic behavior of the supporting structure
AT-7 Experimental identification of parameters of static and dynamic behavior of supporting structures of machine tools
AT-8 Main spindle transmission subsystem of machine tools; functional requirements and models for project solution synthesis
AT-9 Feed drives of machine tools (mechanical structure); functional requirements and models for project solution synthesis
Elaboration of the material includes:
AR-1 FEM : Computational example of analysis of the static behavior of a supporting structure
AR-2 FEM : Computational example of analysis of the dynamic behavior of a supporting structure
AR-3 Guidelines for the synthesis of the project solution: Main spindle system (main spindle and transmission) of the machine tool
AR-4 Guidelines for the synthesis of the project solution: Transmission of the linear / rotary feed movement of the machine tool

Practical teaching

Practical work consists of work in the laboratory and the creation of the design solution according to the given project assignment.
1. Laboratory exercises: (1) Transmissions of the machine tools spindle system of (2) Identification of static and dynamic properties of the mechanical substructures of the machine tool using finite element method. (3) Example of experimental modal analysis for a system with two degrees of freedom.
2. The project of configuring the given machining system, that is, one of its subsystems. Students use modern CAD/CAM/CAE environments in their work, through teamwork and verification with available resources.
Final report on the acquired knowledge in this course is formed according to the instructions and model given at the beginning of the course. The report consists of reports from laboratory exercises and a project.

Prerequisites

Study curriculum and student motivation for learning about machine tools and machining systems according to the goals set and outcomes offered.

Learning resources

1. Lectures in electronic form, 2. Instructions for writing laboratory reports, 3. Instructions for creating a project, 4. Machining systems in the Department of Machine Tools, Department of Production Mechanical Engineering: conventional machines - lathes, milling machine and numerically controlled machine tools - CNC lathes (PH42-CNC and TCN410) and machining centers (LOLA HMC500 and LOLA HBG80), 5. Sensor and acquisition system for experimental modal analysis. 6. CAD/CAM/CAE systems for simulation of static and dynamic behavior of mechanical structures.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	6
calculation tasks	0
seminar works	0
project design	18
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	4
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	20	project design	25
laboratory exercises	15	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 35

References

Yusuf Altintas, Manufacturing Automation (2nd ed.) Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design, Cambridge University Press, ISBN 978-1-107-00148-0, 2012.
M. Weck, C. Brecher, Werkzeugmaschinen 2 - Konstruktion und Berechnung, Springer, ISBN 10 3-540-22502-1 Springer Berlin Heidelberg New York, 2005.
M. Weck, C. Brecher, Werkzeugmaschinen 5, Messtechnische Untersuchung und Beurteilung, dynamische Stabilität, Springer, ISBN 10 3-540-22505-6, 2006.
Suh, N.P., The principles of design, Oxford univerity press, 1990.

Mechatronics Systems

ID: 1536
Responsible/Holder professor ŽIVANA B. JAKOVLJEVIĆ
Teaching profesor(s): JAKOVLJEVIĆ ŽIVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The goal of the course in mechatronic systems is to provide a focused interdisciplinary theoretical knowledge and practical experience for students that encompass fundamental elements from traditional courses in mechanical engineering, production engineering, electronics and computer control engineering.

Learning outcomes

After successfully completing the course, student is capable to:
1. Analyze project task referring to production processes and define concept of mechatronic system using multi-disciplinary approach;
2. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with digital input-output signals;
3. Configure hardware and input-output channels and other system resources of an integrated microprocessor system and create application software for systems with analog and mixed input-output signals;
4. Configure hardware and input-output channels and other system resources of an integrated microprocessor system, create application software for serial communication with the digital environment, including serial communication with a personal computer;

Theoretical teaching

Theoretical teaching is organized in four teaching units:
1. Importance and role of mechatronics in modern manufacturing systems design;
2. Microcontrollers: microcontroller architecture (based on 8-bit PIC and 32-bit ARM (Cortex-M3)), microcontroller components: digital I/O, Timers, ADCs, DACs, PWMs, serial interfaces (USART, SPI, I2C, CAN); microcontroller programming: from C to assembler, interrupts, interrupt service routine;
3. Sensors: absolute and incremental encoders (rotary and linear), strain gauges, force measurement, displacement measurement (LVDT, laser interferometers), accelerometers, gyroscopes, inertial measurement units, thermocouples, RFID, vision systems;
4. Digital signal processing basics: sampling theorem, Fourier transform, Discrete Time Fourier transform, Short Time Fourier transform, signal filtering, FIR filters design, convolution;
5. Electrical servo drives and motion control – stepper and DC motor fundamentals, servo drivers and numerically controlled servo axis, motion control and interpolation, CNC system

architecture;
6. Industrial internet reference architecture; Industrial networks: wired networks overview, IEEE 802.11 (Wi-Fi) and IEEE 802.15.4 based wireless networks; OPC Unified Architecture;

Practical teaching

1. Laboratory exercises:
PL1 Microcontroller programming basics: Digital I/O, ADC;
PL2: Microcontroller programming: DAC;
PL3: Microcontroller programming: serial interfaces;
PL4: Microcontroller programming: PWM and interrupts;
PL5: Digital signal processing basics; FIR filter design; Microcontroller programming: FIR filter implementation;
PL6: Servo drives and motion control – servomotor, servo driver architecture and technical details, induction motor motion control, step motor control.

Project: mechatronic system design using microcontrollers, microprocessor based sensory signal conditioning and processing, and servocontrolled actuators. The project is focused on specific problem closely related to real industrial scenarios.

Prerequisites

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Learning resources

1. Jakovljevic, Z., Mecharonic Systems, lecture handouts;
2. ARM Cortex-M3-based NXP LPC1768 microcontrollers;
3. Breadboards and electronic components;
4. MRF24J40MA 2.4 GHz IEEE Std. 802.15.4 RF Transceiver Modules;
5. Keil \mu Vision software;
6. Accelerometers, encoders, LVDT sensors, custom made strain gauge force sensor, 2-axis piezoelectric dynamometer, binary sensors;
7. Servo motors, induction motors with frequency regulators, step motors;
8. Personal computers.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	6
test, with assessment	0
final exam	5

research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	24	project design	25
laboratory exercises	16	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Pilipović M, Jakovljević Ž, Manufacturing Automation, Faculty of Mechanical Engineering, Belgrade, 2017 /In Serbian/
Rob Toulson and Tim Wilmshurst, Fast and effective embedded systems design: applying the ARM mbed, Newnes, 2016.
Edward A. Lee and Sanjit A. Seshia, Introduction to Embedded Systems - A Cyber---Physical Systems Approach, Second Edition, 2015. Available online at http://LeeSeshia.org
W. Bolton, Mechatronics – Electronic control systems in mechanical and electrical engineering, Prentice Hall, 2003.
Robert H. Bishop, MECHATRONICS - AN INTRODUCTION. Published in 2006 by CRC Press, Taylor & Francis Group, ISBN 0-8493-6358-6.

Micro Manufacturing and Characterization

ID: 0601
Responsible/Holder professor BOŽICA A. BOJOVIĆ
Teaching profesor(s): BOJOVIĆ BOŽICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The course's goals are: students should achieve a basic knowledge of micro-machining technologies through study manufacturing and measuring systems and their functions in the micro scale, as well as the necessary knowledge for the manufacturing and characterization of parts of contemporary materials; students should study in details the chosen method; students will be trained to write term paper, elaborate on lessons learned and be able to continue practicing this discipline in the profession either further education or research in this area.

Learning outcomes

At the end of this course students will be able to:
Apply basic principles of manufacturing in the micron area
Identify the different machine and tools, industrial robots, assembly and transport systems and automation systems applicable to micro manufacturing
Select the suitable methods of micro manufacturing according to techno-economic criteria.
Select the principle of measurement and characterization of functional primitives
Understanding the properties of the material adequate for micro manufacturing.
Apply scientific methods of analysis, synthesis and design, as well as computer technology

Theoretical teaching

AT-1: Introduction to micro technology and an overview of previous situation in that area; AT-2: Methods for micro-cutting process, AT-3: Methods of processing micro-plastic deformation; AT-4: Methods of processing micro-pressure casting polymer; AT-5: Methods of processing micro electro erosive processing; AT-6: Application of laser in microtechnology, AT-7: Microlithography, AT-8: Micro additive technology, AT-9: Micro Metrology, AT-10: Characterization of engineering surfaces.

Practical teaching

PA-1, PA-2 PA-3 PA-4 PA-5 PA-6: Examples of implemented solutions regarding the teaching topics, PZ-1: The task in the field of micro-processing, PZ-2: The task in the field of micro-metrology; PZ-3: The task in the field of characterization; PL-1, PL-2: Laboratory practice in the field of micro-cutting, PL-3: Laboratory practice in the field of micro-measurements, PK-1, PK-2: Consultation regarding the term paper , PS-1: Term paper title choosing and definition of the paper, PS-2: Searching the available literature; PS-3: Searching the Internet resources, PS-4: Analysis of collected information ; PS-5 PS-6 PS-7, PS- 8: Independent work

on term paper , PS-9: Final work on the preparation of term paper, PS-10: Finalisation of the paper by making and preparing presentations;

Prerequisites

Defined by the Study Program Curriculum

Learning resources

Handouts - writing material in the form of pdf and ppt files from the lecture.
3D DLP printer Creality LD002R, UV chamber for photocuring in-house made, Microscope Mustool G600 Digital, Programs for microscope image processing eg. Digimizer ©MedCalc Software Ltd, ProveraMerenje and applicaton as part of MSc work, Scanning microscope JSPM-5200 and software for image processing WinSPM Ver.2.5

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	2
laboratory exercises	6
calculation tasks	4
seminar works	14
project design	0
discussion and workshop	4
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	1
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	30
test/colloquium	20	project design	0
laboratory exercises	10	final exam	30
calculation tasks	10		

Requirements to take the exam (number of points) 30

References

Ehman, K., Bourell, D., Culpepper, M., at al. MICROMANUFACTURING, Springer, Netherlands, 2007.
Lasagni, F., Lasagni, A., FABRICATION AND CHARACTERIZATION IN THE MICRO-NANO RANGE, Springer, Berlin, 2011.
Franssila, S. INTRODUCTION TO MICRO FABRICATION, John Wiley & Sons, Ltd. England, 2004.
Saleem Hashmi, COMPREHENSIVE MATERIALS PROCESSING, Elsevier, 2014

Mahalik, N.P. MICROMANUFACTURING AND NANOTECHNOLOGY, Springer, Germany, 2006

New generation of machine tools and robots

ID: 1107
Responsible/Holder professor SAŠA T. ŽIVANOVIĆ
Teaching profesor(s): ŽIVANOVIĆ SAŠA; SLAVKOVIĆ NIKOLA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

1. Perception of different levels of the new generation of machine tools and robots concept.
2. Acquisition of basics of reconfigurable, high-speed, meso- and micro-machines and highaccuracy machine tools.
3. Practical knowledge about parallel kinematic machines and machines for material addition processes and multi-axis machining.
4. Development of programming skills relevant for the new generation of machine tools and robots.
5. Development of report-making skills.

Learning outcomes

After completed this course the students should be able to:

•Understand the role, importance, types and applications of the new generation of machine tools and robots.
•Understand different levels of the new generation of machine tools and robots concept.
•Select appropriate new generation machine tools and robots for given technological task.
•Select and prepare environment for operation of machine tools and robots.
•Programming the new generation of machine tools and robots.
•Use new programming methods for numerically controlled systems.

Theoretical teaching

New teaching contents:
T1. Definition and classification of the new generation of machine tools and robots.
T2. Reconfigurable machine tools.
T3. High-speed machine tools.
T4. Machines for material addition processes.
T5. Parallel kinematic machines concepts.
T6. Identification of geometry and kinematics in parallel kinematic machines.
T7. Multi-axis machine tools.
T8. Multi-axis machining robots.
T9. Meso- and micro-machines.
T10. High-accuracy machine tools.
Extension:
(a) Extension of T1 and calculation tasks relevant for parallel kinematic machines geometry.
(b) Extension of T2 and calculation tasks relevant for parallel kinematic machines.

(c) Extension of T3 using the examples of meso- and micro-machines.
(d) Extension of T4 using the examples of machine tool calibration.
(e) Extension of T5 using the examples of compensations in the machining system.

Practical teaching

Practical teaching involves auditorial exercises, laboratory work and seminar work writing.
1. Auditorial exercises: (1)Resources for studying the new generation of machine tools and robots. (2)Analysis of reconfigurable machines. (3)Machine tool calibration and compensations in the machining system.
2. Laboratory exercises: (1)Programming of machines for material addition processes. (2)Programming of DELTA robot. (3)Programming of parallel kinematic machines. (4)Programming of multi-axis machining. Instructions are provided for each exercise and the necessary work sheets.
3. A seminar work on the new generation of machine tools and robots.
4. A report is written on the knowledge acquired during the course according to instructions and model provided at the start of the course. A part of the report is a seminar work.

Prerequisites

Study curriculum and student motivation for learning about machine tools and industrial robots according to the goals set and outcomes offered.

Learning resources

1. Documents on the web site http://cent.mas.bg.ac.rs/nastava/ma_bsc/indexnma.htm.
2.Documents for the areas of parallel mechanisms and multi-axis machining of robots.
3. W. R. Moore, Foundations of Mechanical Accuracy, The Moore Special Tool Company, First Edition, Third Printing, 1999.
4. Y. Ito, Modular Design for Machine Tools, McGraw-Hill, 2008, DOI: 10.1036/0071496602.
5. D. Kochan, Ed, Solid Freeform Manufacturing, Advanced Rapid Prototyping, Elsevier, 1993, ISBN 0-444-89652-X.
6. H. Schulz, Hochgeschwindigkeitsfraesen metallischer und nichtmetallischer Werkstoffe, Hanser Verlag, 1989, ISBN 3-446-15589-9.
7. K. Ehmann, D. Bourell, M. Culpepper, T. Hodgson, T. Kurfess, M. Madou, K. Rajurkar, R. DeVor, International Assessment of Research and Development in Micromanufacturing, Final Report, WTEC, 2005.
8. Tsai L.-W. (1999) Robot Analysis: The Mechanics of Serial and Parallel Manipulators, Wiley, New York.
9. Merlet J.-P. (2000) Parallel Robots, Kluwer Academic Publisher, Dordrecht, The Netherlands.
10. PRA-1: Practicum in preparation.
11. LPI-1: Two work-places equipped with prototypes of the new generation of machine tools (3-axis parallel milling machine, desktop 3-axis parallel milling machine).
12. LPI-2: Two work-places equipped with prototypes of the new generation of robots (serial machining robot, DELTA robot).
13. LPS-1: Functional simulators of parallel kinematic machines.
14. LPS-2: Functional simulator of the machine for prototype building.
15. CSP-1: Two work-places equipped with the software for programming of multi-axis machining.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	21
calculation tasks	0
seminar works	4
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	1
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	10
test/colloquium	50	project design	0
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

J. A. McDonald, C. J. Ryall, D. I. Wimpenny (Eds.), Rapid Prototyping Casebook, Wiley, 2001, ISBN: 978-1-86058-076-5.
R. I. Noorani, Rapid Prototyping: Principles and Applications, Wiley, 2005, ISBN 13: 978-0-471-73001-9.
S. S. Makhanov, W. Anotaipaiboon, Advanced Numerical Methods to Optimize Cutting Operations of Five-Axis Milling Machines, Springer, 2007, ISBN 978-3-540-71120-9.
L. C. Hale, Principles and Techniques for Designing Precision Machines, Ph.D. Thesis, 1999, Lawrence Livermore National Laboratory, UCRL-LR-133066.
N. Taniguchi, T. K, K. M, K. I, I. M, T. D. (Eds.), Nanotechnology, Integrated Processing Systems for Ultra-precision and Ultra-fine products, Oxfod University Press, 1996, ISBN10: 0198562837.

New Technologies

ID: 0104
Responsible/Holder professor RADOVAN M. PUZOVIĆ
Teaching profesor(s): PUZOVIĆ RADOVAN; POPOVIĆ MIHAJLO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The aims of introducing new technologies to production are top quality products, low-cost and short-time manufacturing process. This course is intended for students of the Production Engineering Department. Students are familiarized with modern technologies that make possible to extend knowledge acquired in Manufacturing Technology and Production Technologies and Metrology.

Learning outcomes

On successful completion of the course, students should be able to:
•Design technology for building complex machine parts from various materials (metal, metal powder, polymer, ceramic, stone, etc.).
•Design technology for manufacturing of cutting tools (powder metallurgy).
•Identify versatile specificities of plastic parts pressure casting tools, stamping tools for metal parts.
•Use some of the advanced software tools for simulations of the polymer material parts pressure casting process, along with analysis and presentation of experimentally obtained results.
•Draft a plastic parts pressure casting tool for a specified part.
•Apply some of the developed CAD/CAE/CAM software tools for modeling drafted polymer material parts pressure casting tools.

Theoretical teaching

AN-1: Introduction to new technologies; AN-2: Contemporary tools and tool materials; AN-3: Technology of synthesis; AN-4: Finish cutting technologies; AN-5: Machining technology by abrasive suspension; AN-6: Technology of powder metallurgy; AN-7: Technology of polymer shaping; AN-8: Forging technology; AR-1: Consolidation of teaching contents through presentation of new technologies; AR-2: Survey of contemporary cutting tools and tool materials application; AR-3: Demonstration of technology of synthesis; AR-4: Consolidation of teaching contents related to finish cutting methods; AR-5: Giving instructions for the design of tools for building machine parts from plastic masses; AR-6: Giving instructions for forging tools design;

Practical teaching

PP-1: Design of tools for building machine parts from plastic masses or forging tools design (students opt for the design of one of the offered tools); PL-1: Standard and special cutting tools (tool material, geometrical shapes of tools, tool assembly, and tool use); PL-2:

Application of machining technology by abrasive suspension (demonstration on concrete examples); PL-3: Tools for building machine parts from plastic masses (components, molding systems, assembly, exploitation characteristics; PL-4: Forging tools (components, casting systems, assembly, exploitation characteristics).

Prerequisites

Defined by the Study Program Curriculum

Learning resources

1. Puzovic R., Popovic M., New technologies - Handouts (PDF files) /In Serbian/, FME, Belgrade, 2022
2. Laboratory equipment (tools and machines) at IMT
3. CAx software work station (CAD, CAM, CAE, CAPP,...), (CAX)
4. Moldex3D software.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	12
calculation tasks	0
seminar works	0
project design	18
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	4
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	40	project design	15
laboratory exercises	10	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Kalajdžić M., Manufacturing technology, FME, Belgrade, 2023 /In Serbian/
Kalpakjian S., Manufacturing Engineering and Technology , Addison-Wesley Pub.Com.,1995
Privšek H., The art of injection molding, Profidtp d.o.o., Škofljica, Slovenija, 2015 /In Serbian/.

PRODUCTION INFORMATION SYSTEMS

ID: 0786
Responsible/Holder professor RADOVAN M. PUZOVIĆ
Teaching profesor(s): PUZOVIĆ RADOVAN; MLADENOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

1.Acquisition of nowledge about the role and importance of computer-oriented information systems for planning and management of production systems
2. Mastery of theoretical basics of contemporary information systems architecture
3. Acquisition of practical knowledge for applications design and development in the domain of information systems for planning and management of production systems

Learning outcomes

On successful completion of the course, students should be able to:

- Identify basic concepts in the sphere of computer-oriented information systems design and development.
- Identify the application and role of contemporary database management systems.
- Define sub-systems (modules) within the production system, documentation and information flows within the sub-system and their interactions within the overall system.
- Design database logical structure for a corresponding technological sub-system with description of required attributes for each entity and links between the entities.
- Use contemporary software tools in the design and development of production information systems.

Theoretical teaching

Information systems for new concepts of production systems. Possible creation of contemporary concepts, such as CIM/CIE, TQM, Kanban system or MRP-II systems, as well as concepts of organizational structures, such as concepts of virtual enterprises, network production, e-production systems based on architectures of the system in the network environment. Processes in the client/server architecture are also the subject-matter of the course. Production system functional structure, its structuring primarily into subsystems of a production technological system: structural information management, technological information management, stock management, current business operations management, tools system management, transport management, maintenance management, all implying information modeling, database modeling, defining the object-link diagrams (EP diagram), DBMS choice, developing physical data model up to the application development level

Practical teaching

The student acquires practical knowledge for the design and development of software applications in the domain of production systems planning and management. Using some of the available software tools for creating a database, the student passes through all stages of developing new software application for a concrete subsystem. This means the analysis of defined functions of planning and management, design and detailed elaboration of the designed solution, its practical realization, testing and official presentation in front of the teacher and other students

Prerequisites

There are no prerequisites

Learning resources

Instructions for laboratory exercises and for project design /In serbian/.;
Computer classroom.
Software tool for application development (Oracle, MS Access, Progress,...)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	7
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	40	project design	20
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Milačić V.: 2 Production Systems, University of Belgrade, Faculty of Mechanical Engineering, Belgrade, in 1982. (In Serbian)
Stephen N. Chapman: The Fundamentals of Production Planning and Control, Pearson, 2005.
Jorg Thomas Dickersbach and Gerhard Keller: Production Planning and Control with SAP

ERP (2nd Edition) - Hardcover, 2010.

Quality Management

ID: 1167
Responsible/Holder professor SLAVENKO M. STOJADINOVIĆ
Teaching profesor(s): STOJADINOVIĆ SLAVENKO
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

The objective of this course is to acquire knowledge and skills necessary for solving theoretical and practical problems in the field of quality management of products and services, that are necessary for successful scientific-professional work of students and engineers in production engineering. Students should: to master the basic terms, the definition of quality and the development of systematic approaches to improving quality; to get familiar with analytical methods of quality management and statistical techniques of quality engineering; acquire knowledge from statistical methods of quality management; acquire skills from experimental methods of quality management; to get familiar with the quality standards, requirements and the implementation of the ISO 9000 series.

Learning outcomes

After successfully completion of this course, the students should be capable to: determine and define the scope of quality management in an industrial environment; classify, rank, analyze and evaluate the importance of quality characteristics; calculate the partial and total processing error for a particular technology and processing conditions and analyze the accuracy of the process; design and application of statistical quality engineering techniques for concretely production conditions: get static sheet, control card and acceptance plan; generate a measurement protocol on a measuring machine, execute measurement and analyze the measurement results; interpret, application and document requirements ISO 9001 for the organization; prepare and implement a TQM project for the organization.

Theoretical teaching

Theoretical teaching embraces ten units: 1. Definition of product quality in the business or technological system. Definition of quality management. Development of systematic approaches to quality improvement. 2. Analytical method of quality management. Analysis and synthesis of machining errors. 3. Errors of machining due to elastic deformation of the machining system. Compensation methods. 4. Errors of machining due to thermal deformation of the machining system. Machining errors due to wear and fabrication errors. Tool regulation errors. 5. Statistical methods of quality management. Method of layout curve analysis. Control charts. 6. Acceptance plan, definition, classification, application. 7. Measuring chains. Measurement and inspection. 8. Planning of measurement and inspection on CMM. 9. ISO 9001 - requirements and applications. ISO 9001 - certification. ISO 9001 for small and medium organizations. 10. Total quality management. Quality Awards.

Practical teaching

Practical teaching embraces seven units: six auditory and one laboratory exercises, as well as seminar work in the area of quality standards. The content of auditory exercises is as follows: 1. Linear regression; 2. Analytical method - first part; 3. Analytical method - second part; 3. Testing the hypothesis; 4. Control charts; 5. Acceptance plan; 6. Measuring chains.
The topic of the laboratory exercise is: The example of preparation for inspection on the CMM, simulation and generation of the measurement protocol. Development of six individually computational tasks from engineering analysis and synthesis using the quality engineering techniques. Quality management in practice - discussion and workshop (optionally, visit to the selected factory and familiarization with the functioning of ISO 9001 in practice).

Prerequisites

Defined by curriculum of study programme.

Learning resources

1. Stojadinovic, S. (2022), Quality Management, handouts for each lecture. 2.The instruction for making individually tasks and seminar work. 3. The monograph in the field of quality and production metrology. 4.The web site of the course. 5. Facility and technical equipment: Laboratory for production metrology and TQM.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	3
calculation tasks	5
seminar works	8
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	0
check and assessment of seminar works	1
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	5
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	25		

Requirements to take the exam (number of points) 30

References

Stanic, J. (1995), Products quality management - methods I, Faculty of Mechanical Engineering, Belgrade /in Serbian/
Stojadinovic, M.S., Majstorovic, D.V. (2019), An Intelligent Inspection Planning System for Prismatic Parts on CMMs, Springer International Publishing, 978-3-030-12806-7.
Majstorovic, V. (2000), Products quality management I, Faculty of Mechanical Engineering, Belgrade /in Serbian/
Stanic, J. (1992), Products quality management - methods II, Faculty of Mechanical Engineering, Belgrade /in Serbian/
Durakbasa, N., Osanna, H. (2009), Quality in Industry, Abteilung Austauschbau und Messtechnic, Wien

Sheet-Metal Processing Tools

ID: 1362
Responsible/Holder professor MILOŠ D. PJEVIĆ
Teaching profesor(s): POPOVIĆ MIHAJLO; PJEVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: production engineering

Goals

Acquisition of theoretical and practical knowledge in the domain of the design, calculations and construction of tools for sheet-metal processing by punching, drilling, bending, drawing, and combination of these methods. The student acquires a sound understanding of the importance of team work and cooperation in the area of the design based on contemporary technologies and optimal solution.

Learning outcomes

On successful completion of the course, students should be able to:
• Evaluate each element of the tool for its construction and function with respect to the material and performance.
• Identify different concepts of cutting sheet-metal plates, strips and work-pieces, and perform computations for metal efficiency level, which enables students to also understand economic indicators.
• Identify different concepts and specificities of sheet-metal processing tools.
• Create a concept of a sheet-metal processing tool for a specified part.

Theoretical teaching

The mathematical theory of plasticity and physics of plastic deformation in solids (hypotheses and models of solids). Plastic deformation mechanism. Continuum mechanics. Elastic repositioning of sheet metal. Deformation force and work in processing by punching, drilling, bending, drawing. Determination of the sheet-metal holder force. Determination of the press force. Determination of the tool pressure center. Determination of preliminary work-piece measurements for components manufactured by bending and drawing. Determination of the sequence and number of operations. Construction characteristics of tool working elements.

Practical teaching

During laboratory exercises the student is acquainted with practical realization of sheet-metal processing tools. Project design for a concrete practice-related work-piece. Tools for making normal-accuracy components. Single-operating, multiple-operating and combined tools. Tools for making ribs for smaller or larger hole shaping. The hole enlargement by edge drawing. A visit to the factory where students are acquainted with the tool making technological process. Acquainting students with recommendations from practice relevant to tool design.

Prerequisites

Defined by the Study Program Curriculum

Learning resources

1. Standardized tool elements, Sheet-metal processing tool elements, Lab for FTS, machining processes and tools, ЛПС

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	2
laboratory exercises	10
calculation tasks	0
seminar works	0
project design	14
discussion and workshop	4
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	0
test, with assessment	4
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	10	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Jovičić M., Tanović Lj., TOOLS AND TOOLING FIXTURES - calculations and constructrions of sheet-metal processing tools, FME, Belgrade, 2007, КПН

Skill Praxis M - PRO

ID: 1195
Responsible/Holder professor NIKOLA R. SLAVKOVIĆ
Teaching profesor(s): SLAVKOVIĆ NIKOLA; MLADENOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: production engineering

Goals

The student gains practical experience and gets familiarized with the future occupational environment. The student identifies basic functions of the business system in the domain of design, development, and manufacturing as well as the role and tasks of the mechanical engineer within such a business system.

Learning outcomes

Upon successful completion of this course students should be able to:
(1) Apply practical experience on the organization and functioning of the business environment in which they will apply the acquired knowledge in their future professional career.
(2) Students can identify the models of communication with the colleagues and business information flow.
(3) Solve basic processes in the design, manufacturing, maintenance within the context of their future competences.
(4) Establish of contacts and acquaintances are useful during graduate studies as well as for applying for the job in the future.
(5) Prepare by Report professional practice upon on the completed tasks in given topics.

Theoretical teaching

This professional practice M PRO has no lectures. Students use the knowledge acquired during their studies at the Faculty of Mechanical Engineering.

Practical teaching

Practical teaching means work in the companies where various activities related to mechanical engineering are proceeding. The subject matter and business company or research institution is selected in consultation with the professor. In principle, the student is allowed to conduct skill praxis in manufacturing companies, design and consulting firms, enterprises for machine equipment maintenance, public enterprises and municipal service companies or any laboratory at FME. Skill praxis can also be performed abroad. Students are obliged to keep a diary of skill praxis, where they describe the jobs they are doing, write down deductions and perceptions. Having completed the skill praxis the students must make a report they will defend in front of the professor. The report is handed over in the form of a seminar work.

Prerequisites

Defined by the Study Program Curriculum.

Learning resources

Laboratories of the Department of Production Engineering.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	70	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Stephenson D.A., Agapiou J.S., Metal cutting theory and practice, CRC press, 2018.

RAILWAY MECHANICAL ENGINEERING

Brakes of rail vehicles

Fundamentals of Rail Vehicle Dynamics

Locomotive 1

Locomotive 2

Rail vehicles 1

Rail vehicles 2

Railway vehicles maintenance

Skill Praxis M - ZEM

Theory of Traction

Brakes of rail vehicles

ID: 1189
Responsible/Holder professor DRAGAN D. MILKOVIĆ
Teaching profesor(s): MILKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

1. Introducing the brake system of railway vehicles.
2. Acquiring the knowledge necessary to understand the functioning of rail vehicle brake system components.
3. Training for the application of knowledge in the design, development, repair and maintenance of the brakes.

Learning outcomes

After completion of the course the student should be able to:
1. Explain the functional and design characteristics of various types of brakes.
2. Explain the tasks and functioning mode of brake system assemblies.
3. Identify actions required to be aplied in case of malfunctions of the break system during operation and maintenance.
4. Apply appropriate regulations and standards for design and maintenance of rail vehicle brakes.

Theoretical teaching

The general braking conditions. Friction and friction materials. The main types of brakes and braking techniques. The transfer of the braking action by means of the compressed air. The main braking conditions. Transmission speed, transmission time, braking time and release time. The process of braking. Braking, brake weight, weight at changeover. The stopping distance and stopping time. Braking tables. Adjusting the brake force to the load. Thermal and other restrictions of the braking force. Emergency brake. Handbrake. Electromagnetic rail brakes. UIC regulations relating to the brakes of railway vehicles. Braking modes RIC, R, S, SS ... The calculation of the brakes for passenger and freight cars. Formation and tansmission of the braking force: compressor with accessories, the main pipe, tanks, distributor, brake cylinder, mechanical transmission, slack adjuster. Executive parts: brake holders, brake shoes, discs, calipers, brake pads, other accessories. Testing of brakes: type and serial tests of the brakes and brake equipment. Experimental determination of the braking power.

Practical teaching

Clasification of the brakes. Functional scheme of basic types of brakes. Functional scheme of pneumatic brakes. The working principle of control valve. The working principle of the distributor valve. Brake system schemes for typical rail vehicles. Gear ratio and the coefficient of efficiency. The design of the brake with brake shoes. Braking parameters selection based on regulations. The design of disc brakes. Visit the workshop for the brake

maintenance. Braking tables. Examples of calculation. Examples of braking mass determination based on the brake stopping distance tests. Calculation of brake mass. Calculation of the handbrake. The design of the braking force transmission elements. The design of magnetic rail brakes, parking brake, emergency brake. Brakes for high-speed trains.

Prerequisites

It is recommended previously to pass course Railway vehicles 1.

Learning resources

For tasks realization shall be used the appropriate regulations and standards.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	4
calculation tasks	7
seminar works	0
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	7
check and assessment of lab reports	3
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	20	project design	0
laboratory exercises	10	final exam	40
calculation tasks	30		

Requirements to take the exam (number of points) 30

References

Simic, G., Milkovic, D., Radulovic, S., Brakes of railway vehicles, Faculty of Mechanical Engineering, Belgrade, 2022.
Milovanovic, M., Lisanin, R., Vuksic-Popovic M., Krzic, D., Brakes and braking of rail vehicles - basis for design, selection and maintenance, Faculty of Mechanical Engineering, Belgrade 2000.
Milovanovic, M., Lisanin, R., Brakes and braking of rail vehicles, Faculty of Mechanical Engineering, Belgrade 2000.

Fundamentals of Rail Vehicle Dynamics

ID: 1190
Responsible/Holder professor DRAGAN D. MILKOVIĆ
Teaching profesor(s): MILKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

1. Acquiring knowledge about the dynamic behavior of rail vehicles.
2. Exploring methods for studying the dynamic behavior of rail vehicles.
3. Training for the application of knowledge in the design, development, repair and maintenance of railway vehicles.

Learning outcomes

After completion of the course the student should be able to:
1. Explain the characteristic phenomena of dynamic behaviour of rail vehicles.
2. Apply computational methods for determining the main parameters of the dynamic behaviour of the rail vehicles.
3. Participate in the preparation of the test procedures for tests of the dynamic behaviour and proper assesment of the test results.
4. Apply appropriate regulations for design or refurbishment of rolling stock in order to achieve the prescribed dynamic behaviour.

Theoretical teaching

Modeling of the dynamic behaviour of the rail vehicles. Geometrical deviations of the track and deviations of wheelset geometry as the excitation source. An elementary model of the vertical oscillation of vehicles with single-stage suspension. The appearance of resonances during movement along track with vertical harmonic deformations. The influence of damping. The behavior of vehicles with dry damping elements. Model of the railway vehicle with two-stage suspension in vertical direction. Application of matrix calculus in solving the dynamic problems. Fundamentals of rail vehicle lateral dynamics. A hunting movement of the wheelset-Klingel solution. The contact geometry. Equivalent conicity. The forces in the wheel-rail contact. The movement of bounded wheelset. Stability of motion. Critical speed. Modelling of stationary, quasi-static motion of the bogie in the curve using the center of friction method. Criteria for assessing the behavior of rail vehicles in motion. (Y/Q) criterion. Criterion of the H forces. Sperling Ride Index. Tests according to UIC 518. Criteria ISO/ORE (UIC518).

Practical teaching

Examples of excitation: denivelation of the rails, out off roundness and eccentricity of the wheel, track deformations, harmonic deformations. Excitation simulation. Linear and nonlinear characteristics of elastic and damping elements. Linearization of the characteristics. Examples of one degree of freedom models. Typical dry friction elements

used on rail vehicles. The model with dry friction. Example of two axle bogie model in the vertical plane. Effect of selection of generalized coordinates to equation coupling. Example of the freight wagon model with bogies. Example of model of passenger coach two-stage suspension in the vertical plane. Solving problems with more degrees of freedom using computer software. Review of tests of passenger coach dynamic behaviour.

Prerequisites

Previously passed courses in Mechanics of rigid bodies and at least 18 EPSB, with at least one course of Dynamics.

Learning resources

D. Milković, Fundamentals of rail vehicle dynamics, hand-out.
User guides for appropriate software.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	15
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	6
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	40	project design	0
laboratory exercises	0	final exam	30
calculation tasks	30		

Requirements to take the exam (number of points) 30

References

Milutinovic, D., Simic, G., Loads and calculation of railway vehicles' wheels, Faculty of Mechanical Engineering, Belgrade, 2006.
Milkovic, D., Wayside system for wheel-rail contact forces, Faculty of Mechanical Engineering, Belgrade, 2017.

Locomotive 1

ID: 1566
Responsible/Holder professor JOVAN D. TANASKOVIĆ
Teaching profesor(s): TANASKOVIĆ JOVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

1. Introduction student to the basic concepts important for understanding the designing of diesel locomotives.
2. Knowledge acquiring necessary for understanding the designing of diesel locomotives.
3. Competence for use the knowledge acquired in solving practical problems in designing, use and maintenance of diesel locomotives.

Learning outcomes

After successfully finishing of course students would be able to:
- define basic characteristics of diesel locomotives;
- describe tasks and way of functioning of assemblies of diesel locomotive;
- compare tractive characteristics of different types of power transmissions;
- calculate the key parameters using special software package;
- implementation of regulations and standards in field of diesel locomotives.

Theoretical teaching

High speed vehicles, Influential factors on adhesion, Traction force, Resistance during motion, Basic conception of diesel traction vehicles, Introductions with the basic framework, Design of the running bogie and the supporting vehicle structure, Diesel motor - specification of diesel motors for railway vehicles, Power supply characteristics, Modern motors for railway vehicles, Examination and emission of exhaust gases, Characteristics of units for power transmission on railway vehicles, Design of mechanical transmitters, Design of hydrodynamic transmitters, Joint operation of diesel motor and hydrodynamic transmitter, Design of cooling systems.

Practical teaching

Practical training, Auditory exercises (Introductions with examples regarding learned materials - Modern solutions of diesel motors for railway vehicles, Mechanical transmitters for railway vehicles, Hydraulic - hydrostatic and hydrodynamic transmitters for railway vehicles, Regulation of diesel motor and transmitter joint operation, Accessories on diesel locomotives), Solving the set problem (Designing of diesel hydraulic locomotives power supply systems), Introductions with practical problems in the field of inspection and maintenance of diesel locomotives, Visiting the factory for production of diesel locomotives, Discussion and workshops.

Prerequisites

Nothing.

Learning resources

Syllabus, Guidebook for solving the tasks, Handouts, Personal PC, Projector and internet access - internet exploring for additional information's.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	15
test/colloquium	30	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Karl Sachs, Elektrishe Triebfahrzeuge, Springer-Verlag, Wien New York, 1973
Zdravko Valter, Diesel - electric locomotives, Školska knjiga, Zagreb, 1985

Locomotive 2

ID: 1567
Responsible/Holder professor JOVAN D. TANASKOVIĆ
Teaching profesor(s): TANASKOVIĆ JOVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

1. Introduction student to the basic concepts important to understanding the the designing of diesel-electric and electric locomotives.
2. Knowledge acquiring necessary for understanding the designing of diesel-electric and electric locomotives.
3. Competence for use the knowledge acquired in solving practical problems in designing, use and maintenance of diesel-electric and electric locomotives.

Learning outcomes

After successfully finishing of course students would be able to:
- define basic characteristics of diesel-electric and electric locomotives;
- describe tasks and way of functioning of the main assemblies of diesel-electric and electric locomotives;
- compare ways of functioning and control of electric drive motors for DC and AC power;
- calculate the key tractive parameters using special software package;
- implementation of regulations and standards in field of diesel-electric and electric locomotives.

Theoretical teaching

Brief history, Overview of historical development and basic characteristic traction vehicles, High speed vehicles, Influential factors on adhesion, Traction force, Resistance during motion, Basic conception of diesel traction vehicles, Introductions with basic frame, Design of the bogie and the frame, Diesel motor - specification of diesel motors for railway vehicles, Power supply characteristics, Modern motors for railway vehicles, Examination and emission of exhaust gases, Characteristics of units for power transmission on railway vehicles, Design of mechanical gear, Design of hydrodynamic gear, Diesel motor and hydrodynamic gear working together, Design of cooling systems.

Practical teaching

Practical training, Auditory exercises (Introductions with examples regarding learned materials - Modern solutions in the field of electric machines , Generators and Traction motors, Adjustments technique), Solving the set problem (Designing of diesel locomotives power supply systems), Introductions with practical problems in the field of inspection and maintenance of electric locomotives, Practical examples in the field of the electrical vehicles speed regulation - thyristors regulation, transducer. Visiting the maintenance shop for the electric locomotive. Exploring the traction vehicles components. Discussion and workshops.

Prerequisites

Attended the course Locomotive 1.

Learning resources

Syllabus, Guidebook for solving the tasks, Handouts, Personal PC, Projector and internet access - internet exploring for additional information's.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	20
test/colloquium	20	project design	0
laboratory exercises	0	final exam	50
calculation tasks	5		

Requirements to take the exam (number of points) 35

References

Karl Sachs, Elektrishe Triebfahrzeuge, Springer-Verlag, Wien New York, 1973
Zdravko Valter, Diesel - electric locomotive, Školska knjiga, Zagreb, 1985

Rail vehicles 1

ID: 1186
Responsible/Holder professor DRAGAN D. MILKOVIĆ
Teaching profesor(s): MILKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

1. Understanding of different constructions of the freight wagons and passenger coaches
2. Acquiring the knowledge necessary to understand the functioning of wagon or coach assemblies
3. Application of knowledge in the design, development, repair and maintenance of wagons and coaches

Learning outcomes

After completion of the course the student should be able to:
1. Explain the functional and structural characteristics of various types of rolling stock.
2. Explain the tasks and functioning principles of the assemblies of the rail vehicles.
3. Identify actions required to resolve failures in operation and maintenance of rail vehicles.
4. Apply appropriate regulations and standards for design and maintenance of railway vehicles.
5. Applicate computer tools for calculating and designing rail vehicles.

Theoretical teaching

General fundaments for designing rail vehicles. Main assemblies of the rail vehicles. The structural parameters of the vehicle. Standards and regulations in the design, operation and maintenance of rail vehicles. Wheelsets. Axle bearings. Single axis running gear. Typical bogies for wagons. Bogies for passenger coaches. Bogie breakaway torque. Running gear with independent wheels. Calculation of the rail vehicles gauge. Flexibility coefficient. Checking the relative position between the running gear and the carbody. General overview of the loads acting on the structure of the wagon. Unbalanced lateral acceleration. Calculation of the rail vehicle rollover safety. Calculation loads for axle strength check.
Design of the carbody bearing structure. Materials for the bearing structure. Regulations for design loads and allowable stresses for carbody and for bogie frame. Strength calculation. Strength test. Passive safety measures for the crash scenario.

Practical teaching

Division of rail vehicles. Selection of basic parameters and their constraints. The examples and analysis of excerpts from the regulations. Characteristic wheel profile measurements. Pressed-on or shrunk-on fitting of wheelsets and shrunk-on fitting of the wheel tyres on the wheel centers. Examples of axle bearing assemblies. Design of typical freight wagon bogies. Design of passenger coach bogies. Vehicle gauge calculation. Calculation of relative position between running gear and the carbody. Determination of the general vehicle loads.

Calculation of the carbody bearing structure. Checking the stability of the bearing elements of the structure.
Fundamentals of stress measuring techniques. Procedure for strength testing of the carbody.

Prerequisites

Previously finished equivalent of at least: 12 ECTS in Mechanics of rigid bodies, 6 ECTS in Mechanic of deformable bodies and 6 ECTS Machine elements.

Learning resources

G. Simic, Instructions for writing student papers, hand-out
For preparation tasks as a basis should be used the appropriate regulations and standards

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	11
laboratory exercises	0
calculation tasks	0
seminar works	6
project design	8
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	1
check and assessment of projects	5
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	5
test/colloquium	30	project design	30
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Simic, G., Rail vehicles- Constructions and calculations, Faculty of Mechanical Engineering, Belgrade, 2013.

Rail vehicles 2

ID: 1188
Responsible/Holder professor DRAGAN D. MILKOVIĆ
Teaching profesor(s): MILKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

1. Understanding different constructions of the freight wagons and passenger coaches
2. Acquiring the knowledge necessary to understand the functioning of wagon or coach assemblies
3. Application of knowledge in the design, development, repair and maintenance of wagons and coaches

Learning outcomes

After completion of the course the student should be able to:
1. Explain the functional and structural characteristics of various types of rolling stock.
2. Explain the tasks and functioning principles of the assemblies of the rail vehicles.
3. Identify actions required to resolve failures in operation and maintenance of rail vehicles.
4. Apply appropriate regulations and standards for design and maintenance of railway vehicles.
5. Applicate computer tools for calculating and designing rail vehicles.

Theoretical teaching

General characteristics of the elastic suspension system. Suspension with helical springs. Suspension with leaf springs. Suspension with rubber springs. Air suspension system. Elastic pendulum-based systems. Natural and forced tilt of the rail vehicles in curves. Torsional characteristics of the rail vehicles. Damping elements. Active and passive suspension systems. Draw-buff gear. Design and mechanical characteristics of buffers. Draw gear. Automatic couplers. Equipment of the passenger coaches. Doors, windows, stairs. Heating and air conditioning requirements and design performance. Electrical installation. Passenger information system. Fire protection. Noise inside the vehicle and noise emission. Specifics of passenger coaches for high speeds. Specifics of the freight wagons for increased speeds.

Practical teaching

Initial requirements and general constraints for design of the elastic suspension system. Design of suspension springs system with double ring links. Design of the systems with helical springs. Design of the systems with rubber springs. Air suspension system design. Determination of the torsional characteristics of the rail vehicle. Design of the anti roll system. Active and passive tilt systems.
Design of buffers. Limitation of space on the ends of the wagon. Calculation of the buffer plates dimensions. Calculation of the draw gear angular deflection in curves. Gangway connection systems. Examples of design solutions for different equipment of the wagons.

Prerequisites

Previously passed course Railway vehicles 1.

Learning resources

D. Milkovic, Rail vehicles, hand-out
G. Simic, Instructions for writing student papers, hand-out
For preparation tasks as a basis should be used the appropriate regulations and standards

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	5
calculation tasks	0
seminar works	5
project design	9
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	5
test/colloquium	30	project design	30
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Simic, G., Railway vehicles, Constructions and calculations, Faculty of Mechanical Engineering, Belgrade, 2013.

Railway vehicles maintenance

ID: 1568
Responsible/Holder professor JOVAN D. TANASKOVIĆ
Teaching profesor(s): TANASKOVIĆ JOVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

Upon completion of the course the student should be able to:
1. Explain the basic concepts related to the reliability of rail vehicles.
2. Explain the basic concepts related to the maintenance of rail vehicles.
3. Explain the tasks and practices of the workshop for the maintenance of railway vehicles.
4. Perform appropriate calculations related to maintenance of rail vehicles.
5. Apply appropriate tools for computer calculations of electric and diesel electric locomotives.

Learning outcomes

After successfully finishing of course students would be able to:
- define basic terms which are important for understanding of reliability and maintenance of railway vehicles;
- choose an appropriate approach to the maintenance of railway vehicles;
- solve practical problems of maintenance of railway vehicles directed to organisation, implementation of projected activities as well as implementation of knowledge in field of reliability, information and expert systems;
- make detailed scheme of the maintenance workshop of railway vehicles by using modern PC tools;
- discuss about possibilities of improving of the maintenance process using modern methods for monitoring of system failure.

Theoretical teaching

Theoretical basis of reliability.Prediction reliability.Methods of determining the distribution of the data set.Setting reliability requirements and measures for their achievement for rail vehicles.The concept of constructing the basis of reliability. Maintenance of technical systems.Engineering maintenance.Maintenance and life cycle of railway vehicles.Maintenance process.Overview of the developed concept of maintenance railway vehicles in the world.Analysis and assessment of maintenance.Design of technical systems for maintenance.Management of spare parts.Technology in railway vehicles maintenance.Diagnosis of railway vehicles.Maintenance management.The organization of railway repair workshops.Depots.Warehouses.Information and expert systems in the maintenance of rail vehicles.

Practical teaching

Understanding the examples from the theory of reliability of the system.Application of the

railway vehicles.Examples of the material.Methods of determining the distribution of the data set.Setting reliability requirements and measures for their achievement for rail vehicles.Examples of the completed material.Application of computers in determining the reliability and Information and expert systems in the maintenance of railway vehicles.Creating a computer program - Information and expert system in the maintenance of railway vehicles.Visit the workshop for the maintenance of diesel and electric vehicles.Understanding the system of maintenance of rail vehicles.

Prerequisites

Nothing.

Learning resources

It is necessary the use of textbooks, manuals for the project, a handout, computers and the Internet.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	0
seminar works	5
project design	5
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	25
test/colloquium	10	project design	0
laboratory exercises	0	final exam	60
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Dusan Stamenkovic, Maintenance of railway vehicles, Faculty of Mechanical Engineering - Nis, Serbia, 2011.
Slobodan Muzdeka, Logistic - Logistics engineering-reliability, maintainability, readiness, integrated technical security, Belgrade, 1981.
Nikola Vujanovic, Theory of reliability of technical systems, Belgrade, 1990.

Skill Praxis M - ZEM

ID: 1301
Responsible/Holder professor JOVAN D. TANASKOVIĆ
Teaching profesor(s): TANASKOVIĆ JOVAN; MILKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: project design
Parent department: railway mechanical engineering

Goals

Students practical experience and stay in the environment in which the student will realize his professional career. Identifying the basic functions of the business system in the field of development, designing, production, maintenance of railway vehicles, as well as the roles and tasks of mechanical engineer in such a business system.

Learning outcomes

After successfully finishing of skill praxis students would be able to:
- define and discuss about design processes, production and maintenance of railway vehicles;
- implementation of acquired practical knowledge about way of organization and functioning of producers and maintenance workshop of railway vehicles in the future professional career;
- recognize models of communication with colleagues and flows of business information;
- evaluate of the importance of team approach in resolving of problems, improving of production processes and maintenance of railway vehicles.

Theoretical teaching

Introduce students to practical training realization concept and prepare them for all units of prescribed curriculum and way of communication. Guidelines for diary keeping and report writing are given and students record are created.

Practical teaching

Practical work involves work in organizations with various activities in relations with mechanical engineering. Selection of thematic areas, commercial or research organizations students carrier out in consultation with the relevant teacher. Generally a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations for maintenance of railway vehicles and in some of the laboratories at Faculty of Mechanical Engineering. The practice may also be done abroad. During practice, students must keep a diary in which have to enter a description of the tasks performed, the conclusions and observations. Following the practice must make a report which have to present to the relevant teacher. The report is submitted in the form of the paper.

Prerequisites

Nothing

Learning resources

Guide for keeping a practice diary and writing final report.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	90
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	70
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Tanasković J., Fundamentals of railway mechanical engineering, University of Belgrade Faculty of Mechanical Engineering, Belgrade, 2022.
Lucanin, V., Theory of Traction, University of Belgrade Faculty of Mechanical Engineering, Belgrade, 1996.
Simic, G., Wagons, structure and calculation, University of Belgrade Faculty of Mechanical Engineering, Belgrade, 2013.

Theory of Traction

ID: 1187
Responsible/Holder professor JOVAN D. TANASKOVIĆ
Teaching profesor(s): TANASKOVIĆ JOVAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: railway mechanical engineering

Goals

Knowledge acquiring in designing, production and exploitation of railway vehicle, in designing of rail tracks as well as the organization of railway traffic.
Introducing students with:
- The Forces acting on railway vehicle,
- Calculation methods for traction, resistance and braking force and the velocity, using modern computer tools,
- The methods for determination of optimal movement conditions of railway vehicles,
- Ways of solving practical problems related to the movement of railway vehicles and rail tracks configuration.

Learning outcomes

After successfully finishing of course students would be able to:
- define tasks and way of functioning elements, subassemblies and assemblies of tractive vehicles;
- calculate tractive effort, train resistance, braking force and velocity of railway vehicle using special software package;
- discuss about advantages and disadvantages of the different types of power transmissions and their characteristics;
- assessment of advantages and disadvantages of different types of coupling which can be used in tractive railway vehicles;
- implementation of regulations and standards in the field of railway vehicle traction.

Theoretical teaching

Characteristics of the railway transport, Analysis of the influencing factors on the traction forces, Transmission of traction forces – adhesion as requirement for traction forces, Traction features of high-speed railway vehicles, Traction features of the diesel traction railway vehicles, Basic characteristics of running gear and drive of traction vehicle, Traction features of the electric traction railway vehicles, Train resistance – main and additional resistance, High speeds train resistance, Railway vehicles braking force – characteristics of the braking process, Equations of the train.

Practical teaching

Practical learning, Auditory exercises (Introduction to the examples in modern railway transport, Recapitulation of learned material necessary for passing this subject (mechanics,

machine elements and electrical engineering), Using of computer tools to solve problems in train traction, Guidance of wheel set in track, The relative velocity of wheel set in relation to the rail, Forces at the wheel set edge point and the contact point of the wheel-rail , Basic characteristics of traction features, adhesion as requirements for traction forces , Basic characteristics of diesel and electric traction railway vehicles, The resistance forces in motion the train, Task (Determination of traction characteristics of the diesel traction vehicles with mechanical and hydraulic power transmission, Determination of traction characteristics of the diesel traction vehicles with electric power transmission, Determination of traction characteristics of the electric traction vehicle, Analytical determination of the resistance force when moving train, Solving differential equations of train), Discussions and workshops.

Prerequisites

Nothing

Learning resources

Class book, Literature that is available in the Faculty Bookstore and Library; Internet resources (KOBSON).

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	9
laboratory exercises	0
calculation tasks	10
seminar works	5
project design	0
discussion and workshop	6
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	5
test/colloquium	20	project design	0
laboratory exercises	0	final exam	35
calculation tasks	30		

Requirements to take the exam (number of points) 40

References

Lucanin, V., Theory of Traction, University of Belgrade Faculty of Mechanical Engineering, Belgrade, 1996.

Andreas Steimel, Electric Traction - Motive Power and Energy Supply, Oldenbourg Industrieverlag Munich, 2008.
Brenna M., Foiadelli F., Zaninelli D., Electrical Railway Transportation Systems, IEEE PRESS, Wiley, 2018.
Tanasković J., Fundamentals of railway mechanical engineering, University of Belgrade Faculty of Mechanical Engineering, Belgrade, 2022.

STRENGTH OF STRUCTURES

Basics of Composite Materials Mechanics

Composite plates and beams

Finite element method in structural analysis

Selected chapters from the theory of elasticity

Theory of elasticity

Theory of finite element method

Basics of Composite Materials Mechanics

ID: 0721
Responsible/Holder professor IGOR M. BALAĆ
Teaching profesor(s): BALAĆ IGOR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: strength of structures

Goals

Main objective of the course is to teach students the fundamental principles of the mechanics of composite materials. This theory is further applied to design and analyze unidirectional and multidirectional fiber composite laminates. Within the course the basic issues associated with the design of composite materials will be studied as well. A special attention will be devoted to the practical stress and strain analysis of mechanical components made out of composite materials. Issues connected to the characterization of mechanical properties of composite materials will be tackled as well.

Learning outcomes

1. Within the course students will learn various methods of the assessment of elastic constants entering into constitutive equations which describe mechanical behavior of composite materials. Problems of determination of macro behavior of composite materials starting from known properties of components entering into it will be tackled as well. The course will cover also the study of different failure criteria for various types of composite materials.
2. Students will learn how to perform stress – strain analysis of laminate composite materials.
3. The course will devote some attention to the influence of the environmental conditions (e.g. temperature and humidity) to the variation of mechanical properties of composite materials. This will be studied with a special focus on unidirectional and multidirectional composite laminates.
4. By completing this course students will become familiar with basic concepts of mechanics of composite materials. A special attention will be devoted to the practical procedures of stress analysis of mechanical components made out of composite materials, with numerical implementation of the most frequently used techniques.

Theoretical teaching

1. Introduction to composite materials: Basic concepts. Classification, main characteristics and the most frequent applications of composite materials in modern engineering.
2. Macro mechanical elastic behavior of unidirectional lamina composites. The Hooke's Law for a two dimensional lamina. Determining stiffness of parallel arrays of fibers in matrix. Rules of mixture. Off-axis properties of a lamina.
3. Determining strength of unidirectional lamina. Analysis of failure criteria. Diverse failure criteria and their applications.
4. Macro mechanical elastic behavior of multidirectional composite laminates. Stress and strain analysis of single lamina, and of the entire composite material. General laminate plate

theory. Studding of coupling effects – coupled flexure and torsion.
5. Stress – strain and failure analysis of multidirectional composite materials. Strength of lamina under tension and shear. Inter-laminar stresses. Laminate strength analysis. First ply failure.

Practical teaching

1. Analytical examples of the assessment of macro mechanical properties of the composite materials.
2. Examples of the Hooke's law theory applied to the two dimensional unidirectional laminates. Determining of the stiffness matrix for the composite material.
3. Numerical exercises of stress strain analysis of laminate composites. Examples of determination of local and global values for stress and strain.
4. Numerical examples of determination of the ultimate strength using diverse failure criteria. Practical applications of failure theory to the ultimate strength calculations of mechanical components made out of composite materials.
5. Examples of numerical implementations of diverse modeling techniques of composite materials into the available codes. Comparison of numerical and analytical predictions of composite material component behavior.

Prerequisites

None

Learning resources

The whole course material is well covered by hand-outs written by the lecturers of the course. Every attendee of the course will be provided his/hers own copy of the hand-outs. Apart of this, all books listed in literature can be borrowed from the lecturers during the course or ordered on some relevant websites.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	0
calculation tasks	25
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	1
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	1
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	20
test/colloquium	40	project design	0
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

"Mechanics of composite materials", Autar K. Kaw, CRC Press, 2005.
"Engineering Mechanics of Composite Materials", Isaac M. Daniel, Ori lshai, Oxford University Press (2006)
"Principles of composite material mechanics", Ronald F. Gibson, CRC Press (2012)
"Mechanics of Composite Materials", Robert M. Jones, Taylor & Francis (1999)
"Mechanics of Composite Materials with MATLAB" George Z. Voyiadjis and Peter I. Kattan, Springer, 2005.

Composite plates and beams

ID: 1576
Responsible/Holder professor IGOR M. BALAĆ
Teaching profesor(s): BALAĆ IGOR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: strength of structures

Goals

Main objective of the course is to teach students the fundamental principles of the mechanics of laminated composite plates and beams. This theory is applied to analyze unidirectional and multidirectional fiber reinforced composite plates and beams. Within the course the basics associated with the design of composite plates and beams will be studied as well. A special attention will be devoted to the practical stress and strain analysis of structural components made out of laminated composite materials which are subject to tension (compression), bending and torsion.

Learning outcomes

1. Within the course students will learn various methods for determining elasticity constants for one layer of composite material (lamina), as well as, ways of assessment of stiffness matrix for multi-layered composite material (laminate). Students will also learn to define carrying capacity of composite plates and beams in case when mechanical properties of each layer of composite material are known. Students will learn how to apply different failure criteria.
2. Students will learn how to perform stress – strain analysis of laminated composite plates and beams.
3. Within the course students will learn to analyse the influence of the environmental conditions (e.g. temperature and humidity) on mechanical properties of laminated composite materials.
4. By completing this course students will become familiar with fundamentals of mechanics of composite plates and beams. A special attention will be devoted to the practical implementation of composite plates and beam as structural elements.

Theoretical teaching

1. Introduction to composite materials- Basic concepts. Classification, main characteristics and the most frequent applications of composite materials in mechanical engineering with emphasis on laminated composite plates and beams. Concept of lamina and laminate.
2. Theory of elasticity of anisotropic body. Stress and strain tensor. Generalized Hooke's Law. Plane stress state. Fundamentals of anisotropic thin plate theory.
3. Elastic behavior of unidirectional composite lamina. Generalized Hooke's Law for a unidirectional composite lamina. Elastic properties of a lamina in local coordinates (case when local coordinates are aligned with principal material axes). Off-axis properties of a lamina (case when local coordinates are not aligned with principal material axes). The influence of the environmental conditions (e.g. temperature and humidity). Analysis and

application of failure criteria.
4. Elastic behavior of multi-directional composite laminates. Classical lamination theory. Forces and moments in the cross section of laminated composite plate. Stress and strain analysis in cross section of laminated composite plate. Constitutive relations for laminate. Effective elastic constants of symmetric laminate. The environmental conditions (e.g. temperature and humidity) and their influence on laminate. The application of failure criteria on multi-directional composite laminates. Delamination. Interlaminar stresses. Free edge effects.
5. Fundamentals of laminated composite beam theory. Composite beam with rectangular cross section – case when loading plane is perpendicular to its middle plane. Composite beam with rectangular cross section – case when loading plane matches to its middle plane. Thin-walled composite beams of various cross sections.

Practical teaching

1. Analytical examples of variation of stress and strain components when coordinate system is rotated by arbitrary angle.
2. Examples of the Generalized Hooke's law applied to the unidirectional lamina. Determination of the stiffness and compliance matrix for the unidirectional lamina. Examples of determination of local and global stress and strain values for unidirectional lamina exposed to applied load.
3. Stress-strain analysis of laminated composite plates. Examples of determination of local and global stress and strain values of laminated composite plate for defined loads. The influence of temperature – analytical examples.
4. The use of different failure criteria - examples. "Ply by ply" failure approach.
5. Stress-strain analysis of laminated composite beams. Examples of determination of local and global stress and strain values of laminated composite beam for defined loads. The use of different failure criteria – examples on composite beams.
6. Numerical methods used in structural analysis of laminated composite plates and beams. Comparison of results obtained by analytical and numerical methods.

Prerequisites

None

Learning resources

The whole course material is well covered by hand-outs written by the lecturers of the course. Every attendee of the course will be provided his/hers own copy of the hand-outs. Apart of this, all books listed in literature can be borrowed from the lecturers during the course or ordered on some relevant websites.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	15

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	1
check and assessment of projects	0

laboratory exercises	0	colloquium, with assessment	4
calculation tasks	10	test, with assessment	1
seminar works	5	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	20
test/colloquium	40	project design	0
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

"Mechanics of composite materials", Autar K. Kaw, CRC Press, 2005.
"Engineering Mechanics of Composite Materials", Isaac M. Daniel, Ori lshai, Oxford University Press (2006)
"Principles of composite material mechanics", Ronald F. Gibson, CRC Press (2012)
"Mechanics of Composite Materials", Robert M. Jones, Taylor & Francis (1999)
"Mechanics of Composite Materials with MATLAB" George Z. Voyiadjis and Peter I. Kattan, Springer, 2005.

Finite element method in structural analysis

ID: 1575
Responsible/Holder professor VLADIMIR V. BULJAK
Teaching profesor(s): BULJAK VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: strength of structures

Goals

The scope of this course is to provide a thorough theoretical and practical foundation for Finite Element Method (FEM). In the first part of the course the students will become familiar with the application of FEM to the solution of boundary value problems in elasticity. The formulation of weak form of the solution will be in the main focus, regarding problems of statics and dynamics of simpler structures. The main goal of this part of the course is to give a full and detailed view of the development of linearized formulation for diverse structural problems, by employing displacement based FEM. The matrix formulation of the problem will be presented in details. While the main focus is on methodology applied through coding in various computer codes, the students will also learn the basics of use of diverse commercial software.

Learning outcomes

Upon fulfilling the course the students will be able to:
1.Write their own computer codes for building stiffness matrix by employing finite elements of truss type, beam type as well as continuum finite elements in 2D and 3D.
2.Write their own computer codes in order to perform static and dynamic finite element analysis of simpler structures.
3.Write their own computer codes for post-processing of resulting displacement values in nodal points, in order to recover strains and stresses.
4.Understand the foundation on which commercial FEM software are build.

Theoretical teaching

Introduction to numerical modeling. Virtual work principle and its application to the formulation of weak form of the solution in boundary value problems. Shape functions for the displacement field interpolation. Building of the stiffness matrix for one- two- and three-dimensional finite elements. Building of the stiffness matrix for complex structures and solution strategies based on reduced stiffness matrix and Lagrange multipliers. Post-processing of results, recovery of strain and stress field on the basis of known displacement field. Dynamic problems and time integration. Implicit and explicit integration schemes.

Practical teaching

Coding in MATLAB package apt for the evaluation of stiffness matrix for finite elements of different types, i.e. truss elements, beam elements and continuum elements in 2D and 3D. Assembling of global stiffness matrix for structural problems. Application of boundary conditions. Linearization of the problem and different methods for obtaining solution for the

system of linear algebraic equations. Reduced stiffness matrix and Lagrange multipliers method. Development of codes for recovery of strains and stress field. Static and dynamic analysis of structures.

Prerequisites

-

Learning resources

"The finite element method: static and dynamic finite element analysis", Thomas Hughes, Prentice-Hall 2010. ISBN: 0-13-317025-X
"The finite element method: a practical course", G.R. Liu and S.S. Quek, Butterworth-Heinemann, 2003. ISBN: 0-7506-5866-5

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	25
laboratory exercises	0
calculation tasks	3
seminar works	0
project design	2
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	0	project design	50
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

"The finite element method: static and dynamic finite element analysis", Thomas Hughes, Prentice-Hall 2010. ISBN: 0-13-317025-X
"The finite element method: a practical course", G.R. Liu and S.S. Quek, Butterworth-Heinemann, 2003. ISBN: 0-7506-5866-5

Selected chapters from the theory of elasticity

ID: 1574
Responsible/Holder professor VESNA O. MILOŠEVIĆ-MITIĆ
Teaching profesor(s): MILOŠEVIĆ-MITIĆ VESNA; ANĐELIĆ NINA; BALAĆ IGOR; BULJAK VLADIMIR; PETROVIĆ ANA

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: strength of structures

Goals

The purpose of this course is that students understand and learn the basic concepts of the theory of elasticity and to acquire the basis of the tensor calculus. Students will be enabled to model and solve some rheological problems.
Students are enabled to independently determine stress and strain fields in complex types of loading.
Through understanding the rheological processes, they will be able to use computer programs in this field.

Learning outcomes

- By taking of this course, students will master some basic methods and procedures of the theory of elasticity and of the tensor calculus.
- They will be able to calculate stress components on the base of equilibrium equations and to form appropriate tensors of stress and strain for an ideal elastic body.
- They will be introduced with principal stresses (intensity, position) and with maximum shear stress.
- They will be able to calculate stress and strain for some complex types of loading.
- Students will master application of material failure theories.
- They will understand elasticity and stiffness matrices.
- They will be able to solve some real problems related to thin simply supported plates.

Theoretical teaching

Introduction. Stress tensor. Stress components and equilibrium equations in Cartesian and cylindrical coordinate system. Stresses in an arbitrary plane - transformation of stress tensor. Plane state of stress. Pressure vessels. Curved beams, deformation and stress. Compatibility equations. The principal strains. Principal stresses. Stress invariants. Volumetric and deviatoric components. Material failure theories. Torsion expressed over stress function. Membrane theory. Column buckling and stability. Generalized Hooke's law. Lame constants. Plane state of strain. Thin plates. Rheological models and modeling.

Practical teaching

Determination of the stress components on the base of equilibrium equations.
Transformation of stress tensor. Principal stresses, the intensity, the position. The maximum shear stress, the intensity and position. Stress invariants. Calculation of the main strains. Application of failure theories. Tensors of stress and strain for an ideal elastic body. Stress

and deformation of the curved beam. Stress distribution in pressure vessels. Torsion of the beams of different cross-sections. Stability of compressed columns by the energy method. Thin simply supported plates.

Prerequisites

Set by the Curriculum of the study program.

Learning resources

Handouts from the website of the Department for Strength of the constructions

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	40	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

T. Atanacković, Theory of elasticity, FTN University of Novi Sad, 1993. (in Serbian)
S. Tymoshenko, J. N. Gudier, Theory of elasticity, Građevinska knjiga - Beograd, 1962.
T. Maneski, V. Milosevic-Mitic, D. Ostric, Sets of the structural strength, University of Belgrade, 2002. ISBN 86-70803-435-9
Hlitčijev J., Chapters in Theory of elasticity, Naučna knjiga Beograd, 1950. (in Serbian)

Theory of elasticity

ID: 0903
Responsible/Holder professor VESNA O. MILOŠEVIĆ-MITIĆ
Teaching profesor(s): MILOŠEVIĆ-MITIĆ VESNA; ANĐELIĆ NINA; PETROVIĆ ANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: strength of structures

Goals

The purpose of this course is that students understand and learn the basic concepts of the theory of elasticity.
They will acquire the basis of the tensor method, too.
Students will be enabled to model and solve some rheological problems.
Through understanding the rheological processes, they will be able to use computer programs in this field.

Learning outcomes

- By negotiation of this program, students will master some basic methods and procedures of the theory of elasticity and of the tensor method.
- They will be able to calculate stress components on the base of the equilibrium equations and to form appropriate tensors of stress and strain for an ideal elastic body.
- They will be introduced with principal stresses (intensity, position) and with maximum shear stress.
- They will be able to calculate main strains.
- Students will master application of material failure theories.
- They will understand elasticity and stiffness matrixes.
- They will be able to solve some real problems related to thin simply supported plates.

Theoretical teaching

Introduction. The concept of stress. Cauchy's principle. Stress components in Cartesian and cylindrical coordinate system. Stress tensor. Equilibrium equation in Cartesian and cylindrical coordinate system. Stresses in an arbitrary plane - transformation of stress tensor. Principal stresses. Stress invariants. Volume and deviator components. The maximum shear stress. Plane state of stress. Deformation, Lagrange's strain. Small deformation. Geometric interpretation. Compatibility equations. The main deformations. Volume and deviator components. Material failure theories. Plane state of strain. The rate of strain. Linear elasticity. Hooke's law. Modulus of sliding. Lame's constants. Poisson's ratio. Thin plates. Rheological models and modeling.

Practical teaching

Determination of the stress components on the base of balance equations. Determination of the stress components in oblique plane - transformation of stress tensor. Principal stresses, the intensity, the position. Maximum shear stress, intensity and position. Stress invariants. Deformation by Lagrange and Euler. Calculation of the main strains. Application of failure

theories. Tensors of stress and strain for an ideal elastic body. Thin simply supported plates.

Prerequisites

Set by the Curriculum of the study program

Learning resources

Handouts from the website of the Department for Strength of the constructions

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	5
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	3
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	10
test/colloquium	40	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

T. Atanacković, Theory of elasticity, FTN University of Novi Sad, 1993. (in Serbian)
S. Tymoshenko, J. N. Gudier, Theory of elasticity, Građevinska knjiga - Beograd, 1962. (in Serbian)
T. Maneski, V. Milosevic-Mitic, D. Ostric, Sets of the structural strength, University of Belgrade, 2002. ISBN 86-70803-435-9
Hlitčijev J., Chapters in Theory of elasticity, Naučna knjiga Beograd, 1950. (in Serbian)

Theory of finite element method

ID: 1133
Responsible/Holder professor VLADIMIR V. BULJAK
Teaching profesor(s): BULJAK VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: strength of structures

Goals

The objective of this course is to provide thorough methodological introduction to the Finite Element Method. Within the introductory part students will get familiar with the application of this method for solving boundary value problems in the elasticity. Emphasis will be given to formulation of weak form of problems both in statics and dynamics. The main goal of the course is to present to the students how displacement based finite elements can be used to solve linear problems. Detailed derivation of stiffness matrix will be shown with reference to finite elements of various types (both structural and continuum elements). Various technique for the application of boundary conditions, and different methods for solving linear algebraic equations will be outlined. Post processing techniques and recovery of strain and stress fields based on nodal displacements for finite elements of different types will be presented in a detailed manner. In closing sessions of the course students will be shown some of the most popular commercial software used for static and dynamic analysis of structures.

Learning outcomes

Upon completing the course students will be able to:
-Write computer codes for the assembling of stiffness matrix for truss-, beam-, frame- and shell-elements, as well as continuum 2-dimensional and 3-dimensional finite elements;
-Perform both static and dynamic analysis of simple structures within personally developed computer codes;
-Write computer codes for the stress and strain recovery based on linear, small-deformation theory, starting from resulting nodal displacements;
-Understand basics on which most commercial software are build and use them for performing static and dynamic analysis of more complex structures.

Theoretical teaching

Introduction to numerical modeling. Principle of virtual work and its application to the formulation of weak form of the problem. Interpolation functions for representing the displacement field over finite element. Assembling of element and global stiffness matrix. Dicretization for Lagrangian types of meshes. Methods for solving the resulting system of linear algebraic equations. Stress and strain recovery from nodal displacement results. Solutions for dynamic problems. Implicit and explicit scheme for time integration. Stability of the solution.

Practical teaching

Writing computer codes in MATLAB software, for truss-, beam, frame-, shell-elements, as

well as continuum 2D and 3D elements. Assembling of global stiffness matrix and mass matrix. Application of boundary conditions: concept of reduced stiffness matrix, and alternative solution with Lagrange-multipliers technique. Developing codes for strain and stress recovery. Static and dynamic analysis of structures.

Prerequisites

Passed exam Theory of elasticity

Learning resources

Each student should have the access to the personal computer.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	28
elaboration and examples (revision)	2
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	10
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	5
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	20	project design	0
laboratory exercises	5	final exam	70
calculation tasks	5		

Requirements to take the exam (number of points) 0

References

"The finite element method - a practical course" G.R. Liu S. S. Quek, Butterworth-Heinemann, 2013.
"An Introduction to the Finite Element Method" J.N. Reddy, McGraw Hill India, 2006.
"The Finite Element Method: Linear Static and Dynamic Finite Element Analysis", T. Hughes, Dover Publications, 2000.
"Finite Element Method: Volume 1" O. C. Zienkiewicz and R. L. Taylor, Butterworth-Heinemann, 2000.

THEORY OF MACHANISMS AND MACHINES

Application of virtual and augmented reality in mechanical engineering

Applied mechatronics

Constructive geometry and graphics

Constructive processing of curves and surfaces

Design of mechanisms and manipulators in the food industry

Engineering Condition Monitoring

Engineering graphics and simulations

Food Processing Machines

Fundaments of mechanism analysis and synthesis

Mechatronics

Skill Praxis M - IGM

The aesthetics of 3d modeling

Application of virtual and augmented reality in mechanical engineering

ID: 1512
Responsible/Holder professor ZORANA V. JELI
Teaching profesor(s): JELI ZORANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

Mastery of knowledge in the field of Virtual Reality (VR) and Augmented Reality (AR). Introduction to modern ways of graphic communication and information transfer within the field of mechanical engineering, both between engineering teams and between other participants in the industrial production process. Introduction to existing hardware and software solutions (Head Mounted Displays (HMD), VR/AR tracking systems, VR/AR software). Application of engineering knowledge acquired at previous levels of studies and their implementation in VR/AR systems, development of 3D models of parts and assemblies with the necessary technical data displayed directly on the 3D models, development and design of prototypes, and application of VR/AR in maintenance and repair of machine assemblies.

Learning outcomes

The student successfully familiarized himself with existing solutions and trends in the field of VR/AR. He mastered the skills necessary to adapt existing communication methods in the field of mechanical engineering (technical documentation) to the specificities of VR/AR. Also, students acquired the necessary knowledge and mastered various software packages necessary for the preparation of 3D models adapted for VR/AR.

Theoretical teaching

Introduction to the concepts of Virtual Reality (VR) and Augmented Reality (AR). An introduction to new methods and a comparison with previous methods of graphic communication in the field of engineering. Overview of the differences between the styles of how information is presented on technical drawings, 3D models displayed on computer monitors, and the same models displayed in a completely virtual environment through the application of existing hardware solutions (HMD), and models displayed within augmented reality. Overview of characteristics and analysis of virtual reality and augmented reality systems. Introduction to individual components of VR/AR systems and their characteristics and types of hardware solutions for HMD; systems for recognition and tracking of objects within VR/AR; and software solutions necessary for the successful implementation of VR/AR. Introduction to characteristics and differences of preparing 3D models for VR/AR application. Introduction to formats of files for transferring information about 3D models in VR/AR. A review of the safety and ethical challenges of the application of these technologies as well as the benefits of their application from the point of view of improving safety and increasing the exchange and understanding of information in modern engineering practice. And finally, introducing students to trends in the development of VR/AR, in order to prepare

them for new challenges in applying these technologies.

Practical teaching

Introducing students to hardware and software systems for VR/AR, object tracking and detection systems, and head-mounted displays (HMDs). Work in software platforms for virtual and augmented reality in engineering. Analysis and comparison of improvements of VR/AR in relation to the displaying of 3D models on monitors and technical drawings. Designing virtual environments necessary for the realistic display of objects VR/AR in different software packages (SolidWorks, SolidWorks Visualize, Blender...). The application of VR/AR in the design of products and prototypes, then, in their analysis and testing, and finally, the presentation of the results of simulations and tests. Improvement of the assembly processes during the production of devices and machine assemblies using VR/AR. Benefits of using VR/AR to increase operator safety in the industry.

Prerequisites

No conditions

Learning resources

Visualization and Engineering Design Graphics with Augmented Reality Second Edition, Mariano Alcaniz, Jorge Dorribo Camba, Manuel Contero, Jeffrey Otey, 2014.
Virtual and Augmented Reality Applications in Manufacturing, By S.K. Ong, A.Y.C. Nee, London, 2004.
Virtual Reality Technology and Applications, By Matjaž Mihelj, Domen Novak, Samo Beguš, Ljubljana, 2014.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	1
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	4
test, with assessment	0
final exam	4

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	30
test/colloquium	30	project design	0

laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Visualization and Engineering Design Graphics with Augmented Reality Second Edition, Mariano Alcaniz, Jorge Dorribo Camba, Manuel Contero, Jeffrey Otey, 2014.
Virtual and Augmented Reality Applications in Manufacturing, By S.K. Ong, A.Y.C. Nee, London, 2004.
Virtual Reality Technology and Applications, By Matjaž Mihelj, Domen Novak, Samo Beguš, Ljubljana, 2014.

Applied mechatronics

ID: 1510
Responsible/Holder professor EMIL A. VEG
Teaching profesor(s): VEG EMIL
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: theory of machanisms and machines

Goals

The goal of the course is to equip the student with the knowledge needed to solve a mechatronic problem. That is, to develop the ability to devise a mechatronic solution for a classic mechanical problem. Selection of sensors for a mechatronic solution. That choice must satisfy the given criteria: principle of operation (optical, ultrasonic, magnetic...), dimensionally to fit into the overall solution, sending signals (voltage/current, communication). Drive selection: electric motor (tesla motor, direct current motors, servo motors...); pneumatic cylinder/motor; hydraulic cylinder/motor. And finally, the choice of control body: PC, PLC, microcontroller.

Learning outcomes

For the student to come up with a conceptual solution for the mechatronic system. To choose the appropriate drive, sensors and finally control.

Theoretical teaching

Projecting in mechatronics; Conceptual solution of a mechatronic solution, Science of the theory of machines and mechanisms. Classification of mechanisms, Measurements in mechatronics 1; Mechanisms and manipulators; Analog and digital sensors, Measurements in mechatronics 2; Actuators in mechatronics; Linear and rotary actuators, State detection (0,1), Management concepts in Mechatronics; Structure of the processor system, System programming; Programming tools available, Input port programming, Output port programming

Practical teaching

Laboratory exercises; Presentation of typical mechatronic solutions; Decomposition of mechatronic solutions; Analysis of elements, functions and signals of the sensor block, Elementary mechanisms; Examples of different configurations of mechanisms for performing specific movement profiles, Sensors 1; Sensors 2; Elaboration of the idea for a solution for the user numerical-graphic display of results, Actuators; Electric motor drive controlled by a frequency regulator; Work with PC-platform, Work with PIC-platform;

Prerequisites

Attended Mechatronics course.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	15
colloquium, with assessment	0
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Little dictionary of mechatronics, A. Veg, G. Šinikovic, E. Veg, M. Regodić; ISBN 978-86-6060-184-3 published 2024,

Constructive geometry and graphics

ID: 1508
Responsible/Holder professor BRANISLAV D. POPKONSTANTINOVIĆ
Teaching profesor(s): POPKONSTANTINOVIĆ BRANISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

To renew the basics of Constructive geometry and graphics and to enrich the already existing knowledge with new material that is necessary for students of mechanical engineering, and it was not possible to cover it due to the small number of classes in undergraduate studies. For students to acquire advanced knowledge and skills of design, constructive processing and rendering of objects in three-dimensional space in all types of projections.

Learning outcomes

Acquisition of new and advanced knowledge from various fields of constructive geometry and their application in mechanical engineering. Essential understanding of positional and metrical invariants of three-dimensional space in all types of projections. Students are trained to creatively use constructive procedures of shaping, processing and rendering of spatial forms and solve complex positional and metrical problems of three-dimensional

Theoretical teaching

Orthogonal projection (renewal and new teaching units within this area); Collineation and affinity; Oblique projection; orthogonal axonometry - isometry, dimetry and trimetry. Intersection of a cone and a plane (regular plane curves of the second order); rotating surfaces: ball, rotating cone and cylinder, torus and toroidal surfaces; contours of rotating surfaces, sections of rotating surfaces with applications in mechanical engineering; coil and coil surfaces; jurisdictional areas; cross-sections of round and angular straight-line surfaces with applications in mechanical engineering. Central projection, figures of infinitely distant elements - the far-off and the far-off; positional and metric invariants of central projection; linear perspective - with one, two and three views. Basics of restitution and photogrammetry.

Practical teaching

Practical teaching includes the preparation of tasks that follow all the mentioned areas from theoretical teaching.

Prerequisites

There are no requirements to attend.

Learning resources

NUMBER OF HOURS

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	40
calculation tasks	30		

Requirements to take the exam (number of points) 20

References

Solomon Woolf: An Elementary Course In Descriptive Geometry, Merchant Books; 3rd edition, 2007

Constructive processing of curves and surfaces

ID: 1507
Responsible/Holder professor BRANISLAV D. POPKONSTANTINOVIĆ
Teaching profesor(s): POPKONSTANTINOVIĆ BRANISLAV
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

The goal is for students to learn the basic geometric characteristics and invariants of plane and spatial curves, as well as surfaces important for mechanical engineering. The goal is also for students to master both theoretical and concrete, practical methods of generation and constructive processing of the mentioned types of curves and surfaces. Practical methods include the generation and processing of curves and surfaces by direct sketching and drawing procedures, as well as advanced methods that are implemented using appropriate computer tools (SolidWorks).

Learning outcomes

The outcome of the course is the acquisition of knowledge that can be applied in the generation and constructive processing of selected types of curves and surfaces that are used for designing and 3D modeling of various objects in the practice of mechanical engineering. By mastering this subject, students are trained to efficiently design and generate complex machine parts and assemblies.

Theoretical teaching

Plane curved lines, order, class, degree and genus of algebraic curved lines; decomposition of algebraic curves; common points of curved lines; quadratic curves and their strands, projective properties of quadratic curves; asymptotes and singular points of curves; Plicker and Klein relations; flexion of plane curves, flexion and torsion of spatial curves; involute and involute of plane curves, involute of a circle - application in mechanical engineering; roulettes, epicycloids, hypocycloids - application in mechanical engineering; accompanying triad of spatial curves; spatial curves of 4 orders, 1st and 2nd types, spatial curve of 3rd order; surfaces, generation and division of surfaces, E, H, P surfaces; tangents, tangential planes and surface normals, curvature, principal curves and osculating paraboloid surfaces; Euler's theorem on surface curves and Mannheim constructions; Total curvature and developing surfaces and constructive procedures of developing parabolic surfaces of the second order; constructive processing of the cylindrical coil, various plane transcendental and algebraic curves created by projecting the coil: harmonic curves, hyperbolic spiral, roulettes, trochoids; chainworms and catenoids;

Practical teaching

Exercises that are performed directly on paper, with the help of drawing accessories, as well as on computers with the use of appropriate software tools.

Prerequisites

Passed courses Constructive geometry and graphics and Engineering graphics

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	30
elaboration and examples (revision)	0
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	40
calculation tasks	30		

Requirements to take the exam (number of points) 20

References

Laurent Busé , Fabrizio Catanese , Elisa Postinghel; Algebraic Curves and Surfaces A History of Shapes, Springer; 1st ed. 2023 edition

Design of mechanisms and manipulators in the food industry

ID: 1317
Responsible/Holder professor ZORANA V. JELI
Teaching profesor(s): JELI ZORANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: theory of machanisms and machines

Goals

mastering the knowledge of design and construction of all types of mechanisms, with special emphasis on cam and Maltese mechanisms; acquiring the ability to analyze them within the machines and devices used in the food industry; getting acquainted with the types and manner of operation of manipulators, as well as with the possibilities of their construction with simpler functions; introduction and analysis of manipulative processes in the food industry.

Learning outcomes

The student has mastered the procedures for the construction of mechanisms that are mostly used in machines and devices of the food industry, as well as for connecting the work of individual machines in production lines. The student is acquainted with the principles of operation of various software packages (which will deal with modeling and analysis of mechanisms and manipulators) and give him the opportunity to easily master some other packages for modeling and generating the movement of mechanisms in practice.

Theoretical teaching

A brief review of kinematic pairs and plane mechanisms; equivalent mechanisms. Cam mechanisms; cam plate: translational and rotating; translational and rotating lifters: with rounding, roller or disc; law of motion, velocity, acceleration, force; synthesis of cam plates. Maltese mechanisms; gear and toothed mechanisms; law of motion, velocity, acceleration, force; synthesis mechanism. Spatial mechanisms; structure of mechanisms; closed and open kinematic chains; mechanisms with a number of independent drives. Manipulators with 5-class kinematic pairs; spatial three-membered kinematic chains with independent drives; manipulators of the type: TTT, TRT, TRR, RRT and RRR and service space. Creating a part of the program for optimal synthesis of mechanisms in MATLAB for special path shapes of plane mechanisms. Synthesis of spatial manipulator drives; creating the specified types of manipulators in the SolidWorks software package; defining the desired law of movement of the workpiece: 1-expressions, 2-series of oriented positions; reading the law of changes of internal coordinates of the manipulator; defining the manipulator drive. Development of Motion Analysis and display of manipulators.

Practical teaching

Equivalent mechanisms; replacing the higher kinematic pair with a kinematic chain with lower kinematic pairs. Camshaft construction; diagram construction: times, velocities and accelerations; using programs in ACAD to synthesize cam mechanisms. Construction of the

Maltese mechanism; choice of Maltese mechanism; diagrams: movements, velocities and accelerations; defining the parameters of the toothed wheel and the grasshopper. Construction of a mechanism with a characteristic trajectory; synthesis of the mechanism in MATLAB and construction in the SolidWorks software package for a given shape of the working part of the path. Construction of manipulators TTT, TRT, ... in SolidWorks software package; defining independent plants; determination of forces in kinematic pairs; defining driving forces and moments. Construction of manipulators TTT, TRT, ... according to the given law of movement of the workpiece (function or through oriented positions). Development of a specific project of replacing a manipulative action in the post-food process with an action performed by a specific manipulator.

Prerequisites

A desirable condition is passing the course Designing Mechanisms

Learning resources

Script: Design of mechanisms and manipulators in the food industry; author: Dr. Jeli Zorana, Boris Kosić; Necessary additional materials (handouts, task settings, seminar papers, etc.) are provided on web pages or reproduced on paper. Larger electronic materials can be made available to students in direct contact. Classes are realized by combining video display and blackboard.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	2
laboratory exercises	10
calculation tasks	0
seminar works	0
project design	13
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	6
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 40

References

Kinematic Geometry of Mechanisms, Hunt K.H, Oxford, 1978

Engineering Condition Monitoring

ID: 0989
Responsible/Holder professor GORAN B. ŠINIKOVIĆ
Teaching profesor(s): ŠINIKOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

Students are to acquire necessary knowledge to trouble-shoot the machinery, reveal main cause of malfunction and prescribe remedial action. Introduction of equipment and devices for engineering diagnosis and skills development for applying them.

Learning outcomes

In this course students prepare to accumulate engineering knowledge and skill to approach an object, use the technical documentation to understand system operation, apply appropriate methods of check out, collect relevant data, compare the the results with ISO proposed norms, make a decision and specify the list of remedial action.

Theoretical teaching

Lectures: Description of common objects of diagnosis. Typical machinery composition. Subassemblies. Machinery outlines. Different diagnostic models, monitoring priorities and optimization. Diagnosis of: distributing networks for propelants, compressed air, gases, steam, lubricants, etc. Site measurements. Description and classification of different kind of measurements. Diagnostic algorithms and machinery structurizing. Selection of diagnostic parameters. Diagnostic devices. Functions and accessories. Schedule of inspection. Critical machine operating range. Preliminary measurements. Troubleshooting. Reporting. Overhaul and rehabilitaion program definition. ISO verification. Run out check up. NDT inspection. Lubricants inspection.

Practical teaching

Exercises, Lab work: Typical machinery - generators, blowers, pumps, compressors, turbines, transportation lines. Site measurements: temperature, pressure, fluid flow, velocity, position, acceleration, displacement. Site diagnosis: troubleshooting, rehabilitation list. Geometry check out: shape, position and dimensional tolerances. NDT inspection: magnetic particles, chemical agents, ultrasound. Vibrodiagnosis: spectral analysis, peak detection, phase lag measurement. Technical liquids and gases analysis. Proactive strategy of maintenance.

Prerequisites

No prerequisites

Learning resources

A. Veg, G. Sinikovic, Manuscript "Fundamentals of technical diagnosis"
A.Veg, G.Sinikovic, Handbook of vibrodiagnosis

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	24
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	6
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	8
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	25	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

G. Sinikovic, Diagnostic Machinary, Faculty of Mechanical Engineering Belgrade, 2020.

Engineering graphics and simulations

ID: 1511
Responsible/Holder professor MIŠA D. STOJIĆEVIĆ
Teaching profesor(s): STOJIĆEVIĆ MIŠA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

• introducing students to the problems of advanced modeling of more complex machine parts and assemblies, as well as their presentation in the appropriate technical documentation
• gaining insight into different types of technical documentation used in mechanical engineering
• basic training for creating appropriate simulations of parts and assemblies

Learning outcomes

After completing the course, students acquire the necessary knowledge for modeling more complex machine parts, assembling them into a functional assembly, simulating that assembly in order to check the appropriate characteristics, creating technical documentation, analyzing the data obtained by simulation and creating an animation that shows the working process of the appropriate assembly.

Theoretical teaching

The theoretical teaching consists of several units. The first part includes the improvement of knowledge in the field of engineering graphics, modeling and production of technical documentation. In this part, students are introduced to the principles of parametric computer modeling using appropriate CAD software. The approach shown here requires constant creation, modification, analysis and optimization of the assembly or machine design in order to achieve the given initial parameters. The second part of the course presents the processing of special types of drawings used in mechanical engineering. Depending on the field of mechanical engineering where they are used, presentations of different types of supporting documentation that are used in the requested fields will be given. The third part shows the process of setting up appropriate simulations for testing parts of structures as well as simulating the operation of certain mechanisms. For these simulations, the appropriate reports obtained from the simulations of the mechanisms are generated.

Practical teaching

Exercises include making 3D models of more complex machine parts, making technical drawings for parts as well as for the whole assembly. Then the assembly of the parts is carried out in an appropriate way to obtain a functional assembly and check whether the assembly corresponds to the given parameters and whether the finishing of the parts is needed. After determining that the assembly meets the requirements set at the beginning, the preparation of the necessary technical documentation for the assembly, the creation of a

report with the results of the simulation, is started. Creation of different types of drawings used in mechanical engineering and finally, a film is made about the operation of the assembly using appropriate, suitable software packages.

Prerequisites

No condition.

Learning resources

Handouts and presentations from lectures.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	15
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	30		

Requirements to take the exam (number of points) 50

References

Jeli Z., Šiniković G: ENGINEERING GRAPHICS, Faculty of Mechanical Engineering, Belgrade, 2022.
Dynamics and horological errors of escapement mechanisms, B. Popkonstantinović, N. Mladenović, M. Stojićević, Faculty of Mechanical Engineering, Belgrade; 2018.

Food Processing Machines

ID: 1175
Responsible/Holder professor ZORANA V. JELI
Teaching profesor(s): JELI ZORANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

1. Getting acquainted with the basic concepts necessary for dealing with matter in this field. 2. Acquiring skills in preparation of modern design programs for designing and analyzing the operation of food equipment and plants. 3. Developing students' creative abilities to design food systems, machines and systems.

Learning outcomes

1. Knowledge and understanding of the problem of food machines 2. Analyzing existing solutions and their effects 3. Linking knowledge from various fields of technology, tracking the newspapers and applying them 4. Adopting practical knowledge 5. Solving concrete problems in the production of food machines.

Theoretical teaching

Acquiring knowledge about food products in general and their classification, understanding of basic technological requirements and ways of their realization, grain processing machinery, constructive characteristics and examination of various types of mills as characteristic machines in the field of grain processing, machinery in the confectionery industry, overview of characteristic types of machines for different types of confectionery products, their working principles and technical characteristics, transport systems in the confectionery industry, connection of individual machines in these cation of the parent entity for the production of confectionery products, automated production lines for hard biscuits and crackers, the characteristics of machines for test preparation, test processing and obtaining the final form pasta making machines for fruit and vegetable processing, milk processing machinery, machinery for meat processing.

Practical teaching

Practical exercises which include familiarization with the basic technical and technological characteristics of typical representatives of food processing machines for grain processing (mills and sieves), machinery in the baking industry (mixers, dividers, fermentation chambers, formations), machine in the confectionery industry (laminating machines, shaping, cutting), a fruit and vegetable processing machine, a milk processing machine and a meat processing machine. Preparation of a project which includes defining the project task, the necessary calculations and the production of documentation of assemblies or complete devices.

Prerequisites

There are no special conditions for attending the course, preferably listened to and passed Basic Technological Operations in Food Engineering.

Learning resources

Скрипта у припреми. За успешно савладавање предмета неопходно је коришћење упутства за израду пројеката, handout-a, Ineternet ресурса и видео записа.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	8
laboratory exercises	2
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	4
colloquium, with assessment	4
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	20	project design	40
laboratory exercises	5	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 44

References

Food Machines, Peter Batchelor, 2009

Fundaments of mechanism analysis and synthesis

ID: 1509
Responsible/Holder professor ZORANA V. JELI
Teaching profesor(s): JELI ZORANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: theory of machanisms and machines

Goals

Acquiring knowledge and mastering the basic skills of analysis and synthesis of mechanisms. Study of structural, kinematic, and dynamic analysis of mechanisms, on the basis of which the analysis and synthesis of planar and spatial mechanisms are carried out. Familiarity with various software packages used in the field of mechanism analysis and synthesis.
Application of theoretical knowledge acquired in the subjects Mechanics 2 (Kinematics) and Mechanics 3 (Dynamics).

Learning outcomes

The student has mastered the theoretical foundations for a complete structural, kinematic, and dynamic analysis of mechanisms. By using these basics and solving problems of analysis (calculated and using software tools), the student is able to determine the elements necessary for the synthesis of mechanisms. Then, using different methodologies, and mathematical and software tools, the student is able to perform a synthesis of planar and spatial mechanisms. Also, on a concrete example, within the assigned project, the student masters the skill of independently creating a specific mechanism. According to the studied course, students are trained to perform analysis, modeling, synthesis, and generation of mechanisms in various software packages.

Theoretical teaching

Structural analysis of mechanisms: definition and classification; kinematic connections, members and organs; kinematic pairs and chains; kinematic models and kinematic schemes of mechanisms, degrees of freedom of kinematic chains; kinematic transformation, conversion, and inversion; analog mechanisms.
Kinematic analysis of mechanisms: graphical and analytical methods of analysis of position, speed, acceleration, and characteristic points of the lever, curve-sliding, cam, mechanisms with intermittent movement and mechanisms for achieving a high transmission ratio, spatial mechanisms with closed kinematic chains of the type RSSR, RRSC, RCCC, RRSS; kinematics analysis of spatial movement and displacement, relative speed and acceleration in space; application of modern software tools for the analysis of the mentioned types of mechanisms.
Dynamic analysis of mechanisms: kinesthetics, inertial force and moment, pressure angle, determination of driving force and moment, method of equivalent masses.
Fundaments of the synthesis of planar mechanisms: methods of structural and dimensional synthesis of planar mechanisms (lever, curve-sliding, cam, mechanisms with intermittent movement, and mechanisms for realizing a large transmission ratio); tasks of kinematic synthesis of mechanisms; synthesis of the mechanism by changing the function, position, and

path;
Basics of kinematic synthesis of spatial mechanisms: synthesis of spatial mechanisms of the type RSSR, RRSC, RCCC, and RRSS by adjusting the function, position, and path; defining the most current methods of mechanism synthesis; selection of the optimal mechanism synthesis method.

Practical teaching

Structural analysis of mechanisms: the creation of schematic representations, creation of calculation tasks, creation of models of mechanisms in the SolidWorks crank, curve-sliding, cam, mechanisms with intermittent movement, mechanisms for realizing a large transmission ratio, spatial mechanisms with closed kinematic chains of type RSSR, RRSC, RCCC, RRSS according to predetermined geometric parameters. Kinematic analysis of mechanisms: the creation of calculation tasks according to learned graphic and analytical methods, using models created in SolidWorks (in the field of structural analysis of mechanisms), perform kinematic analysis; using SolidWorks and Adams to perform kinematic analysis of selected types of mechanisms; perform a comparison of the results obtained by calculation and computer analyses. Dynamic analysis of mechanisms: setting the task of dynamic analysis of lever and cam mechanisms and solving them using kinesthetic methods, dynamic modeling methods, setting parameters in SolidWorks and Adams for setting dynamic analysis problems, and performing the analysis itself. Basics of the synthesis of planar mechanisms: use of the MatLab/Simulink for generating parameters for the synthesis of planar mechanisms (writing synthesis codes by generating function, position, and path); synthesis of mechanisms based on given parameters and obtaining realistic models in the SolidWorks. Creation of a laboratory model (based on the model from SolidWorks) and commissioning in the laboratory for Hydraulic and pneumatic mechanisms and installations. Creation of a laboratory model using a 3D printer in the Engineering Graphics laboratory (based on the model from SolidWorks) and checking the completed synthesis on the physical model. Basics of kinematic synthesis of spatial mechanisms: generation of a specific type of spatial mechanism in SolidWorks using parametric path synthesis in MatLab. Creation of a 3D model of the mechanisms with all their elements.

Prerequisites

Desirable Practicum in the basics of construction

Learning resources

S. M. Mata, A. B. Torras, J. A. Cabrera Crrillo, F. E. Junaco, A. J. Guerra Fernandez, F. N. Martinez, A. O. Fernandez: Fundaments of Machine Theory and Mechanism
K.H. Hunt: Kinematic Geometry of Mechanisms

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	30

OTHER	
knowledge checks	**15**
assessment of calculation tasks	1
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	4

laboratory exercises	0	colloquium, with assessment	4
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	10
test/colloquium	30	project design	10
laboratory exercises	5	final exam	35
calculation tasks	5		

Requirements to take the exam (number of points) 50

References

S. M. Mata, A. B. Torras, J. A. Cabrera Crrillo, F. E. Junaco, A. J. Guerra Fernandez, F. N. Martinez, A. O. Fernandez: Fundaments of Machine Theory and Mechanism, Springer, 2016.
K.H. Hunt: Kinematic Geometry of Mechanisms, Oxford University Press, 1990.

Mechatronics

ID: 1150
Responsible/Holder professor EMIL A. VEG
Teaching profesor(s): VEG EMIL
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: theory of machanisms and machines

Goals

Mastering the knowledge fund required for competent analysis of the structure of the mechatronic solution, defining the executive mechanism, the control module, and the work algorithm. Developing the creative ability to set up a conceptual mechatronic solution for the problem, which will optimally meet the defined technical requirements.

Learning outcomes

Possessing the engineering capabilities to perform a qualitative analysis of the mechanisms of the electronic and processor modules as key sub-blocks of a mechatronic solution. Based on complete mastering of an inverse engineering task (analysis), active solving of a direct engineering task, synthesis of the original mechatronic solution.

Theoretical teaching

Theory teaching; Introduction to mechatronics; Intelligent machine circuits, systems and their application, Design in mechatronics; Initial vision of the concept of mechatronic solution, Mechanisms in mechatronics; Science on the theory of machines and mechanisms. Classification of mechanisms, Measurements in mechatronics 1; Analog and digital sensors, Measurements in mechatronics 2; Definition of photodiode light and phototransistors, Actuators in mechatronics; Linear and rotary actuators, Actuators with motion transformation, Digital and analogue electronic modules; Logic circuits and applications, Detection of state (0,1), Management concepts in mechatronics; Structure of the processor system, Programming the system; Programming tools available, Programming input ports, Programming output ports

Practical teaching

Practical teaching; laboratory exercises; Display of typical mechatronic solutions; Turbocharger with variable geometry, Decomposition of mechatronic solution; Analysis of elements, functions and signals of the sensor block, Elemental mechanisms; Examples of different configuration mechanisms for performing certain motion profiles, Sensors 1; Measurement of analogue sizes using PC-platform and Lab View software package, Sensors 2; Developing the idea for solving the user numerical-graphic display of results, Actuators; Motorized frequency drive control; Operational amplifier, Working with PC-platform, Working with PIC-platform;

Prerequisites

Presence on the lectures is mandatory (at least 80% of lectures).

Learning resources

Models of mechanisms (articulated four-wire, piston mechanism) Set of sensors (thermocouples, inductive accelerometers, opto sensors). DC PIC development system Pneumatic components (cylinders, valves, PLCs)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	5
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	5
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	50	project design	0
laboratory exercises	20	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Little Mechatronics Dictionary (in Serbian), A. Veg, G. Šiniković, E. Veg, M. Regodić, ISBN 978-86-6060-184-3, (published 2024)
Mechatronics, laboratory experiments (in Serbian); E. Veg, M. Regodić, G. Šiniković, A. Joksimović, ISBN 978-86-6060-182-9, (published 2024.)

Skill Praxis M - IGM

ID: 1514
Responsible/Holder professor GORAN B. ŠINIKOVIĆ
Teaching profesor(s): ŠINIKOVIĆ GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: theory of machanisms and machines

Goals

1. Acquisition of practical knowledge in the field of engineering graphics, computer simulations, mechatronics and virtual reality.
2. Acquaintance with software tools required for application in the field of engineering graphics, computer simulations, mechatronics and virtual reality
3. Developing the student's creative abilities for solving concrete problems in the mentioned areas.

Learning outcomes

After completing the study program the study program, the student acquires the ability to solve practical problems in the area of:
- engineering graphics
- computer simulations
- mechatronics
- virtual reality

Theoretical teaching

-

Practical teaching

Getting to know the work of companies that deal with design, simulations and the development and implementation of mechatronic solutions.

Prerequisites

No additional conditions for attending the course

Learning resources

In order to successfully master the subject, it is necessary to use Internet resources, instructions, manufacturer's prospectus material and videos.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING		OTHER	
active teaching (theoretical)	0	knowledge checks	90

lectures	0	assessment of calculation tasks	0
elaboration and examples (revision)	0	check and assessment of lab reports	0
active teaching (practical)	**0**	check and assessment of seminar works	80
auditory exercises	0	check and assessment of projects	0
laboratory exercises	0	colloquium, with assessment	0
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	10
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	70
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

G. Šiniković: "Professional Practice M IGM", Faculty of Mechanical Engineering Belgrade, 2022

The aesthetics of 3d modeling

ID: 1513
Responsible/Holder professor EMIL A. VEG
Teaching profesor(s): VEG EMIL
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: theory of machanisms and machines

Goals

Acquisition of basic theoretical knowledge about the criteria of aesthetics in the process of designing and constructing
products. Acquisition of theoretical and practical knowledge in 3D modeling, modification of existing models to improve aesthetics and/or functionality. Familiarizing students with the laws of aesthetics in the process of product design; recognition of subjective and objective factors in the formation of aesthetic judgement; treatment of aesthetic elements and principles; use of classical and modern means for creating aesthetic properties; familiarization with the characteristics of modern graphic signs and aesthetic properties of packaging and advertising; the importance of the effect of product aesthetics on the process of modeling, constructing, manufacturing, and finally advertising and marketing.

Learning outcomes

After completing this course, students should be able to:
• They actively use 3D tools for modeling the conceptual product,
• Independently analyze the product and make corrections to improve aesthetics and/or functionality
• Creatively use abstract elements and principles of aesthetics,
• They creatively use practical (classical and contemporary) means to create the aesthetic properties of the product

Theoretical teaching

Definition of Aesthetics and etymology of the name; concept, factors and importance of aesthetic judgment and aesthetic standards; aesthetics as a factor of visual communications; detailed analysis of aesthetic elements of product design; processing and analysis of basic aesthetic principles of product design; Methods of creation and presentation of aesthetic properties (classical and contemporary); Principles of computer modeling of shapes using appropriate CAD software and the concept of a modern graphic sign; the role of the graphic sign in the context of modern visual communications; aesthetics of signs, symbols and meanings; aesthetic properties of product packaging and packaging; advertising and product presentation; the influence of product aesthetics on the process of modeling, constructing and making products.

Practical teaching

Exercises of independent product analysis and correction to improve aesthetics and/or functionality;

Product modeling in appropriate CAD software; Product presentation following universal attitudes about aesthetics and principles of induction of aesthetic values and aesthetic evaluation; discussion on the topic of the development and importance of the aesthetics of an independent product; exercises in the use of aesthetic elements and principles; exercises in the use of classical and modern means of creating and presenting the aesthetic properties of products;

Prerequisites

Defined by the curriculum of the study program/module.

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	15
test, with assessment	0
final exam	0

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	30
test/colloquium	10	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

The book "Esthetics of Visual Communications" by Branislav Popkonstantinović (published 2013.)

THERMAL POWER ENGINEERING

Computer simulations of thermalhydraulic processes and CFD

Energy Planning

Environmental Protection in Thermal Power Engineering

Gas Turbines

Nuclear Reactors

Skill Praxix M - TEN

Steam generators

Steam Turbines 1

Steam Turbines 2

Steam Turbines 3

Thermal Power Plants 1

Thermal Power Plants 2

Thermal Turbomachinery

Turbocompressors

Two-Phase Flows with Phase Transition

Computer simulations of thermalhydraulic processes and CFD

ID: 1320
Responsible/Holder professor SANJA S. MILIVOJEVIĆ
Teaching profesor(s): MILIVOJEVIĆ SANJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

The aim is acquiring knowledge and skills for development and application of analytical and numerical models of thermal-hydraulic processes in energy, thermal and process equipment,as well as application of numerical methods for the simulation and analyses of one-phase and two-phase systems in pipelines and plant equipment, including the methods of Computational Fluid Dynamics - CFD.

Learning outcomes

The students are trained to perform computer simulation and analyses of heat transfer and fluid flow processes of one-phase and two-phase gas-liquid systems with and without phase transitions in energy, thermal and process equipment.

Theoretical teaching

Modelling of thermal and flow processes with lumped and distributed parameters. Balance equations of mass, momentum and energy and constitutive correlations for interface transfer processes. Explicit and implicit numerical methods for the solving of Cauchy problems with defined initial conditions in cases of the lumped parameter models. The method of characteristics for the solving of hyperbolic system of partial differential equations. The application of the method of control volumes of the SIMPLE type for the solving of elliptic and parabolic multidimensional models with distributed parameters. Numerical grid generation. Graphical presentation of results.

Practical teaching

Development of the models with lumped parameters for the pressure dynamics prediction in the pressurized vessels filled with one phase compressible fluid or two-phase mixture of liquid and condensing vapour. Numerical simulation of pressure transients in the pressurizer, in the feedwater tank and the drum of a steam boiler. Development of models with distributed parameters for one-phase and two-phase flows with or without phase transitions. Numerical simulations of pressure and temperature waves propagation in pipeline networks. Computer simulations and analyses of multidimensional two-phase flows in steam generators, evaporators, condensers, heat exchangers, etc.

Prerequisites

Attended courses in Fluid Mechanics, Thermodynamics, and Numerical Methods.

Learning resources

Course handouts. Stevanović, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, Monograph, Faculty of Mechanical Engineering, Belgrade, 2006. Computer equipment. Software for numerical solving of systems of differential equations of various types. Software for simulation and analyses of pressure transients in pipeline networks and pressurized vessels. Software for simulation and analyses of multidimensional two-phase flows.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	35	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Versteeg, H.K., Malalasekera, W., An introduction to Computational Fluid Dynamics, Longman Group Ltd., Harlow, 1995.
Wulff, W., Computational methods for multiphase flow, Multiphase Science and Technology, Vol. 5, Begell House, 1990.
Streeter, V.L., Wylie, E.B., Hydraulic Transients, McGraw Hill, New York, 1967.
Tannehill, J.C., Anderson, D.A., Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, Taylor&Francis, New York, 1997.
Stevanovic, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, University of Belgrade, Faculty of Mechanical Engineering, 2006.

Energy Planning

ID: 0105
Responsible/Holder professor VLADIMIR D. STEVANOVIĆ
Teaching profesor(s): STEVANOVIĆ VLADIMIR; MILIĆ SRĐAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal power engineering

Goals

The aims of the subject are to master the methods for the analyses and planning of the macro energy systems at the level of economy and industry sectors, regions and the country, including analyses and formation of energy balances, prediction of energy flows and the structure of energy consumption, classification of energy carriers and indicators of energy consumption, the relation between the economic growth and energy consumption, the state regulative in the energy sector, the environmental impact of energy consumption etc.

Learning outcomes

Students acquire a knowledge and skills related to energy planning by using statistical and econometric methods and by applying the phenomenological models, as well as related to methods for providing the basis for planning procedures, such as analyses and preparation of energy balances, prediction of indicators of energy consumption, etc.

Theoretical teaching

Macro energy systems, energy systems of Serbia and the World: energy balance of Serbia, energy flows and structure of energy consumption in Serbia and the World. Classification of energy carriers and indicators of energy consumption. Relation between economic growth and energy consumption. Specific and useful energy consumption. Energy efficiency. Energy audit. Rational energy consumption. Techno-economic methods for energy investment evaluations and measures for rational energy consumption. Renewable energy consumption and new energy sources/technologies. Processes and plants for energy accumulations. Methods for energy systems modelling. Energy planning and policy. Law regulative in energy sector. Environmental impact of energy consumption.

Practical teaching

Macro energy systems balancing, prediction of energy, economic and technological indicators of energy consumption, optimization and usage of energy plants for electricity production, planning of energy needs, electricity production costs, optimization of dimensions and operational parameters of energy plants and equipment, measures for rational energy consumption, methods for economic evaluation of energy efficiency measures (the net present value method, the internal rate of return method and the pay back period).

Prerequisites

Passed exams in Thermodynamics and one subject within the Module for Thermal Power Engineering.

Learning resources

Handouts.
Ristic, M., General energetics, Faculty of Mechanical Engineering, Belgrade, 1981.
Personal computers.
Software for energy planning and economic evaluation of investments.
Internet presentations of International Energy Agency and World Energy Council.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	10
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	10
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	65		

Requirements to take the exam (number of points) 30

References

Kleinpeter, M., Energy Planning and Policy, John Wiley & Sons, New York, 1995.
Chateau, B., Lapillonne, B., Energy Demand: Facts and Trends, Springer-Verlag, New York, 1982.
Eastop, T.D., Croft, D.R., Energy Efficiency, Longman Scientific & Technical, Harlow, 1990.
Gottschalk, C.M., Industrial Energy Conservation, John Wiley & Sons, 1996.
Energy Policy, The International Journal, Elsevier.

Environmental Protection in Thermal Power Engineering

ID: 1319
Responsible/Holder professor SANJA S. MILIVOJEVIĆ
Teaching profesor(s): MILIVOJEVIĆ SANJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: oral
Parent department: thermal power engineering

Goals

The aims is acquiring academic knowledge about sources and characteristics of hazardous gases emission and other harmful influences in all phases of thermal power plants exploitation, about the environmental influence of harmful emission, about possible technical solutions, processes and equipment for the emission reduction, harmful waste storage, as well as about the importance of these activities for economic and social development.

Learning outcomes

The students master their knowledge and skills in the field of environmental protection from the harmful emissions from the thermal power plants. Besides being acquainted with the sources of harmful emissions and methods and equipment for their reduction and storage, the students are trained to quantify harmful emissions and to estimate the technical, ecological and economical effects of current methods and measures for environmental protection.

Theoretical teaching

The influence of thermal power plants on environment and harmful emissions, maximum allowed emissions, regulatory laws related to harmful emissions, international activities towards environment protection and reduction of green house gases emissions, technologies and plants for emission reductions from thermal power plants, such as dust removal from flue gases, flue gases desulphurization, NOx removal, carbon dioxide capture and storage. The influence of atmospheric conditions on emissions propagation and harmful matters dispersion, storage of solid combustion products, heat load to the environment from thermal power plants, current developments of thermal power plants efficiencies from the standpoint of emissions reductions.

Practical teaching

Prediction of the harmful emissions during the operation of the thermal power plants, evaluation of conceptual design of plants for the harmful emissions reduction in accordance with the law regulation, ecological and economical effects of methods for emission reduction, criteria for chimney selection, analyses of wet and dry methods for flue gases desulfurization, analyses of plant accidental conditions on environmental pollution.

Prerequisites

Passed exam in Thermodynamics.

Learning resources

Course handouts. Instructions for seminar work. Vendors' technical documentation of plants for environmental protection at thermal power plants.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	0
seminar works	15
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	4
check and assessment of projects	0
colloquium, with assessment	8
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	20
test/colloquium	45	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Salvato, J.A., Nemerow, N.L., Agardy, F.J., Environmental Enginering, Wiley, 2003.
Woodruf, E.B., Lammers, H.B., Lammers, T.F., Steam Plant Operation, McGraw-Hill, NewYork, 1998.
Beer, J.M., High efficiency electric power generation: The environmental role, Progress inEnergy and Combustion Science 33 (2007) 107–134.
Reference Document on Best Available Techniques (BAT) for Large Combustion Plants,European Commission, 2006, 2016.

Gas Turbines

ID: 0300
Responsible/Holder professor MILAN V. PETROVIĆ
Teaching profesor(s): PETROVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

1. The achievement of academic competence in the field of gas turbines and thermal power plant engineering.
2. Mastery of theoretical knowledge about how to transform heat into mechanical work of thermodynamic processes and equipment (gas turbines and gas turbine power plants).
3. The acquisition of practical skills for design and optimization of gas and gas turbine cycle.
4. Mastering the techniques of process modeling.

Learning outcomes

1. Academic deep knowledge of the thermodynamic cycle and flows in gas turbines and gas turbine plants
2. The development of critical thinking about energy use, fuel efficiency and environmental preservation
3. The ability of calculate heat balance diagrams and main parameters of the gas turbine power plants.
4. Ability to use computer technology for modeling and calculations

Theoretical teaching

Theoretical teaching is carried out through 10 teaching modules:
1. Thermodynamic basis of the gas turbines power plants. The basic thermodynamic cycles.
2. The basic and main thermodynamic parameters of the gas turbine plants.
3. The influence of basic parameters on the performance of the gas turbine plants. The choice of optimal parameters of the gas turbine plants.
4. Energy balance of the gas turbine plants. Improvements the thermodynamic gas turbine plants.
5. More complex cycles of gas turbine plants.
6. Combined gas and steam plant turbine. Gas turbine plants with gasification of coal.
7. The application of gas turbines in the energy and airplane propulsion.
8. The construction of gas turbines. Materials of gas turbines. Selection of temperature at the entrance to the gas turbine. Blade cooling and cooling problems.
9. Combustion chambers - functions and operating principles, performance. Types of combustion chambers. Fuel for gas turbines. Auxiliary equipment of gas turbine plants.
10. Operating characteristics of gas turbines - change mode. Regulation of gas turbines.

Practical teaching

Practical training is carried out through:

Auditory exercises:
Basic principles. Historical development. Classification, properties and applications of gas turbines.
The application of gas turbines for the propulsion of vehicles, ships rail.
Instructions for project 1: Calculation of the gas turbine thermal cycle (heat balance diagram) of the gas turbine plants.
Instructions for project 2: Calculation of the combined cycle with gas turbine and steam turbine (CCGT).
Project development:
Calculation of heat balance of the gas turbine power plant.
Calculation heat balance diagram of combined cycle with gas turbine and steam turbine.
Labs:
introduction in principles of operation and design of gas turbines in the Laboratory for steam and gas turbines

Prerequisites

Passed exams in Thermodynamics and Fluid mechanics

Learning resources

Petrovic, M.: Gas turbines and compressors, script, 2004.
Petrovic, M.: Gas turbines and compressors, introduction for exercises, 2004.
Petrovic, M. scripts and handouts for Gas turbines
Instructions for performing laboratory exercises
Software package for calculating of properties of combustion products

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	13
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	7
colloquium, with assessment	0
test, with assessment	2
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	10	project design	30

laboratory exercises	5	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Petrovic, M.: Gas turbines and compressors, script, 2004.
Stojanovic, Thermal Turbomachinery, Gradjevinska knjiga, belgrade, 1967.
Cohen, H., Rogers,G.F.C., Saravanamuttoo, H.I.H.: Gas turbine theory, Logman, 1997.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Boyce, M.: Gas turbine engineering hadbook, GPB, Boston 2002.

Nuclear Reactors

ID: 0345
Responsible/Holder professor VLADIMIR D. STEVANOVIĆ
Teaching profesor(s): STEVANOVIĆ VLADIMIR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

The aims of the subject are acquiring academic knowledge about processes and equipment for nuclear energy utilization, about neutron processes and fission, principles of nuclear reactors design, reactor core cooling, nuclear fuel characteristics, transport and storage of nuclear waste, nuclear reactors safety, nuclear accidents in Nuclear Power Plants Three Mile Island, Chernobyl and Fukushima, as well as current nuclear reactors developments.

Learning outcomes

Students are able to design nuclear reactor core, determine the thermal and neutron characteristics of nuclear fuel, moderator and reactor coolant, define basic elements of nuclear power plant safety and determine basic technical, technological, ecological and economic conditions and boundaries for the application of nuclear energy.

Theoretical teaching

Processes and equipment of nuclear energy plants. Characteristics of nuclear fuel, atomic and nuclear processes important for the nuclear reactors operation. design of nuclear reactor material structure and critical dimensions. Diffusion and thermalization of neutrons. Solving of reactor equation. Operating characteristics and safety of nuclear reactors and nuclear power plants. Feedback between nuclear and thermal processes in the nuclear reactor core. Cooling of the nuclear fuel elements, heat transport and boiling crises. Computer codes for thermal-hydraulic simulation and analyses. Overview of nuclear energy in the World and its current development. The roll of the nuclear energy in the energy sustainable development.

Practical teaching

The students solve the problems related to nuclear reactors design and analyses of its operation conditions. The numerical experiments are performed with the computer simulations of nuclear reactor processes: calculation of the radioactive chain decay, neutron life cycle and reactor equation solving for various types of nuclear reactors, the model development and computer simulation of the loss-of-feedwater accident in a plant with the pressurized water reactor.

Prerequisites

Passed exams in Physics, Thermodynamics, Numerical methods.

Learning resources

Course handouts.

Computer equipment.
Software for numerical solving systems of differential equations.
Software for the design of nuclear reactor core.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	35	project design	0
laboratory exercises	30	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Klimov, A., Nuclear Physics and Nuclear Reactors, Mir Publishers, Moscow, 1981.
Tong, L.S., Design Improvement for Light Water Reactors, Hemisphere, New York, 1988.
Knief, R.A., Nuclear Energy Technology, Hemisphere, 1981.
Foster, A., Wright, R.L., Basic Nuclear Engineering, Allyn and Bacon, Inc., Boston, 1977.

Skill Praxis M - TEN

ID: 1500
Responsible/Holder professor SRĐAN B. MILIĆ
Teaching profesor(s): MILIĆ SRĐAN; PETKOVIĆ ĐORĐE
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: thermal power engineering

Goals

The aim of this course is to introduce students to the process of design and analysis of thermal power plants, processes and systems, power equipment manufacturing process, methods of calculation and analysis of mechanical and thermal loads of energy equipment, technological lines of production, quality control, organization of construction methods, maintenance schedules and technological systems at power plants, transportation, power equipment, modern methods of calculation.

Learning outcomes

The successful completion of course students are introduced to: the appropriate energy processes, major and minor technological systems, the spatial distribution of equipment, methods, process analysis, measurement of process parameters, facilities management systems, etc.

Theoretical teaching

Introduction. The role and importance of professional practice in thermal power engineering. Basics of the measures of security and safety when using equipment and resources for work in general and particularly in the field of thermal energy. Basic principles of thermal turbomachinery. Fundamentals of thermal processes in power plants. Steam turbine plants. Boiler installations. Auxiliary systems. Organization of work in a power plant. Sectors and services. Measurement and regulation equipment in thermal power. Instructions for keeping a diary.

Practical teaching

Organization of visits to factories and
• design and consulting organization in the field of energy,
• organizations that produce and maintain equipment,
• organizations that build and maintain power plants and power plants,
• power plants and other power plants,
where part of the practice are held in the Faculty of Mechanical Engineering in the laboratories of the Department for thermal power engineering. In the laboratories of the Department for thermal students become familiar with the available equipment and measuring devices. In an independent work, students completing the technical report process with practice.

Prerequisites

There are no preconditions.

Learning resources

Petrovic, M.: Steam turbines, script, 2004.
Petrovic, M.: Gas turbines and compressors, script, 2004.
Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004
Petrovic, M.: Scripts and handouts for Steam turbines

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	80
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	70	seminar works	0
test/colloquium	0	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 70

References

Petrovic, M.: Steam turbines, script, 2004.;
Stojanovic, D.: Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.;
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgrade, 1987.;
Petrovic, M: Gas turbine and turbocompressors, script, 2004.;
Boyce, M.: Gas turbine engineering handbook, GPB, Boston 2002.;

Steam generators

ID: 0129
Responsible/Holder professor VLADIMIR D. STEVANOVIĆ
Teaching profesor(s): STEVANOVIĆ VLADIMIR; MILIVOJEVIĆ SANJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

The aims of the subject are acquiring academic knowledge about processes and equipment for steam generation in thermal power plants, building and mastering skills in scientific and engineering methods for the prediction, analyses and research of thermal-hydraulic processes in steam generators, as well as skills in methods for the design, safety analyses and diagnostics of the operational conditions of the steam generators.

Learning outcomes

Mastering the course the students are able to simulate and analyze processes, design equipment and prescribe operational conditions in steam generators by applying the modern scientific and engineering methods for various conditions of exploitation. Also, the application of acquired knowledge and skills in every stage of design, manufacture and exploitation provide the safe, reliable and economically and energetically efficient operation of steam generators.

Theoretical teaching

Design of steam generators; thermal-hydraulic parameters of vapour and liquid two-phase flow: static, flow and thermodynamic quality, vapour void fraction, two-phase mixture density, superficial velocity, two-phase flow mass flux, slip factor, drift velocity, etc.; heat transfer mechanisms in convective heating, boiling and superheating of working fluids or heat carriers; the critical heat flux; pressure change in two-phase flow; modelling of thermal-hydraulic processes in steam generators: the homogeneous model, the slip model, the two-fluid and multi-fluid models of two-phase mixture flows; numerical methods for solving the thermal-hydraulic models of two-phase flow; computer simulations of operational conditions of steam generators; pressure waves propagation and dynamic loads of pipelines in transient conditions; the chocked flow; the condensation induced water hammer; two-phase flow instabilities; steam separation.

Practical teaching

Prediction of two-phase flow parameters for various geometry and boundary conditions. Calculation of two-phase flow pressure drop. Calculation of mass, momentum and energy balances in evaporating channel. Prediction of boiling and dry-out boundaries in evaporating channels. Calculation of thermal-hydraulic parameters in circulation loops in steam generators. A development of one-phase and two-phase flow models for the simulation and analyses of two-phase flow in evaporating channels: mass, momentum and energy balance equations, closure laws for interfacial transport processes. Numerical methods fro two-phase

flow models solving. Computer simulations of circulation loops in steam generators at full and partial loads. Modelling and computer simulation of pressure transients in pressurizers filled with vapour and liquid phases.

Prerequisites

Passed exams in Thermodynamics, Fluid mechanics and Numerical methods.

Learning resources

Subject handouts.
Stevanović, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, Monograph, Faculty of Mechanical Engineering, Belgrade, 2006, ISBN 86-7083-569-X.
Personal computers.
Software for the solving of systems of differential equations.
Software for the simulation and analyses of pressure transients in pipeline networks and pressurizers.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	5
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	25
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	35	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Ishigai, S., Steam Power Engineering - Thermal and Hydraulic Design Principles, Cambridge University Press, 2010.
Reznikov, M.I., Lipov, Yu.M., Steam Boilers of Thermal Power Plants, Mir Publishers, Moscow,

1985.
Whalley, P.B., Two-Phase Flow and Heat Transfer, Oxford Science Publications, Oxford, 1996.
Delhaye, J.M., Thermohydraulics of Two-Phase Systems for Industrial Design and Nuclear Engineering, Hemisphere, 1981.
Stevanović, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, Monograph, Faculty of Mechanical Engineering, Belgrade, 2006, ISBN 86-7083-569-X.

Steam Turbines 1

ID: 0274
Responsible/Holder professor MILAN V. PETROVIĆ
Teaching profesor(s): PETROVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

1. The achievement of academic competence in the field of steam turbines and thermal power engineering.
2. The achievement of theoretical knowledge about how to transform heat into mechanical work learning thermodynamic processes and equipment (steam turbine and steam turbine power plants).
3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam turbines.
4. The achievement of the techniques of process modeling.
5. Mastering the methods of experimental work in thermal power engineering.

Learning outcomes

On completion of this programme, it is expected that student will be able to:
• identify the thermodynamic cycle parameters affecting the quality of the installation and optimization of thermodynamic cycle steam turbine,
• perform calculation of of the heat balance diagram, the steam expansion process in the turbine, the process in the condenser and feedwater heater,
• determine the main thermodynamic parameters of steam power plant that define the quality of plant operation
• set the control boundary and make the balance of the turbine plant and the whole power plant according to the first and second law of thermodynamics,
• perform calculation of main gasodynamic parameters (row efficiceny, loss coefficient , deviation and exit flow angle) of the steam turrbine cascade based on geometric and operating parameters
• apply one-dimensional theory of compressible fluid flow in the one-dimensional turbine stage design,
• identify and select stage between action and reaction type,
• professional and accurately communicate using the terminology of the respective product areas.

Theoretical teaching

Theoretical teaching is carried out through 10 teaching modules:
1) Thermodynamic background of the steam turbines and steam turbine cycles. Thermodynamic improvements, increase of live steam temperature and pressure, condensation, and decrease of the condensation pressure.
2) Reheat. Regenerative feed water heating. The basic thermodynamic cycles and heat

balance diagrams.
3) Steam turbine power plant -the 1st and 2nd law of thermodynamics.
4) The fluid dynamics background of steam turbines, gas-dynamic processes in steam turbines.
5) Cascades of the steam turbine. Geometry and operating parameters. The main gas-dynamic parameters of the steam turbines cascades.
6) The aerodynamic losses in the cascades.
7) 1D theory of elementary stages of steam turbines. Euler equation for the turbine. Efficiency of the stage.
8) Axial elementary impuls stage.
9) Axial elementary reaction stage of Parsons type.
10) Internal efficiency of the stage. Internal losses. Determination of main dimensions of stage.

Practical teaching

Practical teaching is carried out through:
Auditory exercises: basic principles. Historical development. Classification and application of steam turbines. Explanation of the heat balance diagrams and the functioning of components of the steam turbine plants. Instructions for calculation of the heat balance diagram and the main thermodynamic parameters of the steam turbine plants. Instruction to create an energy and exergy balance of the steam turbine plant according to the 1st and the 2nd law of thermodynamics.
Labs: Experimental determination of the specific steam consumption of steam turbines at the Laboratory of Mechanical Engineering.
Project design: Calculation of the heat balance diagram, the main thermodynamic parameters and the balance of the steam turbine plant.

Prerequisites

Passed exams in Thermodynamics and Fluid mechanics

Learning resources

Petrovic, M.: Steam turbines, script, 2004.
Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004
Petrovic, M.: Scripts and handouts for Steam turbines
Instructions for performing laboratory exercises
Software package for calculating of properties of steam and water.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	9
laboratory exercises	4

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	7
colloquium, with assessment	2

calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	17		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	10	project design	30
laboratory exercises	5	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Petrovic, M.: Steam turbines, script, 2004.
Stojanovic, Themal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgarde, 1987.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Leyzerovich, A.: Steam Turbines for Modern Fossil-Fuel Power Plants, CRC Press, 2008

Steam Turbines 2

ID: 0174
Responsible/Holder professor MILAN V. PETROVIĆ
Teaching profesor(s): PETROVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

1. The achievement of academic competence in the field of steam turbines and thermal power engineering.
2. The achievement of theoretical knowledge about how to transform heat into mechanical work learning thermodynamic processes and equipment (steam turbine and steam turbine power plants).
3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam turbines.
4. The achievement of the techniques of process modeling.
5. Mastering the methods of experimental work in thermal power engineering.

Learning outcomes

On completion of this programme, it is expected that student will be able to:
• optimization calculation of the turbine stage and select dimensionless stage parameters;
• selects the type of turbine cascade, construct airfoils and calculated the corresponding losses,
• set up a concept of the turbine relating to number of cylinars and the number of flow
• determine number of the turbine stages,
• conduct a detailed calculation of a turbine stages determining the main dimensions of the steam turbine,
• applty the theory of 3D flow for the turbine stages,
• perform basic design of steam turbine based on the carried calculations,
• knows the problems of operation and design of the last steam turbine stage,
• analysis of the problems of strength of the various elements of steam turbines
• analye the main problems vibration structural elements of the steam turbine,
• select the methods of regulating and analyze the opeartion of steam turbine at off design conditions.

Theoretical teaching

Theoretical teaching is carried out through 10 teaching modules:
1) 3D flow in steam turbines stages.
2) 3D flow in stages with large length blades.
3) Design of steam turbines.
4) Multistage steam turbines.
5) Blades - design, stress, constant strain blades, vibration and erosion.
6) Steam turbine rotors - construction, stress, vibration.

7) Housing of steam turbines - design, stress, deformation and thermal dilation. Commissioning of steam turbines in operation, heating, cooling.
8) Steam turbine bearings - design, lubrication. Labyrinth seals. Protection components of steam turbines.
9) Operating characteristics of steam turbines, consumption cone.
10) Regulation of steam turbines, thermodynamic and functional problems.

Practical teaching

Practical training is carried out through:
Auditory exercises:
Instructions for the project. Calculation and construction of steam turbines. Selection of blade profiles. Design turbine of high, medium and low pressure. Calculation of the number of stages. Calculation of the turbine last stage.
Labs:
Measurement of vibration of the rotor and the frequency of free oscillations of the steam turbine blades in the Laboratory of Mechanical Engineering.
Project development:
Calculation and design of steam turbines
Excursion:
Visit one thermal power plant in Serbia

Prerequisites

Passed exams in Thermodynamics and Fluid mechanics

Learning resources

Petrovic, M.: Steam turbines, script, 2004.
Petrovic, M.: Instruction for steam turbine projet, Belgrade, 2004
Petrovic, M.: Scripts and handouts for Steam turbines
Instructions for performing laboratory exercises
Software package for calculating of properties of steam and water.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	12
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	7
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	10	project design	30
laboratory exercises	5	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Petrovic, M.: Steam turbines, script, 2004.
Stojanovic, Themal Turbomachinery, Gradjevinska knjiga, belgrade, 1967.
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgarde, 1987.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Leyzerovich, A.: Steam Turbines for Modern Fossil-Fuel Power Plants, CRC Press, 2008

Steam Turbines 3

ID: 1548
Responsible/Holder professor ĐORĐE D. PETKOVIĆ
Teaching profesor(s): PETKOVIĆ ĐORĐE
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal power engineering

Goals

Introduction to the concept of combined production of electricity and heat, as well as steam turbines for this type of application. Specific design of turbines for industrial processes and electricity generation. Operation of components and the entire plant at off-design regimes. Diagrams of regimes for combined power generation. Turbines for special purpose, utilization of waste heat.

Learning outcomes

On completion of this programme,it is expected that student will be able to select type of the steam turbine for combined production of power and heat (CHP), select operating parameters, perform thermodynamic calculation of backpressure turbine for combined production of power and heat in nominal and off-design mode, select organic Rankine cycle for use of waste heat.

Theoretical teaching

Introduction, Thermodynamic effects of the application of combined heat and power generation, Types of heat consumers and heat demand, Steam turbines for combined production, Operation of components at off-design regimes, Operation of power plants at off-design regimes, Diagrams of regimes of steam turbines for combined production, Steam turbines for nuclear power plants, Steam turbines for special purposes (Organic Rankine Clausius Cycle, Steam turbines for a combined gas and steam turbine plant).

Practical teaching

Development of a computer program for the calculation of a steam power plant for combined production of electricity and heat, including solutions with a condensing and counter-pressure turbine, as well as for calculation of the stage of an axial turbine at off-design.

Prerequisites

Finished courses in Steam Turbines 1 and 2

Learning resources

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	24
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	1
test, with assessment	0
final exam	4

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Petrovic M. V., Stojanovic D.: Steam Turbines, Script, Faculty of Mechanical Engineering, Belgrade, 2022.
Stojanovic, D.: Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Vasiljevic, N.: Steam Turbines, Faculty of Mechanical Engineering, Belgrade, 1987.
Scegljajev A.V.: Parni turbiny, Energia, Moscow, 1976.
Leyzerovich, A., Wet-steam Turbines for Nuclear Power Plants, PennWell, Tulsa, 2005.

Thermal Power Plants 1

ID: 1546
Responsible/Holder professor SRĐAN B. MILIĆ
Teaching profesor(s): MILIĆ SRĐAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

Getting to know the procedures for the selection of the type, parameters and configuration of the thermal power plant according to demand of energy consumption, available sources of primary energy, energy and economic performances and other important criteria. Also, learning on the performance and technological characteristics of individual technological systems in thermal power plants. Exercise program is based on the implementation of certain practical knowledge of the course program by solving of specific examples.

Learning outcomes

On completion of this course, it is expected that student will be able to:
• identify different technological subsystems within the thermal power plant,
• projects technological scheme of thermal power plants with steam and gas turbines,
• conduct techno-economic analysis of the operation of thermal power plants, calculate the production
price electricity and determine the economic feasibility parameters,
• calculate and optimize the condenser plant,
• determine the necessary flow of cooling water,
• perform calculation and optimization of feed water heater.

Theoretical teaching

The influence of the main factors and criteria for the selection of the thermal power plant. The structure and characteristics of the final energy consumption. The choice of configuration and parameters of the thermal power plants: basic and main thermodynamic parameters for steam and gas power plants, thermodynamic improvements of steam and gas turbine power plants. Estimation of the cost of electrical energy production and the optimization criteria of the thermal power plants: the total costs of energy production, comparative cost factors as optimization criteria and indicators of economic viability. Power plant and a complex technological system. Technological scheme of thermal power plants. Technological scheme of the main system for the production of electricity that includes the start and stop function block. Other systems: fuel supply, drainage, transportation and disposal of ash and slag, condensation plant with a system for supplying cooling water, system for the control and management of steam plants.

Practical teaching

Visits to power plant are planned to learn about the major technological power generation systems (steam turbine plant and boiler house) with the main auxiliary technological

systems. Foresees a Three tasks related to the calculation of production costs and prices of unit of electricity, design of technological scheme of the main power plant cycle and the application of economic parameters to optimize the thermal power plant. Test of students knowledge is planned by 3 tests in theoretical fields, examination and evaluation of calculation tasks and report on the visit to power plant.

Prerequisites

Passed exams in Thermodynamics and Fluid mechanics.

Learning resources

Written manuscript and textbooks:
1. Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988. - KCJ
2. Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ
3. Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.-KDA
4. Vasiljevic, N., Savic, B., Sojakovic, M.: Investigation of optimal design and operating conditions of condensing part of steam power plants, Faculty of Mech. Engineering, Belgrade 1991.
5. Schroeder, K: Grosse Dampftkraftwerke, Springer Verlag, Berlin, 1962
6. CEGB: Modern Power Station Practice, Pergamon press, Oxford, 1971

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	8
colloquium, with assessment	3
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	35	project design	20
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 39

References

1. Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988. - KCJ
Li, K. W., Priddy, A. P.: Power Plant System Design, Wiley, 1985.
Kosowski, K. et al.: Steam and Gas Turbines, with examples of Alstom technology, 2nd Edition, Alstom Power, 2007.
Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ
Aus der Wiesche, S., Joos, F.: Handbuch Dampfturbinen, Grundlagen, Konstruktion, Betrieb, Springer Vieweg, 2018

Thermal Power Plants 2

ID: 1547
Responsible/Holder professor SRĐAN B. MILIĆ
Teaching profesor(s): MILIĆ SRĐAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

The aim of the course is to provide a knowledge base in the field of planning, design, contracting, acceptance tests, operation and maintenance of thermal power plants. Exercise program consists of making of a shortened power plant conceptual design based on the implementation of certain acquired practical knowledge of the course program.

Learning outcomes

On completion of this course, it is expected that student will be able to:
• make preliminary design of the thermal power plant with steam and gas turbines,
• analyze and choose the location for the construction of thermal power plants,
• choose the most suitable thermal power technology for a given type of use,
• perform calculation of the working conditions and capacity of individual system and components of the thermal power plants,
• define the concept and disposition projected plants,
• carry out measurements of the most important operating parameters (pressure, temperature and
flow) on the steam turbine plant,
• conduct tests of steam turbine plant to determine the thermal efficiency of the steam turbine plan as well as the efficiency of the steam turbine,
• analyze test data of steam turbine plant and apply the appropriate correction to translate the real working conditions to the design conditions,
• calculate production price of electricity and heat in combined energy production and economic feasibility parameters determine.

Theoretical teaching

The main phases of the design of thermal power plants. Criteria for selection of the type and location of the power plant. The content of the preliminary design to the investment program. The general layout and composition of the thermal power plant. Guidelines for contracting and procurement of equipment of thermal power plants. Acceptance and operational testing of the thermal power plant. Behavior of the thermal power plants in operation: start and stop modes. Maintenance and monitoring of the thermal power plants operating conditions: maintaining the protection and regulation, monitoring of the turbine, the turbine deposition and their removal, the importance of maintaining the quality of the water regime, condensing plants, regenerative heating system of main condensate and feedwater, turbine sealing system, etc. The importance of following of diagnostic operating conditions, cost control and the functional readiness of the power plant. Reliability and

availability of power plant.

Practical teaching

Making of a conceptual design of a power plant: selection of the power plants micro location, general concepts, choice disposition of all power plant parts, analysis of selection schemes and thermal parameters. The main mechanical unit: an analysis of selection schemes and thermal parameters, the choice of boiler, selection of steam turbine plants. Calculation task consists in the development of computer programs for calculating the impact parameter deviations live steam on the cost of the steam turbine plant.

Prerequisites

Course in Steam Turbines.

Learning resources

Written manuscript and textbooks:
1. Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988. - KCJ
2. Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ
3. Stojanović, D.: Thermal turbomachinery, Građevinska knjiga, Beograd, 1973.-KDA
4. Vasiljevic, N., Savic,B>, Sojakovic, M.: Investigation of optimal design and operating conditions of
condensing part of steam power plants, Faculty of Mech. Engineering, Belgrade 1991.
5. Schroeder, K: Grosse Dampftkraftwerke, Springer Verlag, Berlin, 1962
6. CEGB: Modern Power Station Practice, Pergamon press, Oxford, 1971

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	20
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	8
colloquium, with assessment	3
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	35	project design	20

laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 39

References

1. Kostyuk, A. and Frolov V.: Steam and Gas Turbines, Energoatomizdat, Mir Publishers Moscow, 1988. - KCJ
Li, K. W., Priddy, A. P.: Power Plant System Design, Wiley, 1985.
Kosowski, K. et al.: Steam and Gas Turbines, with examples of Alstom technology, 2nd Edition, Alstom Power, 2007.
Rižkin, V.: Thermal power Plants Energoatomizdat, Moskva, 1987.-KSJ
Aus der Wiesche, S., Joos, F.: Handbuch Dampfturbinen, Grundlagen, Konstruktion, Betrieb, Springer Vieweg, 2018

Thermal Turbomachinery

ID: 1499
Responsible/Holder professor SRĐAN B. MILIĆ
Teaching profesor(s): MILIĆ SRĐAN; PETKOVIĆ ĐORĐE
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal power engineering

Goals

1. The achievement of academic competence in the field of steam and gas turbines and thermal power
engineering.
2. The achievement of theoretical knowledge about how to transform heat into mechanical work
learning thermodynamic processes and equipment (steam and gas turbines and thermal power plants).
3. The acquisition of practical knowledge to optimize thermodynamic cycle and steam and gas turbines.
4. The achievement of the techniques of process modeling.
5. Mastering the methods of experimental work in thermal power engineering.

Learning outcomes

1. Academic deep knowledge of the thermodynamic cycle and flows in steam and gas turbines and
turbine plants
2. The development of critical thinking about energy use, fuel efficiency and environmental preservation
3. The ability of calculate heat balance diagrams and main parameters of the steam and gas turbine
power plants.
4. Ability to use computer technology for modeling and calculations

Theoretical teaching

1)Thermodynamic background of the steam turbines and steam turbine power plants. Thermodynamic
improvements of the thermodynamic cycles.
2) Reheat. Regenerative feed water heating. The basic thermodynamic cycle.
3) Steam turbine power plant -the 1st and 2nd law of thermodynamics.
4) Cascades of the steam turbine. Geometry and operating parameters. The main aerodynamic
parameters of the steam turbines cascades.
5) The aerodynamic losses in the cascades.
6) 1D theory of elementary stages of steam turbines. Euler equation for the turbine. Efficiency of the

stage
7) Axial impulse stage. Axial reaction stage. Internal efficiency of the stage. Internal losses degrees.
8) Thermodynamic basis of the gas turbine plant. The basic thermodynamic cycle. The basic and main
thermodynamic parameters of the gas block.
9) The influence of basic parameters on the performance of the gas turbine plant. The choice of optimal
parameters of the gas turbine plant.
10) Balance of energy of the gas turbine plant. Possibilities to improve the thermodynamic gas turbine
plant. More complex configurations of gas turbine plant. Combined gas and steam plant turbine.

Practical teaching

Auditory exercises: basic principles. Historical development. Classification and application of steam turbines.
Explanation of the heat balance diagrams and the functioning of components of the steam turbine plants. Instructions for calculation of the heat balance diagram and the main thermodynamic parameters of the steam turbine plants. Instruction to create an energy balance of the steam turbine plant according to the 1st and the 2nd law of thermodynamics.
Labs: Experimental determination of the specific steam consumption of steam turbines at the Laboratory of Mechanical Engineering.
Project design: Calculation of the heat balance diagram, the main thermodynamic parameters and the
balance of the steam turbine plant.

Prerequisites

Passed exams in Thermodynamics and Fluid mechanics.

Learning resources

Petrovic, M.: Steam turbines, script, 2004.
Petrovic, M.: Gas turbines and compressors, script, 2004.
Petrovic, M.: Instruction for steam turbine project, Belgrade, 2004
Petrovic, M.: Scripts and handouts for Steam turbines
Instructions for performing laboratory exercises
Software package for calculating of properties of steam and water.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	14

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	7

laboratory exercises	4	colloquium, with assessment	2
calculation tasks	0	test, with assessment	0
seminar works	0	final exam	5
project design	12		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	10	project design	30
laboratory exercises	5	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

Petrovic, M.: Steam turbines, script, 2004.;
Stojanovic, D.: Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.;
Vasiljevic, N.: Steam turbines, Faculty of Mechanical Engineering, Belgrade, 1987.;
Petrovic, M: Gas turbine and turbocompressors, script, 2004.;
Boyce, M.: Gas turbine engineering handbook, GPB, Boston 2002.;

Turbocompressors

ID: 0336
Responsible/Holder professor MILAN V. PETROVIĆ
Teaching profesor(s): PETROVIĆ MILAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

1. The achievement of academic competence in the field of compressors and thermal power plant engineering.
2. Mastery of theoretical knowledge about how to transform mechanical work into internal energy of fluid by learning of thermodynamic processes and equipment.
3. The acquisition of practical skills for design and optimization of turbocompressors.
4. Mastering the techniques of process modeling.

Learning outcomes

On completion of this programme, it is expected that student will be able to:
• perform design of a multistage axial compressor writing own program code,
• select dimensionless parameters of compressor stages,
• apply one-dimensional theory of the compressor stage, determine the main dimensions of the stage, calculate efficiency and the stage operating parameters,
• apply the appropriate solutions of 3D flow and define 3D blade geometry of the compressor stage
• select the type of aero profile, calculate the aerodynamic losses and deviation
• define the meridian flow path of the entire machine
• apply different control modes for the turbocompressor
• analyse compressor behavior at off-design operating parameters.

Theoretical teaching

1. Thermodynamic background of turbocompressors. Isothermal, isentropic, polytropic and real process. Isentropic efficiency and polytropic efficiency.
2. The aerodynamic background of turbocompressors.
3.Cascades of turbocompressors. Geometric and operating parameters of the cascades.
4.Main aerodynamic cascade parameters. Aerodynamic losses in compressor stages.
5.Theory of the cascade aerodynamic coefficients.
6.Mean-line theory of compressor stages. Energy balance, Euler equation.
7.Design factors of turbocompressors. Dimensionless velocity triangles. Dependence of the compression ratio from the operating parameters.
8.Dependence of efficiency of the normal stages of axial compressor from the cascade aerodynamic coefficients and from the stage operating parameters.
9. 3D flow in axial compressors stages. Optimal design factors. Determination of main dimensions of axial compressors.
10. The behavior of the compressors at variable loads. Regulation of turbocompressors.

Practical teaching

Practical training is carried out through:
Auditory exercises:
Introduction. Energy conversion in the compressors. The types of compressors. Application areas.
Instructions for project 1: Calculation of main dimensions of axial compressors.
Instructions for project 2: Design of the compressors cascades.
Project development:
Calculation of main dimensions of axial compressors.
Calculation of compressors cascades.
Labs:
Learning the principles of operatin and desing of compressors in Laboratory of steam and gas turbines.

Prerequisites

Passed exams in Thermodynamics and Fluid mechanics

Learning resources

Petrovic, M.: Gas turbines and compressors, script, 2004.
Petrovic, M.: Gas turbines and compressors, introduction for exercises, 2004.
Petrovic, M. scripts and handouts for Gas turbines
Instructions for performing laboratory exercises
Software package for calculating of properties of air and combustion products

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	9
laboratory exercises	4
calculation tasks	0
seminar works	0
project design	17
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	1
check and assessment of seminar works	0
check and assessment of projects	7
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	10	project design	30
laboratory exercises	5	final exam	50

calculation tasks	0

Requirements to take the exam (number of points) 25

References

Petrovic, M.: Gas turbines and compressors, script, 2004.
Stojanovic, Thermal Turbomachinery, Gradjevinska knjiga, Belgrade, 1967.
Cohen, H., Rogers,G.F.C., Saravanamuttoo, H.I.H.: Gas turbine theory, Logman, 1997.
Traupel,W.: Thermische Turbomaschinen, Springer verlag, Berlin, 1982
Boyce, M.: Gas turbine engineering hadbook, GPB, Boston 2002.

Two-Phase Flows with Phase Transition

ID: 0325
Responsible/Holder professor VLADIMIR D. STEVANOVIĆ
Teaching profesor(s): STEVANOVIĆ VLADIMIR; MILIVOJEVIĆ SANJA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal power engineering

Goals

The aim is acquiring academic knowledge about two-phase flow patterns, mechanisms of transport processes in two-phase flows, intensity of evaporation and condensation and methods for two-phase flows simulation and analyses within design, safety analyses and prescription of operating conditions and parameters of energy plants.

Learning outcomes

The students are trained to perform computer simulation and analyses of gas-liquid two-phase flows within design of energy plants, safety analyses, operating conditions diagnostics, defining of operating conditions, etc.

Theoretical teaching

Two-phase flow patterns and related maps. Two-phase flow modeling by multi-fluid models and corresponding closure laws for interface transport processes. Mechanisms of pressure change in two-phase flow and prediction methods. The effect of flooding in counter-current gas-liquid flow. Pool boiling and convective boiling. The critical heat flux and prediction methods. Condensation of pure vapour and condensation in the presence of noncondensables. Sonic waves propagation in two-phase flow. The chocked two-phase flow. Numerical methods for the solving of two-phase flow models. Computation of two-phase flows in components of energy and process plants.

Practical teaching

Prediction of two-phase flow parameters: static, flow and thermodynamic quality, void fraction, two-phase flow density, superficial velocity, slip factor, drift velocity, etc. Empirical correlations for the prediction of void fraction, slip factor and drift velocity. The influence of the pressure level on the two-phase flow parameters. Prediction of pressure change in two-phase flow. Development of multi-fluid models of two-phase flow: balance equations, closure laws and solving methods. Application of the multi-fluid two-phase flow model to energy and process equipment, such as: evaporating channel, condensation in a pipe, heat exchangers with phase transitions, evaporators, steam boilers with boiling around tubes in a bundle, evaporating tubes in steam boiler furnace, condensers, pressurizers, feedwater tanks, steam boiler drum, steam accumulator, pipelines, etc.

Prerequisites

Passed exams in Thermodynamics, Fluid Mechanics and Numerical Methods.

Learning resources

Course handouts.
Computer equipment.
Computer codes for thermal-hydraulic simulations of two-phase flows and pressure transients in pipelines, pressurized vessels, heat exchangers with boiling or condensation in tube bundles.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	15
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	5
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	5	seminar works	0
test/colloquium	35	project design	0
laboratory exercises	30	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Whalley, P.B., Two-Phase Flow and Heat Transfer, Oxford University Press, Oxford, 1996.
Wallis, G.B., One-Dimensional Two-Phase Flow, McGraw-Hill, New York, 1969.
Clift, R., Grace, J.R., Weber, M.E., Bubbles, Drops and Particles, Academic Press, New York, 1978.
Delhaye, J.M., Giot, M., Rietmuller, M.L., Thermalhydraulics of Two-Phase Systems for Industrial Design and Nuclear Engineering, McGraw-Hill, 1981.
Stevanovic, V., Thermal-Hydraulics of Steam Generators – Modelling and Numerical Simulation, University of Belgrade, Faculty of Mechanical Engineering, 2006.

THERMAL SCIENCE ENGINEERING

Air Conditioning Systems

Air-conditioning Fundamentals

Building energy certification

Central Heating Systems

Energy Efficiency in Buildings M

Heat Pumps

Industrial cooling facilities

Pipelines

Power steam boiler 1

Power steam boilers 2

Refrigeration Equipment

Refrigeration in Food Technologies

Refrigeration Systems

Skill Praxis M - TTA

Steam Boiler processing

Steam Boilers elements and equipments

Thermal Power Plants and Heat Plants

Air Conditioning Systems

ID: 1258
Responsible/Holder professor MAJA N. TODOROVIĆ
Teaching profesor(s): TODOROVIĆ MAJA; SRETENOVIĆ-DOBRIĆ ALEKSANDRA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Getting knowledge and skills in air conditioning - various central air conditioning systems; mastering methods for calculating air ducts, choosing elements for intake and extract of air, and using those methods in air conditioning project design.

Learning outcomes

Upon successful completion of the course, students should be able to:
• Select the appropriate elements for supply air inlet in the air-conditioned room in order to achieve optimal air distribution in space
• Apply of different methods for the calculation of pressure drop in air ducts
• Explain the basic features central air conditioning systems (all air and air to water systems)
• Apply measures to increase energy efficiency of the air conditioning systems
• Estimate of the advantages and disadvantages of different systems for ventilation and air conditioning
• Apply their knowledge to solving practical problems in air conditioning development, design and installation
• Be efficient in team work

Theoretical teaching

Air distributing elements; duct calculation methods; air distribution; airflow range; air inlet and extract position; air conditioning systems - classification; central single-duct low pressure system with constant air volume, zone air conditioning systems; high pressure air conditioning systems: with constant and variable airflow rate; air to water air conditioning systems; induction unit; two pipes systems change over and no change over; three-pipe and four-pipe systems; hydronic systems with fan coil units; combination with ventilating systems, local air conditioning systems; compact and split systems; energy efficiency of ventilation and air conditioning systems.

Practical teaching

Auditory is composed of more sections, in order to complete project design. Design and regulating air conditioning systems, calculating energy consumption and using waste heat. Laboratory consists of measuring airflow in ducts and distributive elements, regulating air conditioning systems, measuring airflow range and intermediate operating mode. Visit to Thermal science exhibition in HVAC congress or to factory for air conditioning equipment is planned.

Prerequisites

In order to attend subject it is required to pass the exam: Air Conditioning Fundamentals.

Learning resources

M. Todorovic, A. Sretenovic: Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

ASHRAE Handbook of Fundamentals, Atlanta, Georgia, 2009
Recknagel, Sprenger, Schramek, Čeperković: Heating and Air Conditioning, Interklima, Vrnjačka Banja, 2012
B. Todorovic, Air conditioning; SMEITS, Belgrade, 2009.

Air-conditioning Fundamentals

ID: 1257
Responsible/Holder professor MAJA N. TODOROVIĆ
Teaching profesor(s): TODOROVIĆ MAJA; SRETENOVIĆ-DOBRIĆ ALEKSANDRA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Getting knowledge in Air Conditioning - thermal comfort, heat gain and cooling load, air handling unit and its elements, mastering methods for calculating cooling loads for non-stationary conditions of heat transfer and using those methods in air conditioning project design.

Learning outcomes

Upon successful completion of the course, students should be able to:
• Understand influence of indoor thermal conditions on human thermal comfort
• Identified the process of unsteady heat transfer through the building envelope and inside air conditioned space
• Perform cooling load calculation for air conditioned buildings
• Select the appropriate amount of air for airconditioning system
• Carry out the selection of air handling unit elements heaters, coolers, humidifiers)
• Compare the characteristics of different systems for air filtration

Theoretical teaching

Defining air conditioning; thermal ambiance conditions; thermal comfort in closed spaces; thermal regulation; meteorology and climate; Solar constant; atmosphere clearance; radiation on horizontal and vertical surfaces; outside and inside heat sources; heat transfer through single-layer and multiple-layer walls in non-stationary conditions of heat transfer; heat gains from solar radiation through window; heat storage factors; protection from solar radiation; shading effect on cooling load; heat gains from internal sources; calculation air flow rate for air conditioning; air treatment in air handling unit; air handling unit and its elements; heating and cooling coil; heat output control of heating and cooling coil; spraying chamber; evaporator; filtration; filter efficiency.

Practical teaching

Auditory part consists of more sections: basic and complex processes in
Molier h-x diagram, calculating cooling load from inside and outside heat sources, calculating airflow rate for air conditioning, defining air parameters in summer and winter operating mode, in order to independently complete project assignment. Laboratory exercise is demonstrative - air handling unit and its elements, air conditioning accessoris. Visit to Technical fair or factory for air conditioning equipment is planned.

Prerequisites

In order to attend this subject, it is needed to pass exams: Thermodynamic M and Fluid mechanics M.

Learning resources

M. Todorovic, A. Sretenovic: Handouts

B.Todorovic: Air conditioning, SMEITS, Belgrade, 2009.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

ASHRAE Handbook of Fundamentals, Atlanta, Georgia, 2009
Recknagel, Sprenger, Schramek, Čeperković: Heating and Air-conditioning, Interklima, Vrnjačka Banja, 2002

Building energy certification

ID: 1254
Responsible/Holder professor TAMARA S. BAJC
Teaching profesor(s): TODOROVIĆ MAJA; BAJC TAMARA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

Acquiring knowledge and skills in the field of energy certification of buildings - the concept of energy building certificate, building energy consumption, energy needs and significant parameters; comfort conditions and design parameters, central heating and air conditioning systems, energy sources, final and primary energy, domestic hot water systems; optimization of HVAC systems and the application of passive techniques, methodology of calculation of indicators, classification of buildings by type and energy codes; elaboration of energy efficiency, energy certificate.

Learning outcomes

Students acquire specific skills and knowledge in the field of energy certification of buildings; known methods for the calculation of indicators to determine the energy code of the building and can be applied in practice. Connects the basic knowledge and applies them to the elaboration of energy efficiency of the building.

Theoretical teaching

The concept of energy building certificate, Energy Performance of Buildings Directive – main objectives; Legislative in the Republic of Serbia; building energy consumption, energy needs and significant parameters; comfort conditions and design parameters, central heating and air conditioning systems, energy sources, final and primary energy, domestic hot water systems; optimization of HVAC systems and the application of passive techniques, application of renewable energy sources, methodology of calculation of indicators, classification of buildings by type and energy codes; measures for energy efficiency improvement; energy audit, elaborate of building energy efficiency, building energy certificate.

Practical teaching

Practical skills consist of parts: Example of calculation of thermal properties of the building envelope elements - calculation of the coefficient of thermal conductivity, specific transmission and ventilation losses, building shape factor, determination of design conditions and technical systems' schedules of use, determining energy needs and indicators that define the energy code; application measures to improve energy efficiency of buildings - individual measures and measure sets improvement, financial analysis. Individual Project task – Building energy efficiency elaborate on the example of residential building.

Prerequisites

Without conditions.

Learning resources

1. Todorović M., Energy certification of buildings – handouts, 2022.
2. ***, Rulebook on energy efficiency of buildings, Official Gazette of Republic of Serbia No. 61/2011
3. ***, Rulebook on conditions, content and manner of issuing energy performance certificate of buildings, Official Gazette of Republic of Serbia No. 69/2012

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Todorović M., Ristanović M., Efficiant energy usage in buildings, University of Belgrade, Belgrade, Serbia, 2015.
Todorović M., Energy certification of buildings – handouts, 2022.
***, Rulebook on energy efficiency of buildings, Official Gazette of Republic of Serbia No. 61/2011
***, Rulebook on conditions, content and manner of issuing energy performance certificate of buildings, Official Gazette of Republic of Serbia No. 69/2012

Central Heating Systems

ID: 1256
Responsible/Holder professor ALEKSANDRA A. SRETENOVIĆ
Teaching profesor(s): SRETENOVIĆ-DOBRIĆ ALEKSANDRA; BAJC TAMARA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

Acquiring knowledge and skills in the field of central heating - hot water two-pipe systems with natural and forced circulation of hot water, hot water one-pipe systems, steam heating system of low pressure, air heating, panel heating, district heating, solar systems, mastering the methods for calculation of pipe network.

Learning outcomes

Students acquire specific skills and knowledge of central heating systems: knowledge of different heating systems, known methods of calculation of central heating systems and can apply them in practice. Connects basic knowledge and apply it to solve concrete problems in the technique of heating.

Theoretical teaching

Two-pipe hot water central heating pump systems, pipe heating system; correction of surface heaters, heating steam low pressure, upper and lower divorce; Steam traps, condensate return to boiler; calculation of pipe networks, heat transfer by radiation; panel heating systems, heat transfer from the budget tube, through multi-layered plate, the surrounding air, underfloor heating, air heating, ventilation chamber and its components, industrial ventilation, remote distribution of heat; characteristics of district heating, heat transport distance; substation for direct and indirect connection; heating sliding diagrams, renewable energy sources, active and passive use of solar energy and geothermal energy.

Practical teaching

Auditory exercises consist of parts: pipe sizing for two-pipe hot-water network system with natural and forced circulation of water in the system and facilities 90/70oC to prepare and distribute hot water, and to individual work of reference. Lab exercise - testing thermal properties of heaters; temperature impact on the heat output of radiators; influence of the flow rate to heat output of radiators; behavior of heaters in non-stationary conditions (visit the exhibition of thermal engineering in the Congress of HVAC or visit the factory).

Prerequisites

In order for a student attending the subject must have passed the exams in the subject: Thermodynamics B and Heating technique Fundamentals

Learning resources

Handouts - M. Todorović, A. Sretenović

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

B. Todorović - Central Heating Systems Design - Faculty of Mechanical engineering, Belgrade, 2009.

Energy Efficiency in Buildings M

ID: 1259
Responsible/Holder professor ALEKSANDRA A. SRETENOVIĆ
Teaching profesor(s): SRETENOVIĆ-DOBRIĆ ALEKSANDRA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

• gathering knowledge and skills required for energy efficient building design;
• understanding of basic principles and calculation methods for energy efficient building design;
• presentation of the concept and advantages of energy efficient buildings, zero and near zero energy buildings (ZEB, nZEB);
• general overview of the methodologies that are used for estimation of building energy use and energy efficiency;
• analysis of different scenarios and measures for improving energy efficiency of buildings and lowering energy consumption, while maintaining comfort;

Learning outcomes

After successfully finished course, student should be capable to:
• apply methodology for calculating energy use for heating and cooling of buildings and CO2 emissions;
• define all parameters necessary for estimating energy efficiency of buildings;
• understand importance and advantages of increasing energy efficiency in buildings;
• understand and apply methodology for estimating energy performance of buildings, suggest different scenarios for improvements and measures for energy savings;
• have and use knowledge on existing methodologies and software for building and HVAC system design and measures for energy savings;
• apply strategies for energy savings;

Theoretical teaching

Energy sources and energy use in world and in Serbia, parameters that define HVAC energy use (climate, architecture, HVAC systems, consumers), automatic control of HVAC systems in buildings, national building typology, methods for calculating HVAC energy use, artificial intelligence methods, renewable energy sources, legislation in Europe and Serbia, energy use classification, building reconstruction, CO2 and greenhouse gases emission

Practical teaching

Methodology for calculating degree-days, calculation of thermal bridges, thermovision and thermographic building inspection, characteristics of passive houses and zero energy buildings, examples of HVAC energy use calculations using various methodologies, examples of using renewable energy sources in buildings

Prerequisites

Passed course Thermodynamic M

Learning resources

Handouts given to students prior to lectures

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	5
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	30
test/colloquium	20	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

Nilsson, P.E. "Achiving the Desired Indoor Climate - Energy Efficiency Aspects of System Design", The Commtech Group, Narayana Press, Denmark, ISNB 91-44-03235-8, 2003
bel, E., Elmroth, A. "Buildings and Energy - a systematic approach", Alfaprint, Formas, ISNB 978-91-540-5997-3, 2007
Hodgson, P.E. "Energy, the Environment and Climate Change", University of Oxford, UK Published by Imperial College Press, 2010
Kreith, F., Goswami, D.Y. "Handbook of Energy Efficiency and Renewable Energy", Published by CRC Press, Taylor&Francis Group, 2007
Eicker, U.: "Low Energy Cooling for Sustainable Buildings", Stuttgart University of Applied Sciences, Germany, John Wiley & Sons Ltd, 2009

Heat Pumps

ID: 1120
Responsible/Holder professor UROŠ M. MILOVANČEVIĆ
Teaching profesor(s): MILOVANČEVIĆ UROŠ; OTOVIĆ MILENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

Learning outcomes

Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

Theoretical teaching

Characteristics of heat pumps: Systematization of thermal systems performing refrigeration cycles, The criteria for evaluation of thermodynamic quality of refrigeration cycles, Heat sources for heat pumps, (atmospheric air, surface water, groundwater and soil, geothermal energy, heat accumulators, solar plate collectors), Thermodynamic improvement of refrigeration cycles; Sorption refrigeration systems; Properties of refrigerant-absorbent mixtures: Basic steady-flow processes with binary mixtures; Basic vapour absorption refrigeration system, (VARS), Steady-flow analysis of the VARS, Maximum COP of ideal absorption refrigeration system, Comparison between compression and absorption refrigeration systems.

Practical teaching

Auditory training: systematization of thermal systems performing refrigeration cycles, predicting of heat pumps performaнces, mass and heat balance of drying processing, determination of characteristics of the heat pump elements, (compressor, condenser,evaporator), binary mixtures, the basic operations with binary mixtures, thermodynamic calculation of single effect VARS
Laboratory exercise: demonstration of heat pumps for air conditioning system of a hotel building;

Design project of heat pump system: work in groups of 5 students (for a particular object and refrigerant), calculation and selection of elements of heat pump,
Analysis of complete vapour compression heat pump plant.

Prerequisites

Necessary passed the test: Refrigeration Equipment, Refrigeration Systems

Learning resources

Handouts which are available in advance for each week of classes

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 26

References

M. Markoski: Refrigeration, Mechanical Engineering, 2006
Handouts, 2023

Industrial cooling facilities

ID: 1545
Responsible/Holder professor MILENA M. OTOVIĆ
Teaching profesor(s): OTOVIĆ MILENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

Achieving competencies and academic skills as well as methods for their acquisition. Development of creative abilities and mastery of practical skills specific to performing the profession. The goals are concrete and achievable and fully in line with the established basic tasks and goals of the study program.

Learning outcomes

Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

Theoretical teaching

Cooling needs of industrial and other facilities; Natural and artificial refrigeration; Application of refrigeration and heat pumps; Methods of producing low temperatures; Air cycle refrigeration systems; Ideal reverse Brayton cycle; Vapour compression refrigeration systems; The Carnot vapour compression refrigeration cycle; Improvements of vapour compression cycle (subcooling, multistage throttling, multistage compression with intercooling); Standard vapour compression refrigeration facilities; Multi-evaporator system with individual compressor; Cascade systems; The specific refrigeration effects; Primary and secondary refrigerants, Refrigerant selection criteria, Designation of refrigerants; Refrigeration compressors (systematization, application); Reciprocating refrigeration compressors (basic elements, basic parameters of operation), Operating characteristics (performance) of reciprocating refrigeration compressors, Processes in an ideal and actual compressor, Volumetric efficiency, Actual compression process, Capacity control of reciprocating compressors; Rotary refrigeration compressors, twin screw compressors; Auxiliary equipment in refrigeration: automation, thermostatic expansion valve, oil separators, etc.

Practical teaching

Auditory training: thermal insulation, selection of insulation materials, the diffusion of water vapor through thermal insulation layer, vapour barrier, calculation of refrigeration load, characteristic examples of refrigeration cycle. Design project of refrigeration system, for a particular object and refrigerant (work in groups of 5 students): calculation and selection of insulating structures, determination of refrigeration load, thermodynamic calculation of refrigeration cycle, equipment selection, etc.

Laboratory exercise: demonstration of refrigeration installation in an industrial facility.

Prerequisites

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Learning resources

Handouts, 2024 (available in advance for each week of classes)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 26

References

M. Markoski: Refrigeration, Mechanical Engineering, 2006
Handouts, 2024 (available in advance for each week of classes)

Pipelines

ID: 1498
Responsible/Holder professor MILENA M. OTOVIĆ
Teaching profesor(s): OTOVIĆ MILENA; MILOVANČEVIĆ UROŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Achieving competencies and academic skills as well as methods for their acquisition. Development of creative abilities and mastery of practical skills specific to performing the profession. The goals are concrete and achievable and fully in line with the established basic tasks and goals of the study program.

Learning outcomes

The student acquires subject-specific abilities that are the function of quality performance of professional activities: analysis, synthesis and prediction of solutions and consequences, thorough knowledge and understanding of the profession, connecting the basic knowledge from different fields and their application to solving specific problems, monitoring and applying novelties in profession, development of skills and dexterity in the use of knowledge.

Theoretical teaching

Basic terms; corrosion and corrosion protection; material behavior at elevated and low temperatures; flange joints; pipeline fittings and valves; compensation of pipeline thermal expansions; analysis of thermal stresses in pipelines; pipeline layout; pipeline supports.

Practical teaching

Auditory exercises: demonstration exercises (description and examples of the construction of pipeline elements, standardization and typification in the area of pipelines, production of pipes, construction of pipeline supports, examples of application of pipeline fittings and valves); design calculation tasks (analysis and calculation of forces of flange joints, calculation of thermal expansions and thermal stresses of pipelines).

Prerequisites

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Learning resources

Handouts - available in advance for each week of classes

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING		OTHER	
active teaching (theoretical)	30	knowledge checks	15

lectures	20	assessment of calculation tasks	5
elaboration and examples (revision)	10	check and assessment of lab reports	0
active teaching (practical)	**30**	check and assessment of seminar works	0
auditory exercises	20	check and assessment of projects	0
laboratory exercises	0	colloquium, with assessment	5
calculation tasks	10	test, with assessment	0
seminar works	0	final exam	5
project design	0		
discussion and workshop	0		
research	**0**		

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	0
laboratory exercises	0	final exam	50
calculation tasks	20		

Requirements to take the exam (number of points) 26

References

Book: M. Markoski: Pipelines (Faculty of Mechanical Engineering, 2006)
Handouts - available in advance for each week of classes, 2023.

Power steam boiler 1

ID: 1116
Responsible/Holder professor GORAN M. STUPAR
Teaching profesor(s): STUPAR GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

Learning outcomes

After successfully completing the course, the students will be able to:
• Calculate the material balance of the combustion process and the enthalpies of combustion products for solid fuels.
• Choose the excess air and apply flue gases recirculation.
• Get to know more about the structure of the irradiated and convective evaporator.
• Acquainted with the main superheater types and temperature control systems of a superheated vapor.
• Acquainted with the basic types of water heaters and air heaters.
• Calculate the heat balance of the steam boiler and its heat surfaces.

Theoretical teaching

Worikng principle of a steam boiler and definitions of basic concepts; Fuels for steam boilers; Combustion material balance; Excess air; Flue gases enthalpy; Steam boiler heat balance, losses and efficiency; Steam boiler furnace; Steam boiler evaporators with natural and forced circulation loop; Half-radiation and convection evaporators; Radiation, half-radiation and convection superheaters; Reheaters; Different types of water heaters; Recuperative air heaters and regenerative air heaters.

Practical teaching

Auditory exercises consist from demonstration exercises(classification of boilers; steam boiler construction; main and auxiliary devices and equipment); Working project - coal combustion material balance (coal calorific value, theoretical air volume for combustion , theoretical flue gas volume,
flue gases enthalpy diagram as a function of temperature and excess air); worikng principle of a industrial steam boiler; wetermining the losses, efficiency and fuel consumption of the given steam boiler; furnace dimensioning; heat and material balance of steam boiler heating surfaces.

Prerequisites

Necessary condition: Bachelor's degree.

Learning resources

Handouts which will be at student's disposal a week in advance.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	10
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian)

Power steam boilers 2

ID: 1119
Responsible/Holder professor GORAN M. STUPAR
Teaching profesor(s): STUPAR GORAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

Learning outcomes

After successfully completing the course, the students will be able to:
• Perform a thermal calculation of the boiler heat surfaces.
• Select the fuel bed combustion systems.
• Choose the device for pulverized coal preparation.
• Perform the air and flue gases aerodynamic calculations of the power plant steam boiler.
• Acquainted with hydrodynamic principles of evaporator with natural and forced convection, water heater and superheater.

Theoretical teaching

Thermal calculation of the steam boiler heating surfaces; Devices for fuel bed combustion - flat grate stoker, chain grate stoker, inclined grate stokers; Coal dust preparation systems; Mill processes; Heat and material balance of coal drying process in mills; Mill constructions; Coal dust separators; Mill gas classifiers; Coal dust burners; Aerodynamic of the air and flue gas tract (balanced draft boiler, forced draft boiler and natural draft boiler, choice of fan and it's regulation); Hydrodynamics of steam boiler (hydrodynamics of water heater, evaporator and superheater).

Practical teaching

Auditory exercises consist from demonstration exercises (Classification and construction of steam boilers with appropriate heating surfaces, auxiliary devices and equipment); Working project - Thermal calculation of industrial steam boiler; Thermal calculation and dimensioning of heating surfaces (furnace, convection evaporator, convection superheaters, water heater and air heater); After dimensioning steam boiler heating surfaces, it's necessary to make steam boiler drawing in three sections.

Prerequisites

Necessary condition: Bachelor's degree and passed Power steam boilers 1.

Learning resources

Handouts which will be at student's disposal a week in advance.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	10
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010, (In Serbian)

Refrigeration Equipment

ID: 1114
Responsible/Holder professor UROŠ M. MILOVANČEVIĆ
Teaching profesor(s): MILOVANČEVIĆ UROŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

Learning outcomes

Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

Theoretical teaching

Refrigeration compressors (systematization, application); Reciprocating refrigeration compressors: basic elements, basic parameters of operation, operating characteristics (performance) of reciprocating refrigeration compressors, processes in an Ideal and actual compressor, volumetric efficiency, Actual compression process, Capacity control of reciprocating compressors); Rotary refrigeration compressors, twin screw compressors; Auxiliary equipment and refrigeration pipelines, Condensers: classification of condensers, analysis of condensers; Evaporators: classification, direct expansion fin-and-tube type evaporators, flooded evaporators, evaporator defrosting; Expansion devices: thermostatic expansion valve.

Practical teaching

Auditory training: A survey of the application area of certain types of compressors; Volumetric efficiency calculation; The compressor displacement calculation; Capacity control of reciprocating compressors; Design of rotary screw compressors; Compressor performance curves; Calculation of refrigeration load of condensers, Calculation of piping, insulation, safety valves and elements of automation.
Laboratory exercise: demonstration of cooling installation in an industrial plant; Design project of refrigeration system: work in groups of 5 students

(for a particular object and refrigerant), calculation and selection of elements refrigeration plants.

Prerequisites

Required exams passed: thermodynamics, the basics of refrigeration

Learning resources

Handouts which are available in advance for each week of classes

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 26

References

M. Markoski: Refrigeration, Mechanical Engineering, 2006
Handouts, 2023

Refrigeration in Food Technologies

ID: 1544
Responsible/Holder professor MILENA M. OTOVIĆ
Teaching profesor(s): OTOVIĆ MILENA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

Learning outcomes

Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

Theoretical teaching

Natural and artificial refrigeration, Application of refrigeration, Vapour compression refrigeration systems, The Carnot vapour compression refrigeration cycle, Improvement of vapour compression cycle, (subcooling, multistage throttling, multistage compression with intercooling), Standard vapour compression refrigeration plants, Refrigerants, refrigerant selection criteria; Designation of refrigerants; Reciprocating refrigeration compressors: Basic elements, basic parameters of operation, operating characteristics (performance) of reciprocating refrigeration compressors; Condensers: classification of condensers; Evaporators: classification, evaporator defrosting; Cooling and quick freezing of food products.

Practical teaching

Auditory training: Moist air, thermodynamic properties of moist air, Mollier's "h-x" diagram, Important psychrometric processes, thermal insulation, selection of insulation materials, the diffusion of water vapor through thermal insulation layer, vapour barrier, calculation of refrigeration load, thermodynamic analyses of refrigeration cycle, Basic calculation for sizing of compressors, condensers and evaporators, process systems for quick freezing and storage of food products;
Laboratory Exercise: Demonstration of refrigeration devices in industrial plants; Design project of refrigeration system: work in groups of 5 students (for a particular object and refrigerant), calculation of a refrigeration plant.

Prerequisites

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Learning resources

Handouts which are available in advance for each week of classes

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	15
laboratory exercises	3
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	2
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	24	project design	26
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 21

References

M. Markoski: Refrigeration, Mechanical Engineering, 2006
Handouts, 2024

Refrigeration Systems

ID: 1117
Responsible/Holder professor UROŠ M. MILOVANČEVIĆ
Teaching profesor(s): MILOVANČEVIĆ UROŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermal science engineering

Goals

Achieving of competence and academic skills as well as methods for their acquisition. The development of creative abilities and practical skills which are essential to the profession. Objectives are concrete and achievable and in full accordance with the defined basic tasks and objectives of the study program.

Learning outcomes

Student acquires subject-specific abilities that are essential for the quality of professional activities: analysis, synthesis and prediction of solutions and consequences; application of knowledge in practice; linking the basic knowledge in various fields with their application to solve specific problems.

Theoretical teaching

Thermodynamic basis: Moist air, thermodynamic properties of moist air, Mollier's "h-x" diagram, Important psychometric processes, Dalton's and Lewis's Law of evaporation, Wet bulb temperature of moist air, Evaporation heat transfer calculation, Merkel's coefficient; Heat exchangers: NTU method, Heat exchanger characteristics; Characteristics of compressors; Condensers: Sizing of air-cooled, water-cooled and evaporative condensers; Evaporators: the process of refrigerant boiling, the processes on the cooled fluid side, Sizing of air cooling evaporators, Characteristics of evaporators; Analysis of complete vapour compression refrigeration systems.

Practical teaching

Auditory training: Psychometric processes, Evaporation heat transfer; prediction of the compressor characteristic, sizing of condensers (air-cooled, water-cooled and evaporative), sizing of evaporators, evaporator characteristic calculation; Analysis of complete vapour compression refrigeration systems;
Laboratory exercise: demonstration of the installation in an industrial refrigeration plant;
Design project of refrigeration system: work in groups of 5 students (for a particular object and refrigerant), calculation and selection of elements of refrigeration plants, PI diagram of refrigeration plant.

Prerequisites

Required exams passed: Refrigeration Equipment

Learning resources

Handouts which are available in advance for each week of classes

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	5
calculation tasks	0
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	20
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 26

References

M. Markoski: Refrigeration, Mechanical Engineering, 2006
Handouts, 2023

Skill Praxis M - TTA

ID: 1255
Responsible/Holder professor TAMARA S. BAJC
Teaching profesor(s): BAJC TAMARA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: thermal science engineering

Goals

Practical experience and student learning in the environment in which the student will realize his professional career.
Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineer in such a business system.

Learning outcomes

Students get practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, in the context of his future professional competence. Students are establishing the personal contacts and acquaintances that will be able to use during studies or entering into future employment.

Theoretical teaching

There are not theoretical classes.

Practical teaching

Practical work involves work in organizations that perform various activities in scope of mechanical engineering. Selection of thematic areas, commercial or research organizations is carried out in consultation with the concerned teacher. In general, a student can perform the professional practice in manufacturing organizations, design and consulting organizations, organizations engaged in mechanical equipment maintenance, and public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice also can be done abroad. During practice, students must keep a daybook in which enters a description of the performed tasks, the conclusions and observations. After the practice in company is finished, a report must be delivered and defended in front of the subject teacher. The report is submitted in the form of the daybook.

Prerequisites

Without conditions.

Learning resources

Literature recommended by professor and documents obtained by the expert from the organization where the practice is done.

* Bajc T., Mechanical engineering in practice - TTA, e-publication, University of Belgrade Faculty of Mechanical engineering, Belgrade, Serbia, 2023.

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	40
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	50

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	50
test/colloquium	0	project design	0
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 50

References

Bajc T., Mechanical engineering in practice - TTA, e-publication, University of Belgrade Faculty of Mechanical engineering, Belgrade, Serbia, 2023.

Steam Boiler processing

ID: 1053
Responsible/Holder professor DRAGAN R. TUCAKOVIĆ
Teaching profesor(s): TUCAKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

Learning outcomes

After successfully completing the course, the students will be able to:
• Perform the thermal boiler calculation.
• Calculate the heat balance of the mill drying process and chose the type and size of the mill.
• Perform the air and flue gases aerodynamic calculations of the steam boiler and choose an appropriate fan.
• Perform the strength calculation of basic elements of a steam boiler.
• Acquire the process of corrosion and wear of heating surfaces, as well as their protection.

Theoretical teaching

Thermal calculation of the steam boiler heating surfaces - calculation of furnace, calculation of half-radiation and convection heating surfaces; Mill processes (coal dust characteristics, heat and material balance of mill drying process, mill control diagram);
Aerodynamic of the air and flue gas tract (balanced draft boiler, forced draft boiler and natural draft boiler); Hydrodynamics of steam boiler (hydrodynamics of water heater, evaporator and superheater); Steam boiler strength calculation; Corrosion, wear, defilement and cleaning of steam boiler elements.

Practical teaching

Auditory exercises consist of demonstration exercises (Classification and construction of steam boilers with appropriate heating surfaces, auxiliary devices and equipment);
Guidelines for preparation of the project - Based on information (obtained and calculated) in the project from subject Steam boiler elements and equipment, it is necessary to develop thermal calculations for given industrial steam boiler. In this project it is necessary to perform thermal calculation and dimensioning of the following heating surface - furnace (radiation evaporator), convective evaporator, steam superheaters, water and air heaters. After dimensioning the steam boiler heating surfaces, it's necessary to make the steam boiler drawing in three sections.

Prerequisites

Necessary condition: Bachelor's degree;
Preferred passed exam: Steam boilers elements and equipments

Learning resources

handouts which will be at student's disposal a week in advance

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	14
discussion and workshop	10
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)

Steam Boilers elements and equipments

ID: 1052
Responsible/Holder professor DRAGAN R. TUCAKOVIĆ
Teaching profesor(s): TUCAKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

Learning outcomes

After successfully completing the course, the students will be able to:
• Calculate the material balance of the combustion process of solid fuels.
• Choose the excess air and calculate the enthalpies of combustion products.
• Choose the system of temperature control of a superheated vapor.
• Select the fuel bed combustion systems.
• Perform the preliminary thermal boiler calculation.
• Get to know more about the plant by visiting the thermal power plant.

Theoretical teaching

Introduction; Solid fuels; Combustion material balance; Determination of excess air; Regulating the temperature of superheated steam - (Inherent regulation; Flue gas regulation; Steam regulation); Regulating the temperature of reheated steam; Apparatus for combustion of the opposite scheme - flat grate stoker; Apparatus for combustion of the cross scheme - chain and inclined grate stoker; Coal dust preparation systems; Devices for storage and transportation of coal; Mill constructions; Coal dust separators; Coal dust classifiers; Coal dust burners

Practical teaching

Auditory exercises consist of demonstration exercises (Classification and construction of steam boilers with appropriate heating surfaces, auxiliary devices and equipment); Steam boiler heat balance; Working project - Worikng principle of industrial steam boilers; Determining the losses, efficiency and fuel consumption of the given steam boiler; Furnace dimensioning; Heat and material balance of steam boiler heating surfaces; Making of the boiler draft.

Prerequisites

Necessary condition: Bachelor's degree ;
Preferred passed exam: steam boiler basics

Learning resources

handouts which will be at student's disposal a week in advance

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	12
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	8
discussion and workshop	10
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	4
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)

Thermal Power Plants and Heat Plants

ID: 1054
Responsible/Holder professor DRAGAN R. TUCAKOVIĆ
Teaching profesor(s): TUCAKOVIĆ DRAGAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermal science engineering

Goals

Reaching the competence and academic skills and methods for it's acquiring. Developing creative capabilities and mastering the specific practical skills. Goals determine the specific results which should be achieved within the subject. Goals also represent basis for control of the achieved results. Activities in this subject are in accordance with basic tasks and goals of the study program.

Learning outcomes

After successfully completing the course, the students will be able to:
• Acquire the essence of heat balance condensing thermal power plant.
• Be familiar with the regenerative heating feedwater schemes.
• Get to know about the water supply, transport fuels, slag and ash transport and flue gases depuration before its removal to the atmosphere.
• Get to know more about the principles of determining the location and general plan for thermal power plants and heating plants.
• Compare theoretical knowledge with plant derived from visiting a thermal power plant or heating plant.

Theoretical teaching

Consumption of electrical and thermal energy; division of thermal power plants and technological scheme of thermal power plants; Efficiency and heat balance of condensation thermal power plant; Thermal efficiency and energy indicators of heating power stations; Steam parameters and reheating; Regenerative feed water heating; loss of steam, water and condensate and their fill; Power plant water supply; Transportation and storage of fuel in power plants; Transportation of slag and fly ash in thermal power plants; Filtration and drainage of flue gases into the atmosphere; Location and general plan for power plants;

Practical teaching

Auditory exercises consist from demonstration exercises (Presentation and explanation of thermal power plant schemes; Representation and explanation of the power plant elements; Steam parameters of thermal power plants and reheating; Regenerative heating of condensate and feed water; The main operating facilities of domestic power plants; Displaying general plans for local power stations; Problems of exploitation of power plants); Instructions for making calculation task - Main features of the power plant block; Instructions for preparation of the paper - Elements of the power plant main facilities.

Prerequisites

Necessary condition: Bachelor's degree;
Preferred passed exam: Steam boilers elements and equipments and Steam boiler processing

Learning resources

handouts which will be at student's disposal a week in advance

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	0
calculation tasks	6
seminar works	8
project design	0
discussion and workshop	10
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	2
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	6
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	15
test/colloquium	30	project design	0
laboratory exercises	0	final exam	40
calculation tasks	15		

Requirements to take the exam (number of points) 30

References

Lj. Brkic, T. Zivanovic, D. Tucakovic: Thermal Power Plants, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)
Lj. Brkic, T. Zivanovic, D. Tucakovic: Steam Boilers Thermal Calculation, Faculty of Mechanical Engineering, Belgrade, 2010. (In Serbian)

THERMOMECHANICS

Heat and Mass Transfer

Heat transfer

Solar energy

Thermodynamics M

Heat and Mass Transfer

ID: 1375
Responsible/Holder professor MIRKO S. KOMATINA
Teaching profesor(s): KOMATINA MIRKO; TODOROVIĆ RUŽICA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermomechanics

Goals

Students shall gain knowledge in heat and mass transfer scientific discipline that is the basis for design of devices and plants in process engineering, thermal engineering and power engineering.
Students shall learn steady state and transient heat conduction, forced and free heat convection and -heat convection in condensation and boiling; as well and radiation heat transfer, modern methods of heat exchangers design and - modes of mass (substance) transfer.

Learning outcomes

Upon successful completion of the course, students should be able to:
•Interpret and analyze the problems of unsteady heat conduction in the bodies of different geometry and to apply them to specific problems.
•Explain the heat transfer in semi-infinite bodies.
•Perform the heat transfer calculation in semi-infinite bodies.
•Apply numerical methods for solving the problems of unsteady heat conduction.
•Apply the basic laws of radiation in the in the calculation of radiation of the gas mixture.
•Interpret, explain and apply the basic laws of mass transfer on solving the problems of combined heat and mass transfer.

Theoretical teaching

1. Heat conduction - basic concepts, Fourier law, Fourier differential equation; steady state conduction; rods and fins; transient conduction; numerical and other methods.
2. Heat convection - conduction and advection; similarity theory, forced and free convection; and in boiling and condensation.
3. Heat exchangers - mean logarithmic temperature difference method; method of exchanger efficiency and number of transfer units (ε-NTU method).
4. Radiation heat transfer - basic mechanisms, wave and quantum theory, fundamental laws; radiation exchange between 2 surfaces with intermediate two atomic (thermally transparent) gas or mixture of triatomic CO2 and H2O i.e. the "greenhouse effect" gases.
5. Mass (substance) transfer - diffusion, concentration gradient, diffusivity and Fick's law.Convection of mass and non dimensional criteria.

Practical teaching

1. Numerical exercises - steady state conduction; bodies with inside heat sources, critical thickness of pipe insulation, rods and fins. Transient heat conduction; lumped capacitance

method semi infinite solid; numerical methods.
2. Numerical exercises: forced and natural convection; determining Nusselt number and heat convection coefficient, boiling and condensation convective heat transfer.
3. Numerical exercises: heat exchangers - mean logarithmic temperature difference method; method of heat exchanger efficiency and number of heat transfer units (ε-NTU method);
4. Numerical exercises: radiation exchange between 2 surfaces with intermediate; A) two atomic (thermally transparent) gas; B) mixture of CO2 and H2O i.e. the "greenhouse effect" gases.
5. Numerical exercises - mass diffusion, concentration gradient, diffusivity and Fick's law; convection of mass and non-dimensional criteria.

Prerequisites

Physics, Thermodynamics B

Learning resources

1. Хендаути из простирања топлоте и супстанције, сајт Машинског факултета, Београд.
2. Милинчић, Д.: Простирање топлоте, Машински факултет, Београд, 1989.
3. Козић, Ђ., Гојак, М., Коматина, М., Антонијевић, Д., Сањников, А.: Збирка задатака из преношења топлоте, Машински факултет, Београд, 2002.
4. Козић, Ђ., Васиљевић, Б., Бекавац, В.:Приручник за термодинамику, Београд, 2006
5. Васиљевић Б,Бањац М.Приручникзатермодинамику:табеле и дијаграми.2020

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	5
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	7
test, with assessment	6
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

F.P. Incropera, D.P. deWitt: Fundamentals of Heat Transfer, John Wiley & Sons, 1980. 2
J.P. Holman: Heat Transfer, McGraw Hill, 2002
Cengel, Y.: Heat Transfer A Practical Approach, McGraw - Hill, 2003
Andrian Bejan, Convection Heat Transfer, Wiley, 2004.

Heat transfer

ID: 1451
Responsible/Holder professor MILOŠ J. BANJAC
Teaching profesor(s): BANJAC MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermomechanics

Goals

Students should gain basic theoretical and professional knowledge and skills that will enable them to independently recognize and solve a moderately complex multidimensional stationary and transient heat transfer problems that faced by engineers of thermo-technique, thermo-energetic and processes engineering.

Learning outcomes

After successful completion of this course students should be able to:
1) describe and explain the physical essence and mechanisms and express the basic hypotheses and laws that describe the processes of heat transfer: steady and unsteady heat conduction, natural and forced heat convection with and without changing phase state (boiling and condensation) and heat radiation of gases and vapors,
2) calculate the temperature field and heat flow in solid bodies, especially rods, ribs and ribbed surfaces on the basis knowledge of the boundary and initial conditions in case of steady heat conduction
3) calculate the temperature field in simple geometric solid bodies in case of unsteady heat conduction with the change the aggregate state - the melting and solidification
4) calculate the local and average values the coefficient of heat transfer, ie. heat flux in case free and forced convective heat transfer for fluid flows across, through and around solid bodies but without changing its phase state,
5) calculate the heat flux, mass flow and thickness of the layer of condensate in case convective heat transfer during condensation of steam on the vertical and inclined solid surface,
6) calculate the heat flux, mass flow and thickness of the layer of condensate in forced flow condensation of steam on the vertical and inclined solid surface,
7) calculate the radiation heat flux from semi-transparent absorbing gases on opaque gray surfaces and the radiation heat flux from semi-transparent absorbing gases with solid particles on opaque gray surfaces.

Theoretical teaching

1. Basic principles and laws of energy, momentum and mass transfer
2. Steady heat conducting - Heat transfer from extended surfaces
3. Heat transfer with phase change - processes of melting and solidification
4. Heat transfer by convection without changing the the aggregate state of the fluid; Boundary layer theory; Local and averaged values of the coefficient of heat transfer.
5. Analogies between the phenomena of transferring of substance, momentum and energy

6. Heat transfer with phase change - boiling and condensation
7. Coupled heat and mass transfer problems
8. Thermal radiation of gases and vapors. Radiation exchange between flue gases with and without solid particles and surface of solid body.

Practical teaching

1. Радионица и дискусија посвећена општим појмовима и законитостима преношења преношења енергије и импулса
2. Рачунски примери и лабореаторијска вежба у вези с провођење топлоте кроз штапове, ребра и оребрене површи
3. Рачунски примери у вези с неустаљеним провођењем топоте са променом агрегатног стања – процеси топљења и очвршћавање
4. Рачунски примери у вези са конвективним прелажење топлоте без промене агрегатног стања флуида, теорија граничног слоја, локалне и осредњене вредности коефицијената прелажења топлоте
5. Рачунски примери у вези са прелажењем топоте при промени агрегатног стања флуида, кључању течности и кондензовању паре
7. Рачунски примери у вези са истовременим преносом топлоте и супстанције
8. Топлотно зрачење гасова и пара: Размена топлоте зрачењем између димних гасова са и без чврстих честица на површину чвстог тела.

Prerequisites

Passed exams: Applied Thermodynamics or Thermodynamics M
Desirable, passed exams: Basic heat and mass transfer

Learning resources

1. Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	25
elaboration and examples (revision)	5
active teaching (practical)	**30**
auditory exercises	30
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	5
test, with assessment	5
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

Milincic, D., Vasiljevic, B., Djordjevic, R.: Heat Transfer Problems, Faculty of Mechanical Engineering of University of Belgrade, Belgrade, 1991.
Milincic, D.: Heat transfer, Naucna knjiga, Belgrade, 1989.
Incropera, F., DeWit, D., Bergman, T, Lavine, A: Introduction to Heat Transfer, Wiley, 5th edition, 912 pages, 2006.
Cengel, Y.: Heat Transfer A Practical Approach, McGraw - Hill; 2nd edition 1024 pages, 2003.
Cengel, Y., Ghajar, A: Heat and Mass Transfer: Fundamentals and Applications + EES DVD for Heat and Mass Transfer, McGraw-Hill Science/Engineering/Math; 4 edition, 924 pages, 2010.

Solar energy

ID: 0924
Responsible/Holder professor MILAN D. GOJAK
Teaching profesor(s): GOJAK MILAN; RUDONJA NEDŽAD
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: thermomechanics

Goals

Achieving academic competences in the field of solar energy utilization. Acquiring theoretical and practical knowledge on converting solar into thermal energy, acquiring skill of modeling and simulation of processes.

Learning outcomes

Upon successful completion of this course students should be able to:

- Explain the characteristics of solar radiation at a specific location;
- Analyze energy transport in the elements of the solar thermal systems;
- Formulate the mass and energy balances for the elements of the solar system (for solar collectors, thermal energy storages, heat exchangers, pipelines);
- Determine reprezentative energetic caracteristics of appropriate elements of the system;
- Analyze and thermodynamically evaluate the operation of various solar thermal systems.

Theoretical teaching

Relevance and filds of solar energy utilization. Solar energy: characteristics, potential, apparent motion of the Sun, available solar energy at Earth's surface. Heat transfer in solar system elements: blackbody radiation laws, grey and real body, radiation properties of materials, Kirchhoff law, selective surfaces, radiation heat transfer, convection, conduction, combined heat transfer. Components of thermal solar systems and thermodynamic models: solar collectors (types, operation temperatures ranges, construction, operation principles, heat transfer model, thermal and other properties); thermal energy storage (water storage, phase change and other materials, construction, energy balance); heat exchangers (thermal characteristics); transfer fluids (relevant properties); pipelines (balance equations); other components. Systems control. Characteristics of solar systems of various purposes.

Practical teaching

Modeling and simulation of operation of components and solar systems: dynamic of using of solar energy in a chosen object, relevant climatic and other parameters; choice and description of system operation, physical and mathematical model; computation algorithm, operation simulation. Parameter analysis of operation of certain elements and systems, thermodynamic analysis and optimization. Comparison with results obtained by using available computer programs.

Prerequisites

Completed exam in thermodynamics

Learning resources

1. Handouts
2. Printed literature
3. Laboratory
4. Computer programs
5. Catalogs

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	3
calculation tasks	2
seminar works	10
project design	12
discussion and workshop	3
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	4
check and assessment of projects	5
colloquium, with assessment	0
test, with assessment	2
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	20
test/colloquium	20	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Gojak, M., Rudonja, N.: Solar thermal systems, University of Belgrade - Faculty of Mechanical Engineering, 2020.
Duffie, J., Beckman, W.: Solar engineering of thermal processes, John Wiley & Sons, Inc., 2006.
Kreith, F., Goswami, Y.: Handbook of Energy Efficiency and Renewable Energy, Chapter 18 - Solar thermal energy conversion, CRC Press 2007.
Kalogirou, S.: Solar thermal collectors and applications, Progress in Energy and Combustion Science 30, 231-295, 2004.
ASHRAE Applications Handbook: CHAPTER 32 - SOLAR ENERGY USE, 1999.

Thermodynamics M

ID: 0202
Responsible/Holder professor MIRKO S. KOMATINA
Teaching profesor(s): GOJAK MILAN; BANJAC MILOŠ; KOMATINA MIRKO; RUDONJA NEDŽAD; TODOROVIĆ RUŽICA

Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: thermomechanics

Goals

Student should gain knowledge in thermodynamics and thermal devices and plants that are present in process engineering, thermal engineering and power engineering. Through practical and theoretical education should understand from thermodynamic aspect the transformation of thermal energy into mechanical work and gain physical fundamentals on phenomena that go on in steam turbine, gas turbine and refrigeration devices as well as in plants for drying various materials and air conditioning of corresponding spaces.

Learning outcomes

Upon successful completion of this course, students should be able to:
•Interpret, explain and implement the First and Second principle of thermodynamics to the closed and open thermodynamic systems.
•Interpret and apply the equations of state of real gases and explain their deviations from the ideal gas model.
•Recognize the devices in which real thermomechanical processes are evolved and perform their thermodynamic analysis.
•Determine the energy indicators of the ideal gas and real right-handed and left-handed cyclic processes with and perform their thermodynamic analysis.
•Recognize and describe the exergy of the open and closed thermodynamic system.
•Apply the energy and exergy analysis of thermomechanical processes on devices and facilities.
•Recognize and determine the thermodynamic properties of wet gases and implement them in the analysis of thermomechanical processes in devices and facilities with moist air.

Theoretical teaching

1.First law of thermodynamics for open thermomechanic system. Mass balance. Energy balance.
2.Second law of thermodynamics for open thermomechanic systems.
3.Exergy of closed and open thermomechanic systems.
4.Thermodynamic analysis of operation of basic thermomechanic devices and plants.
5.Thermodynamics of complex systems, outflow.
6.Humid air - devices and plants that operate with humid air.

Practical teaching

1.Numerical exercises on First law of thermodynamics for open thermomechanic system.

2.Numerical exercises on Second law of thermodynamics for open thermomechanic systems.
3.Numerical exercises on exergy of closed and open thermomechanic systems.
4.Numerical exercises on thermodynamic analysis of operation of thermomechanic devices and plants.
5.Numerical exercises on thermodynamics of complex systems.
6.Numerical exercises on processes, devices and plants that operate with humid air.

Prerequisites

Necessary: Physics, Thermodynamics B

Learning resources

1. Милинчић, Д., Вороњец, Д.: Термодинамика, Машински факултет, Београд, 1990
2. Козић, Ђ.: Термодинамика, Инжењерски аспекти, Машински факултет, Београд, 2019
3.Васиљевић Б,Бањац М.Мапа за термодинамику,2020
4. Козић, Ђ., Васиљевић, Б., Бекавац, В.:Приручник за термодинамику, Београд, 2006
5. Хендаути за Термодинамику М, сајт Машинског факултета, Београд.
6.Вороњец, Д., Козић, Ђ.: Влажан ваздух, СМЕИТС, Београд, 2005.
7. Васиљевић Б,Бањац М.Приручник за термодинамику:табеле и дијаграми.2020

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	25
laboratory exercises	0
calculation tasks	5
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	4
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	3
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	5
test/colloquium	60	project design	0
laboratory exercises	0	final exam	35
calculation tasks	0		

Requirements to take the exam (number of points) 20

References

Y.A.Cengel, M.A.Boles. Thermodynamics. An Engineering Approach. 5rd Edition, McGraw Hill, 2006.
A. Bejan: Advanced Engineering Thermodynamics, John Wiley & Sons, 1988
Moran M., Sharpio H., Fundamentals of Engineering Thermodynamics, John Wiley & Sons Ltd, 2006.

WEAPON SYSTEMS

Artillery Weapons Design

Automatic Weapons

Fire control systems

Flight Dynamics and Aerodynamic of Projectiles

Hybrid technical systems

Interior Ballistics

Missile design and launchers

Missile guidance and control

Missile navigation, guidance and control algorithms

Missile Propulsion

Optical Devices and Optoelectronics

Physics of explosive processes

Projectile design

Skill Praxis M - SIN

Terminal Ballistics

Artillery Weapons Design

ID: 1560
Responsible/Holder professor DEJAN T. JEVTIĆ
Teaching profesor(s): JEVTIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: weapon systems

Goals

Detailed analysis of design solutions for individual elements of artillery weapons. Detailed study of design methodologies for the main structural elements of weapons. Practical implementation of calculations for basic structural elements of artillery weapon through the realization of projects

Learning outcomes

Mastering the calculation of basic parameters that characterize the function of individual pieces of artillery systems. Acquiring the ability of students to create their own software tool for the design of individual structural elements of artillery weapons. Qualifications for the design of the main structural elements of artillery systems.

Theoretical teaching

Behaviour of the artillery weapon during firing. Design of muzzle brakes. Design of recoil mechanisms (recuperator, hydraulic recoil brake, hydraulic counterrecoil brake and fluid compensator). Design of devices and mechanisms of artillery mounts (cradle, top carriage, bottom carriage arms and equilibrators). Organization of surface and bore of gun barrel. Design of simple monoblock tube. Deformations and stresses in the walls of the doublelayer tube in rest state and when firing. Design of reinforced doublelayer tube. Basic concepts of autofrettage. Design of monoblock tube with autofrettage. The main types of breechblocks and their characteristics. Design of breechblock mechanism elements for: obturation, triggering and firing, opening, case ejection and closing. Characteristics and functions of breech rings. Design of breech rings.

Practical teaching

Calculation of gun stability during firing. Design of muzzle brakes. Design of recoil mechanisms (recuperator, hydraulic recoil brake, hydraulic counterrecoil brake and fluid compensator). Design of devices and mechanisms of artillery mounts (cradle, top carriage, bottom carriage arms and equilibrators). Design of simple monoblock tube. Deformations and stresses in the walls of the doublelayer tube in rest state and when firing. Design of reinforced doublelayer tube. Basic concepts of autofrettage. Design of monoblock tube with autofrettage. Calculation of breechblock mechanism elements for: obturation, triggering and firing, opening, case ejection and closing. Design of breech rings.

Prerequisites

There is no prerequisite to attend the course

Learning resources

1. Micković D.: Design of Artillery Weapons – Handouts

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	20
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	2
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Micković D.: Design of Artillery Weapons – Handouts

Automatic Weapons

ID: 1386
Responsible/Holder professor DEJAN T. JEVTIĆ
Teaching profesor(s): JEVTIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: weapon systems

Goals

Introducing of students to the basic elements of the automatic weapons. Formation of the system of differential equations that describe the movement of elements of the mechanisms of automatic weapons during the firing cycle. The study of methods for solving these differential equations. Preliminary design of various systems of automatic weapons.

Learning outcomes

Mastering the calculation of basic parameters that characterize the function of various systems of automatic weapons. Acquiring the ability of students to create their own software tool for preliminary design of an automatic weapon. Qualifications for the design of individual elements of the automatic systems and optimisation of function of different types of automatic weapons.

Theoretical teaching

Forces acting on the parts of an automatic weapon. Types of automatic weapons. Bolt locking systems and mechanical safety. Analysis of the cartridge case functions during firing. Analysis of differential equations of motion of elements in the mechanisms of automatic weapons with non-movable and movable receiver and methods for solving them. Characteristics of the movement of members of automatic weapon mechanisms. Determination of the transfer ratio and coefficient of efficiency of mechanisms that are used in the construction of an automatic weapon. Strikes in the mechanisms of automatic weapons. Movement of parts of automatics under the action of springs. Preliminary design of an automatic weapon: blow back operation systems (simple blow back, blow back with advanced primer ignition, delayed blow back, blow back with a locked breech), recoil operated systems (long recoil, short recoil), gas operation systems (long stroke pistons, short stroke pistons, direct gas action).

Practical teaching

Calculation of forces acting on elements of an automatic weapon. Bolt locking systems and mechanical safety. Analysis of the cartridge case functions during firing. Methods of solving differential equations of motion of elements in the mechanisms of automatic weapons with non-movable and movable receiver.Characteristics of the movement of members of automatic weapon mechanisms. Determination of the transfer ratio and coefficient of efficiency of mechanisms that are used in the construction of an automatic weapon. Strikes in the mechanisms of automatic weapons. Movement of parts of automatics under the action of springs. Preliminary design of an automatic weapon: blow back operation systems (simple blow back, blow back with advanced primer ignition, delayed blow back, blow back with a

locked breech), recoil operated systems (long recoil, short recoil), gas operation systems (long stroke pistons, short stroke pistons, direct gas action).

Prerequisites

Desirable - passed exam in the subject Classical Armament Design.

Learning resources

1. Micković D.:Handouts - Automatic Weapons

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	7
laboratory exercises	0
calculation tasks	0
seminar works	5
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	1
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Automatic Weapons - Engineering Design Handbook, US Army Materiel Command Pamphlet 706-260, 1970
Vasiljević M.: Automatic Weapons, TŠC KoV JNA, Zagreb, 1970

Fire control systems

ID: 1297
Responsible/Holder professor MILOŠ D. MARKOVIĆ
Teaching profesor(s): MARKOVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written+oral
Parent department: weapon systems

Goals

Goal of subject is orientated to the student knowledge about basic technologies integrated in the battle that provides precise engagement and reliable shooting of target by direct, indirect or other type of weapon fire. Modern systems employed and design by the basic knowledge about LOS, NLOS, and other shooting elements and principles understand sensor principles, automatic devices and software proceedings, based on ballistic shooting elements. Modern navigation and position principles of weapon fire represented by fundamental vectoral battle mechanics, of platforms motion, targets and projectiles flight in FCS composition models. Processes are represented by artillery, AD, BMD, and armored vehicles battle mechanics and platforms and units integrated systems.

Learning outcomes

Student is trained and educated to solve individual employment of weapon and their integrations of performances with other non weapon helping defense equipment and battle functions. Those understand shooting functions precision positioning and errors estimation, preparing weapon for selected target mission, and ballistics and flight mechanics estimation for optimal target shooting. Also student achieve basic knowledge for Command information battle technology and weapon fire precision strike technology. Software, autoimmunization and mechatronics sensor integration, in the battlefield mechanics of unsteady state vectoral proposals provides FCS software and hardware knowledge, for weapon designers.

Theoretical teaching

1. Ballistic trajectories in shooting principles for LOS and NLOS projectiles and types of weapon fire.
2. Conventional indirect fire artillery shooting and FCS.
3. Shooting artillery of armored vehicles in motion and direct fire autoimmunization stabilization and errors estimations. Devices and equipment of weapon stabilization and equipment for FCS
4. Air defense gun systems and AD combat platforms and AD responsibilities areas
5 Sensors, tracking targets equipment, sighting, automatic optoelectronics, and IR technology laser range finders and navigation GIS and GPS systems and errors performances and analyzes.

Practical teaching

1. Examples of trajectories and corresponding tactical weapon type.
2. Armored vehicles and tank weapons stabilization and shooting FCS integration

3. Automatic control principles for tracking and shooting for air defense platforms and systems /gun and missiles
1.4. UAV and navigating principles of GIS and GPS precision strike on the target., and new concepts of C2I, C3I, C4I, C4ISTAR, in command and control FCS navigation.

Prerequisites

No requirements.

Learning resources

1. Milinovic M., Markovic, M.: Layhandout - Fire control systems, 2000.

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	6
laboratory exercises	3
calculation tasks	0
seminar works	0
project design	3
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	0
test, with assessment	0
final exam	2

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	30	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

MIL-HDBK-799(AR): FIRE CONTROL SYSTEMS - GENERAL, April 1996.

Flight Dynamics and Aerodynamic of Projectiles

ID: 1084
Responsible/Holder professor IVANA N. TODIĆ
Teaching profesor(s): TODIĆ IVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: weapon systems

Goals

Introduce students to the basics of calculations and modeling the dynamics of flight of the projectile. Introduce students to the basics of the structure and implementation of the program for the modeling of the dynamics of flight. The introduction of the experimental methods and analyses of flight tests. Introduce students to the basics of aerodynamic calculations. Introduce students to the basics of the structure and implementation of the program for calculations of aerodynamic of the projectile. Introduction to experimental methods in aerodynamics.

Learning outcomes

Student is qualified for independent work on the calculations and flight dynamics modeling of guided and unguided projectiles. Student is qualified for experimental work in the field of flight testing. Student is qualified for independent work on the calculations of aerodynamic characteristics of guided and unguided projectiles. Student is qualified for experimental work in the field of aerodynamic tests.

Theoretical teaching

Stability of aerodynamically stabilized projectiles (static stability, dynamic stability; transverse resonance oscillations and rolling). Stability of gyro-stabilized projectiles (static stability dynamic stability). Maneuverability of guided missile (control methods; rolling stabilization, control by the normal force). Projectile flight dynamics modeling (Introduction to modeling, modeling with 3 and 6 degrees of freedom). Quaternions and transformation using quaternions. Modeling unguided missiles (introduction to modeling unguided missiles; elaboration of case modeling). Modeling guided missile (introduction to the modeling of guided missiles; elaboration of case modeling). The basic method of aerodynamic calculations (division method of aerodynamic calculations; introduction to the method of breaking up into components; aerodynamic tests). The aerodynamic characteristics of the body (body geometry, calculation methods aerodynamics of the body). The aerodynamic characteristics of the wings and fins (geometry; calculation methods). Aerodynamic interference (interference wing-body, wing-wing interference). Software packages for aerodynamic calculations (base structure; standard software packages). Aerodynamic design (methods of aerodynamic design, selection of parameters, case study).

Practical teaching

Stability aerodynamically stabilized projectiles (assignments) Stability gyro-stabilized projectiles (examples) Maneuverability of guided missile (assignments) Fundamentals of

projectile flight dynamics modeling (modeling packages 6DOF, MATLAB, Simulink). Modeling unguided missiles (case modeling). Modeling guided missile (case modeling). The basic method of aerodynamic calculation (Introduction to the method of breaking up the components). The aerodynamic characteristics of the body (Examples). The aerodynamic characteristics of the fins (Examples). Aerodynamic Interference (Examples). Software packages for aerodynamic calculations (case study). Aerodynamic design (examples).

Prerequisites

none

Learning resources

Djordje Blagojevic, Aerodynamics of the projectile - handouts, Belgrade, 2010.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	5
calculation tasks	10
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	25
laboratory exercises	0	final exam	45
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

McCoy, R.L.: Modern Exterior Ballistics, Shiffer Publishing, 2012.
R. Nielsen, Missile Aerodynamics, New York, 2001.
1. Blagojević Đ .: The dynamics of flight of the projectile, Belgrade, 2004;
2. Zipfel, P.H .: Modeling and Simulation of Aerospace Vehicle Dynamics, New York, 2007.
Slobodan Janković, aerodynamics of of the projectile, Faculty of Mechanical Engineering, Belgrade, in 1979.

Hybrid technical systems

ID: 1562
Responsible/Holder professor IVANA N. TODIĆ
Teaching profesor(s): TODIĆ IVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: weapon systems

Goals

Acquisition of general and basic knowledge about hybrid technical systems (HTS) as the most complex form of TS, familiarization with the structure and concept of HTS as a whole, principles of operation of basic system components, and basic approaches to modeling and simulation. Enable students to understand the complexity and procedures of system integration through precise and detailed general methodology. Development of teamwork skills and integration of knowledge from different areas. Training for further learning.

Learning outcomes

Upon successful completion of this course, students should be able to:
• plan and implement complex processes of modeling and simulation of hybrid technical systems (HTS)
• plan and implement procedures for HTS integration
• develop new design solutions for HTS elements
• create a new product based on technical requirements as part of a complex system or the system as a whole
• develop experimental procedures for verifying HTS elements
• conduct SIL (Software in the Loop) and HIL (Hardware in the Loop) testing of HTS

Theoretical teaching

Hybrid technical-technological systems: explanation and definition of the concept, basic terms; HT systems: basics of development and design of HT systems, structure and basic elements; modularization and hierarchization; Integration: functional, spatial; Methods of designing and linking heterogeneous technical units; Role of information technologies; Mechanical components and assemblies; Electrical components and assemblies; Electronic components and sensors; Microcontrollers and programmable logic controllers (PLC); Hydraulic components and assemblies; Pneumatic components and assemblies; Executive elements; Control; Modeling and simulation of HT systems: calculation and definition of system behavior as a whole and interaction of individual components, computer models and system simulations; Manufacturing process as an HT system: computer-integrated manufacturing, product manufacturing process, automation; Implementation of various HT systems; Application of 3D technology in verification of HTS elements.

Practical teaching

Auditory exercises include the presentation of software project packages and packages for simulation and analysis. Additionally, a relatively complex actuator system example (e.g.,

electro-mechanical actuator) is worked on as a representative of HT systems through computational modeling and simulation. After completing the calculation and simulation, practical work with the actuator: measurement of certain parameters and control presentation; Three seminar papers: HT system as a whole; Calculation and simulation of EMA, HA or PA; Modeling of HT systems. Verification of mechanical assemblies using 3D printing.

Prerequisites

none

Learning resources

Moodle (modular, object-oriented dynamic environment for Internet education) Lectures, PowerPoint presentations, computer lab with design and simulation software, Laboratory for HTS, 3D printer, Lecture handouts.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	0
seminar works	10
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	10
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	45
test/colloquium	0	project design	0
laboratory exercises	15	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 45

References

M. Miloš: Hybrid technical systems - professor's notes (handouts) - Faculty of Mechanical Engineering, Belgrade, 2014. ;
M. Ognjanović: Innovative development of technical systems - Faculty of Mechanical Engineering, Belgrade, 2014.
N. Avgoustinov: Modelling in Mechanical Engineering and Mechatronics – Springer, 2007;

W. Bolton: Mechatronics-Electronic Control Systems in Mechanical and Electrical Engineering – Pearson, 2012.
B. Wilamowski, D. irwin: Control and Mechatronics – CRC Press, 2012.

Interior Ballistics

ID: 1385
Responsible/Holder professor DEJAN T. JEVTIĆ
Teaching profesor(s): JEVTIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: weapon systems

Goals

Study of methods of solving the basic task of interior ballistics and ballistic design. The study of the basic characteristics of special types of weapons. Consideration of methodology of interior ballistic tests.

Learning outcomes

Mastering the calculation of direct and indirect task of interior ballistics of various types of weapons, and the methodology of interior ballistic tests.

Theoretical teaching

Introduction to interior ballistics.
Gun propellants and their characteristics.
Basic processes and laws during firing.
Solution of the basic task of interior ballistics (Task statement. The analytical method of solving. Propellant gas temperature calculation. Tabular method of solving the basic task of interior ballistics).
Ballistic design.
The solution of the task of internal ballistics for the combined (howitzer) charge.
Interior ballistics of recoilless weapons.
Interior ballistics of mortars.
The introduction of interior ballistic corrections (Ermolaev method).
Interior ballistic tests (objective, classification and measuring parameters). Interior ballistic test preparation. Pressure measurement. Measurement of gun muzzle velocity. Measuring of recoil system impulse.

Practical teaching

Production of gunpowder.
Basic processes and laws during firing.
Solution of the basic task of interior ballistics (Task statement. The analytical method of solving. Propellant gas temperature calculation. Tabular method of solving the basic task of interior ballistics).
Interior ballistic design (Task of gun tube design. Interior ballistic characteristic of weapons. General dependence of structural tube characteristics on charge conditions. Directive diagram and its analysis).
The solution of the task of interior ballistics for the combined (howitzer) charge.
Introduction of interior ballistic corrections (Ermolaev method).

Prerequisites

Passed exams (preferred): Thermodynamics B, Fundamentals of Projectiles Propulsion, Physics of Explosive Processes

Learning resources

1. Interior ballistic design tables
2. Correctional coefficients tables

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	4
laboratory exercises	0
calculation tasks	4
seminar works	0
project design	10
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	2
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	30	project design	30
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

Jaramaz, S, Mickovic, D.: Interior ballistics, Faculty of Mechanical Engineering, Belgrade, 2011.

Missile design and launchers

ID: 1299
Responsible/Holder professor MILOŠ D. MARKOVIĆ
Teaching profesor(s): MARKOVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written+oral
Parent department: weapon systems

Goals

Goal of subject is to achieve student in detail contents of missiles subsystems its integration and key performances of flight and terminal phase, functions. Goal of knowledge's are directed on the technology roll and influences on the particular quality and quantity of missiles performances. Missile is considered as the flight vehicle and ammunition for the different payload purposes and defense missions . Student developing detailed skills and knowledge for design, analyzes, syntheses of missiles and rockets and about its advanced technology applications on the component design its research and methodology of calculations and development.
Goal of subject is to achieve student knowledge in two basic launcher equipment
Sub systems. Sub systems of equipment and devices for shooting and missiles positioning and launching, and subsystems of equipment and devices for other defense and military integrated functions available on the self-propelled weapon launcher.
Student through practical project research of concept and component integration realize knowledge of software and hardware integration on the launcher and new technologies implementation on the self propelled or portable weapon missile launching Systems.

Learning outcomes

Student achieve level of individual designer of tactical missiles and other jobs and purposes of missile syntheses .Also, student is accomplished for the analyzes and syntheses of all levels and types in the missile and ammunition rocket technologies by tools of applied mechanics and software analyzes of integrative rocket and missile technologies and performances .Parametric composition of missile flight mechanics, special ballistics and rocket propulsion propellants performances and other interdisciplinary integration selection and estimations, is comprehension output of subject.
Student realizes skills and knowledge for individual integrating of launcher weapon, their conceptual solutions and critical thinking and opinion about advantages for applied Systems and sub systems. Also launcher and its equipment is integrative design system test for knowledge of missile system design and defense functions. Student through practical selections of functions and its solutions gets knowledge of compromises in technology possibilities and threshold performances of practical use and its requirements.

Theoretical teaching

Role of missiles in military use. Missiles configuration. The concept of missile components dispositions. Components and subassemblies, their structural and functional connection,

especially in guided, especially in unguided missiles. Determination of missile initial mass and solid rocket motor performances. Missile propulsion integration. Aerodynamic configurations of guided and unguided missiles. Aerodynamic design. Analyzes of guidance laws and their influence on guided missile design. Dynamic performances of the missile. Fundamentals of autopilot and role in guided missile design. Missile control systems. Missile loads during flight. Structure and structure materials of unguided and guided missiles. Missile component stress analyses. Content of subsystems for MLRS, AT, AD, BM, launchers mechanisms integrated for missiles launching, and shooting, devices functional and equipment design. Equipment for launching stability, energy supply and other conditions for functional and environmental uses of defense and functional missiles weapon technology. Launchers stability analysis and interactions with missiles.

Practical teaching

1. Missiles projectiles preliminary design guided and unguided 2. Concept of missile tactical mission, preliminary design of requirements and performances 3. Seminar case study of missile or rocket preliminary design for new missile of chosen mission, presentation of solution. 4. Critical technology in project designs a consulting for solutions optimization. 5. Project solution idea. 6. Kinematics and dynamics of launching mechanisms in joint work with system integration concept, elevation mechanism, stabilization mech. direction mechan., fire mech. and launching forces estimation. 7. Presentation of joint launcher project and its substitution with critical estimations of components, and technology.

Prerequisites

No requirements.

Learning resources

1. Milos Markovic: Handout - Missile design and launchers, Belgrade 2020.
2. Vucurovic O.: Basis of missile design, University of Belgrade, Mechanical engineering, 2003.
3. Vucurovic O.: Design issues of launching devices, University of Belgrade, Mechanical engineering, 2006.
4. Milinovic M.: Fundamentals of Rocket and Launcher Design - Chapter in Launcher Design, University of Belgrade, Mechanical engineering, 2002.
5. Markovic, M., Jevtic, D., Djurovic, R., Milicic, L.: Missile design and launchers - practicum, University of Belgrade, Mechanical engineering, 2023, ISBN: 978-86-6060-160-7.

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	10
laboratory exercises	10
calculation tasks	0
seminar works	0

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	2
check and assessment of seminar works	0
check and assessment of projects	10
colloquium, with assessment	0
test, with assessment	0
final exam	3

project design	10
discussion and workshop	0
research	**0**

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	30
laboratory exercises	30	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

E. Fleeman, Missile design and system engineering. American Institute of Aeronautics and Astronautics, 2012.
Zarchan P.: Tactical and Strategic Missile Guidance, Volume 239, Progress in Astronautics and Aeronautics, 2012.
Krasnov N.F. et al.: Rocket aerodynamics, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, June 1971
Siouris G. M.: Missile Guidance and Control Systems, Springer, 2004.
Архангельский И. И.: ПРОЕКТИРОВАНИЕ ЗЕНИТНЫХ УПРАВЛЯЕМЫХ РАКЕТ, МОСКВА, Издательство МАИ 2001.

Missile guidance and control

ID: 1085
Responsible/Holder professor IVANA N. TODIĆ
Teaching profesor(s): TODIĆ IVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: weapon systems

Goals

Acquiring basic knowledge in the field of missile guidance and control with the possibility of applications in the fields of research and development, designing, manufacturing, marketing, operational use and analysis of modern guided missiles. Mastering the methodology of the calculations of dynamic characteristics of guided missiles (maneuverability, stability, etc. The eigen frequencies.) and autopilot synthesis and guidance law for the method of proportional navigation.

Learning outcomes

The student acquires general knowledge in the areas of analysis and synthesis system of guided missiles that enables participation and communication in work teams involved in the development of guided missiles. With the use of modern software tools developed in MATLAB and Simulink, are qualified for the trajectory calculation of guided missiles, aerodynamic transfer function calculation and the synthesis of the autopilot and the missile guidance system. It has a basic knowledge of verification and assessment of the quality of guidance system.

Theoretical teaching

Introduction to the theory of guidance and control of the missiles (discusses the basic principles of guidance and control). Analysis of dynamic characteristics of missiles and calculation of aerodynamic transfer functions. Basic requirements and methods of designing autopilots (Block is dedicated to improving the dynamic properties of rockets by autopilot use). Theoretical basis of proportional navigation (We examine the proportional navigation as one of the fundamental laws of guidance)

Practical teaching

The practical realization of guided missiles (analyzed various construction solutions of guided missiles to review the role of guidance and control subsystem. The application of MATLAB and Simulink in design). Designing pitch and roll autopilots. Simulation homing systems (applying SIMULINK program, students are trained in the selection parameters PN). The project of the system of homing missile (Project includes aerodynamic function transfer calculations and synthesis of the autopilot and homing system)

Prerequisites

None.
Passed exams (preferably): flight dynamics and aerodynamics of projectiles, Fundamentals of

automatic control

Learning resources

Cuk, D .: Lectures in course Missile guidance and control, Faculty of Mechanical Engineering, Belgrade, 2002 (handouts)

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	10
elaboration and examples (revision)	2
active teaching (practical)	**12**
auditory exercises	3
laboratory exercises	3
calculation tasks	3
seminar works	0
project design	3
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	3
colloquium, with assessment	0
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	0	project design	40
laboratory exercises	0	final exam	50
calculation tasks	0		

Requirements to take the exam (number of points) 25

References

P. Garnel: Guided Weapon Control System, Pergamon Press, New York, 1980.;
Danilo Ćuk: Design of Beam-Riding Laser Guidance System,MTI, 1998.
Danilo Ćuk: Theory of Homing Systems, Proportional Navigation,MTI, 1998.

Missile navigation, guidance and control algorithms

ID: 1388
Responsible/Holder professor IVANA N. TODIĆ
Teaching profesor(s): TODIĆ IVANA
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: weapon systems

Goals

Acquiring knowledge in the field of navigation guidance and control of missiles with the possibility of application in the fields of research and development, design, production, marketing, operational use and analysis of modern guided missiles. Mastering the methodology of calculating the dynamic characteristics of guided missiles. Acquisition of knowledge in the field of autopilots, different autopilot algorithms, as well as their synthesis. Introduction to different types and algorithms of control laws and their synthesis. Mastering inertial navigation as well as getting acquainted with algorithms for coupling inertial navigation with other types of navigation.

Learning outcomes

The student acquires general knowledge in the field of analyzing and synthesizing a GNC system of guided missiles that enable participation and communication in work teams involved in the development of guided missiles. The student is trained for independent work in the fields of navigation algorithms as well as the selection of the necessary inertial seasons either for the navigation systems or for the needs of the missile guidance and control system. The student masters various algorithms and techniques from the calibration of inertial sensors and elements of the guidance and control system to synthesis of guidance algorithms and autopilots, algorithms for missiles stabilization. With the use of modern software environments MATLAB and SIMULINK, the student is trained to apply and analyse algorithms in this field.

Theoretical teaching

Basics of inertial navigation. Historical development of inertial navigation and strap-down INS. Coordinate frames. Kinematic Euler equation and algorithms of solving (Euler's angles, quaternions, Hamilton's parameters, Rodriges's theorem). Gyroscopes and accelerometers. Calibration of inertial units, testing and error correction. The basics of the global positioning system. Aided navigation systems.
Introduction to the theory of guidance and control of the missiles (the basic principles of guidance and control). Analysis of dynamic characteristics of missiles and calculation of aerodynamic transfer functions. Requirements and methods of designing autopilots. Analyses and syntheses of proportional navigation, the command to LOS guidance and different approaches for trajectory correction and trajectory guidance.

Practical teaching

INS algorithms. Influence of sensor errors on inertial navigation. Calibration algorithms.

Algorithms of integrated navigation systems.
The practical realization of guided missiles (analyzed various construction solutions of guided missiles to review the role of guidance and control subsystem. The application of MATLAB and Simulink in design). Designing pitch, yaw and roll autopilots. Each student should solve a project of guidance system for the given missile data.

Prerequisites

none

Learning resources

Titterton, D.H. and Weston, J.L., "Strapdown Inertial Navigation Technology – 2nd edition", IEE Radar, Sonar, Navigation and Avionic Series 17, ISPB 0-86341-358-7, 2004
Savage, P.G., "Strapdown Inertial Navigation Integration Algorithm Design Part 1: Attitude Algorithms", Journal of Guidance, Control, and Dynamics, Vol. 21, No. 1, pp. 19-28, Jan.-Feb. 1998
Savage, P.G., "Strapdown Inertial Navigation Integration Algorithm Design Part 2: Velocity and Position Algorithms", Journal of Guidance, Control, and Dynamics, Vol. 21, No. 2, pp. 208-221, Mar.-Apr. 1998
Salychev, O., "Inertial Systems in Navigation and Geophysics", Bauman MSTU Press, ISBN 5-7038-1346-8, MOSCOW 1998
Salychev, O., "Applied Inertial Navigation: Problems and Solutions", Bauman MSTU Press, ISBN 5-7038-2395-1, MOSCOW 2004
Cuk, D .: Lectures in course Missile guidance and control, Faculty of Mechanical Engineering, Belgrade, 2002 (handouts)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	0
laboratory exercises	5
calculation tasks	10
seminar works	0
project design	15
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	5
colloquium, with assessment	5
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	20	project design	25

laboratory exercises	0	final exam	45
calculation tasks	0		

Requirements to take the exam (number of points) 0

References

P. Garnel: Guided Weapon Control System, Pergamon Press, New York, 1980.;
Danilo Ćuk: Design of Beam-Riding Laser Guidance System,MTI, 1998.
Danilo Ćuk: Theory of Homing Systems, Proportional Navigation,MTI, 1998.
Titterton, D.H. and Weston, J.L., "Strapdown Inertial Navigation Technology – 2nd edition", IEE Radar, Sonar, Navigation and Avionic Series 17, ISPB 0-86341-358-7, 2004
Salychev, O., "Applied Inertial Navigation: Problems and Solutions", Bauman MSTU Press, ISBN 5-7038-2395-1, MOSCOW 2004

Missile Propulsion

ID: 0689
Responsible/Holder professor PREDRAG M. ELEK
Teaching profesor(s): ELEK PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: weapon systems

Goals

Introducing students to the fundamentals of determination of rocket engines performance parameters. Introducing students to the design of rocket engines with liquid and solid propellants, as well as special units of liquid rocket engines. Fundamentals of thrust vector control of rocket motors. Introduction to methods of rocket engines testing.

Learning outcomes

After successful completion of the course, students should be able to:
- define the performance parameters of rocket engines,
- independently calculate the main structural parts of solid propellants rocket engines,
- analyze all subsystems of liquid propellants rocket engines,
- understand different concepts of the thrust vector control systems of a rocket,
- apply the acquired knowledge in the field of experimental work on the tests of rocket engines.

Theoretical teaching

1. Performance parameters of solid propellants rocket motors (Fundamentals of combustion of solid rocket propellants; pressure equation in the solid rocket motor, pressure stability, thrust of rocket engine)
2. Performance parameters of liquid propellants rocket engines (Fundamentals of combustion of liquid propellants; characteristic length and time of residence; ignition, injectors)
3. Heat transfer in rocket engines (Fundamentals of heat transfer in rocket engines, thermal protection, cooling of liquid propellants rocket engines)
4. Design of rocket engine with solid propellants (Fundamentals of design of solid propellants rocket motors, thrust vector control, nozzle design, chamber design; design of propellant charge)
5. Design of rocket engines with liquid propellants (Fundamentals of design of liquid propellants rocket engines; chamber design; turbo-pump power systems; tank pressurization systems; thrust vector control systems)
6. Testing of rocket engines (Research, development and verification tests)

Practical teaching

1. Performance parameters of solid propellants rocket motors (Examples of calculations; introduction to the software package BALIST)
2. Performance parameters of liquid propellants rocket engines (Examples of calculations;

introduction to the software package COMBUS)
3. Heat transfer in rocket motors (Calculation of thermal protection of rocket motor with solid propellants; Calculation of chamber cooling in the case of liquid propellants rocket engine)
4. Design of rocket engines with solid propellants (Examples of design calculations)
5. Design of rocket engines with liquid propellants (Examples of the calculation of subsystems)

Prerequisites

Passed exams (preferred): Fundamentals of projectile propulsion, Thermodynamics B

Learning resources

1. Elek, P.: Missile propulsion - lectures, Faculty of Mechanical Engineering, Belgrade, 2012. (in Serbian)
2. Blagojevic, Dj.: BALIST - Program for calculation of performance parameters of solid propellant rocket motors, Belgrade, 1998.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	9
laboratory exercises	3
calculation tasks	3
seminar works	3
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Jaukovic, Dj.: Fundamentals of rocket engineering; Part I: Rocket propulsion, Military Academy, 1972. (in Serbian)
Jojic, B., Blagojevic, Dj., Pantovic, A., Milosavljevic, V.: Hanbook for sounding rockets design,

Part II: Propulsion group, SAROJ, Belgrade, 1978. (in Serbian)
Sutton, G.P., Biblarz, O.: Rocket propulsion elements, 7 ed, John Wiley and Sons, 2001.
Hill, P., Peterson, C.: Mechanics and Thermodunamics of Propulsion, Pearson, 2010.

Optical Devices and Optoelectronics

ID: 1561
Responsible/Holder professor MILOŠ D. MARKOVIĆ
Teaching profesor(s): MARKOVIĆ MILOŠ
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 2
Final exam: written
Parent department: weapon systems

Goals

The aim of the course is to enable students, future mechanical engineers specializing in military systems design, to acquire the necessary knowledge for cooperation with designers of complex optical and optoelectronic systems. After attending lectures and exercises, students should be able to set up and calculate basic optical systems.

Learning outcomes

The course enables students, future mechanical engineers specializing in military systems, to: - set up basic optical systems (lenses, working systems, oculars, Keplerian and Galilean telescope configurations); - calculate optical systems using modern optical design software.

Theoretical teaching

Fundamental concepts and definitions used in optics. Ideal and paraxial optics as basic approximations used in the design of optical systems. 1. Theory of aberration, which defines the deviation of a real image from an ideal image. 2. Evaluation of the quality of images formed by optical systems. 3. Losses of light energy during propagation through optical systems. 4. Basic quantities and laws in optoelectronics. The working principle of a laser. Basic components of a laser system. Laser rangefinder.

Practical teaching

Description of the major optical components that make up classical optical systems.
Calculation of the propagation of ideal and paraxial rays through optical systems.
Calculation of the propagation of real rays through optical systems.
Designing telescopic systems (Keplerian and Galilean telescope configurations).
Working principle of an image amplifier.
Working principle of an optical radiation detector. Detailed explanation of the working principle of a CCD detector.
Working principle of a laser and presentation of the basic components of a laser system. Detailed explanation of a laser rangefinder.
Working principle of thermal imaging and presentation of the basic components of various types of thermal imaging devices.

Prerequisites

There are no special prerequisites for taking the course.

Learning resources

Software package – Optical Surface Layout and Optimization LT ver. 5.4 OSLO Optics Reference Manual, CCO

NUMBER OF HOURS

Total number of hours: 30

ACTIVE TEACHING	
active teaching (theoretical)	**12**
lectures	8
elaboration and examples (revision)	4
active teaching (practical)	**12**
auditory exercises	6
laboratory exercises	0
calculation tasks	0
seminar works	6
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**6**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	1
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	20	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

D. Vasiljević: Optical Devices and Optoelectronics, the Faculty of Mechanical Engineering in Belgrade in 2005. The ISBN number is 86-7083-493-6.

Physics of explosive processes

ID: 1136
Responsible/Holder professor PREDRAG M. ELEK
Teaching profesor(s): ELEK PREDRAG; MILIVOJEVIĆ ALEKSANDAR
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 6
Final exam: written
Parent department: weapon systems

Goals

The goal of course is that students learn the basic principles of combustion of materials and physics of explosion which are of importance for the realization of a function of weapon systems. Students should learn the contents of the process of explosion and burning of gunpowder and rocket propulsion materials as integrated chemical-technological systems.

Learning outcomes

Student gets knowledge for calculations of physics of explosion processes that influence warhead mechanisms and target efficiency. Student understand influencing parameters on the energy release by combustion processes. Student forms the scientific and experimental base for the development and creation of new knowledge in the field of energetic materials and energy release processes in defense technologies.

Theoretical teaching

1. Fundamentals of thermochemistry and thermodynamics of the explosive processes
2. Explosives sensitivity to external influences
3. Fundamentals of the hydrodynamic theory of detonation
4. The effect of explosions on the surrounding environment
5. Contact detonations. Active part of the explosive charge
6. Explosive propulsion. The formation of plane detonation wave
7. General assumptions and laws of ignition of fuel-oxidizer systems and exothermic reaction
8. Combustion of solid rocket propellants, powders and pyrotechnic mixtures (kinetics and thermochemistry)
9. Combustion products and energy characteristics of the various types of fuel mixtures and methods of measuring the burning rate

Practical teaching

1. Calculation of thermochemistry and thermodynamics of the explosive processes
2. Explosives sensitivity to external influences. Applications
3. Fundamentals of the hydrodynamic theory of detonation. Selected examples
4. The effect of explosions on the surrounding environment. Selected examples
5. Contact detonations. Active part of the explosive charge
6. Explosive propulsion. The formation of plane detonation wave. Examples
7. Ignition and combustion of gas and liquid reactants and boundary conditions
8. Kinetic properties of powder and rocket propellants and models of decomposition of solid fuels

9. External influences and methods of measuring kinetic and energy parameters in different environmental conditions

Prerequisites

There are no obligatory prerequisites. Passed exam preferred: Fundamentals of projectile propulsion

Learning resources

1. Jaramaz, S.: Physics of Explosion, Faculty of mechanical Engineering, Belgrade, 1997.
2. Maksimovic, P.V.: Technology of explosive materials, Military Publishig Company, Belgrade, 1972 (in Serbian)
3. Adzic, M.: Fundamentals of combustion, Faculty of Mechanical Engineering, Belgrade, 2007 (in Serbian)
4. Milinovic, M.: Principles of combustion of solid propellants, Принципи сагоревања чврстих погонских материја, Faculty of Mechanical Engineering, Belgrade, 2007 (in Serbian)

NUMBER OF HOURS

Total number of hours: 75

ACTIVE TEACHING	
active teaching (theoretical)	**30**
lectures	20
elaboration and examples (revision)	10
active teaching (practical)	**30**
auditory exercises	6
laboratory exercises	8
calculation tasks	16
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**15**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	0
check and assessment of projects	0
colloquium, with assessment	10
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	0
test/colloquium	60	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Jaramaz, S.: Physics of Explosion, Faculty of mechanical Engineering, Belgrade, 1997.
Akhavan, J.: The chamistry of explosives, Royal Society of Chemistry, 2011.
Stamatovic, A.: Physics of Explosion, Ivexy, Belgrade, 1996.

Projectile design

ID: 1138
Responsible/Holder professor PREDRAG M. ELEK
Teaching profesor(s): ELEK PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: weapon systems

Goals

The main objective of the course is that students understand the importance, the basic concepts and methods of projectile design as an integral part of the science of weapons systems. Students should understand the key ideas about the types and purpose of projectiles, safety in the use and mechanisms of action.

Learning outcomes

Student gets contemporary knowledge about the main types of projectiles (high-explosive, armor-piercing, special) and the basics of their design. Student could use methods of calculation of different types of projectiles and their components.

Theoretical teaching

1. Introduction to the projectile design. Basics of projectile safety during the movement in the gun barrel. Stress of projectile elements in the gun barrel.
2. High-explosive projectiles. Fragmentation warhead. Number, individual mass and shape of fragments. Configuration and direction of the fragments beam. Fragments' ballistics. Efficiency and specific efficiency of fragmentation warhead. Blast effect.
3. Shaped charge projectiles. Theoretical basis for a shaped charge effect. Hydrodynamic theory. Misznay-Shardin's effect.
4. Armor-piercing projectiles. The influence of the mechanical characteristics of the projectile and armor on the penetration process.
5. Special purpose projectiles. Design characteristics of special-purpose projectiles. Smoke projectiles. Illuminating projectiles. Incendiary projectiles. Aerosol projectiles.

Practical teaching

1. Introduction to projectile design. Projectile safety during movement in the gun barrel. Stress of projectile elements in the gun barrel. Selected problems.
2. High-explosive projectiles. Fragmentation warhead. Number, individual mass and shape of fragments. Configuration and direction of the fragments beam. Fragments' ballistics. Efficiency and specific efficiency of fragmentation warhead. Examples
3.High-explosive projectiles. Measures to increase the fragmentation effect of the projectile. Blast effect. Examples.
4. Shaped charge projectiles. Examples.
5. Term paper - Preparation of seminar work with the subject determined by arrangement with the student.
6. Armor-piercing projectiles The influence of the mechanical characteristics of the projectile

and armor on penetration process. Examples.
7. Armor-piercing projectiles. Depth of penetration. Analysis of selected examples.

Prerequisites

Passed exam (preferred): Physics of explosive processes.

Learning resources

Jaramaz, S.: Manuscript for lessons, 2016.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	4
laboratory exercises	0
calculation tasks	12
seminar works	2
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	2
check and assessment of projects	0
colloquium, with assessment	2
test, with assessment	0
final exam	5

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Jaramaz, S.: Warheads Design and Terminal Ballistics, Faculty of Mechanical Engineering, Belgrade, 2000.
Stamatović, A.: Design of projectiles, Ivexy, Belgrade, 1995.
Carleone, J.: Tactical missile warheads, AIAA, 1993.

Skill Praxis M - SIN

ID: 1475
Responsible/Holder professor DEJAN T. JEVTIĆ
Teaching profesor(s): JEVTIĆ DEJAN
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: seminar works
Parent department: weapon systems

Goals

Practical experience and student's stay in the environment in which he will realize his professional career. Identifying the basic functions of the business system in the field of design, development and production, as well as the roles and tasks of mechanical engineer in such a business system.

Learning outcomes

Students get practical experience on the organization and functioning of the environment in which they will apply their knowledge in their future professional career. Student identifies models of communication with colleagues and business information flows. The student recognizes the basic processes in the design, manufacture, maintenance, in the context of his future professional competence. Personal contacts and acquaintances are established that student will be able to use during study or entering into future employment.

Theoretical teaching

Teaching is practical.

Practical teaching

Practical work involves working in organizations that perform various activities in connection with mechanical engineering. Selection of thematic areas and commercial or research organizations is carried out in consultation with the concerned professor. Generally a student can perform the practice in manufacturing organizations, project and consulting organizations, organizations engaged in mechanical equipment maintenance, public utility companies and some of the laboratories at Faculty of Mechanical Engineering. The practice may also be made abroad. During practice, students must keep a diary in which he will enter a description of the tasks performed, the conclusions and observations. Following the practice they must make a report to defend of the subject professor. The report is submitted in the form of the paper.

Prerequisites

No.

Learning resources

Micković D.: Design of Artillery Weapons - Handouts

NUMBER OF HOURS

Total number of hours: 90

ACTIVE TEACHING	
active teaching (theoretical)	**0**
lectures	0
elaboration and examples (revision)	0
active teaching (practical)	**0**
auditory exercises	0
laboratory exercises	0
calculation tasks	0
seminar works	0
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**90**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	80
check and assessment of projects	0
colloquium, with assessment	0
test, with assessment	0
final exam	10

Assessment of knowledge (maximum number of points - 100)

feedback during course study	0	seminar works	60
test/colloquium	0	project design	0
laboratory exercises	0	final exam	40
calculation tasks	0		

Requirements to take the exam (number of points) 30

References

Jaramaz, S, Mickovic, D.: Interior ballistics, Faculty of Mechanical Engineering, Belgrade, 2011.
Micković D.: Design of Artillery Weapons - Handouts, 2015.

Terminal Ballistics

ID: 0691
Responsible/Holder professor PREDRAG M. ELEK
Teaching profesor(s): ELEK PREDRAG
Level of studies: M.Sc. (graduate) academic studies
ECTS credits: 4
Final exam: written
Parent department: weapon systems

Goals

The main goal of the subject is that students understand the importance, the basic concepts and methods of terminal ballistics, as an integral part of the science of weapons systems. Students should understand the key ideas about the projectile/target interaction and their use in projectile design as well as ballistic protection.

Learning outcomes

After successful completion of the course, students should be able to:
- define all types of projectiles/warheads action on targets,
- calculate the main parameters of all types of penetration processes,
- analyze the characteristics of blast effect,
- model the mechanisms of high-explosive projectiles fragmentation effect,
- apply the experimental methods for determination of projectile efficiency parameters,
- understand the functional composition and the fundamentals of fuze design.

Theoretical teaching

1. Scope of terminal ballistics
The effect of projectile on target. Types of projectiles. Types of targets. Tasks of terminal ballistics. Behavior of materials under dynamic conditions.
2. Penetration mechanics
Fundamentals of penetration mechanics. Armor piercing projectiles. Experimental determination of penetration. Long rod penetration. Shaped charge jet penetration.
3. Fragmentation
Mechanism of projectile fragmentation. Fragment velocity. Mass distribution of fragments. Experimental determination of the efficiency of fragmentation projectile.
4. Blast effect
Shock wave, pressure and impulse. Blast effect of projectiles. Underground explosion. Underwater explosion
5. Fuzes
Classification of fuzes. Functional composition of fuzes. Calculation of reliability and safety of fuzes. Testing of fuzes.

Practical teaching

1. Approaches to solving problems in terminal ballistics
Examples of target kill probability. Models of material behavior under dynamic loads.
2. Penetration/Perforation

Simple penetration models penetration for thin targets. Penetration at high velocities.
3. Penetration/Perforation
Models of shape charge jet and long rod penetration.
4. Workshop - Preparation of the paper with a topic that is determined by arrangement with the student.
5. Fragmentation
Experimental evaluation of the efficiency of projectile fragmentation.
6. Blast effect
Determination of blast effect parameters.
7. Fuzes
Models of the effect of certain types of fuzes. Calculation of reliability and safety of fuzes.

Prerequisites

Exams passed (preferred): Projectile design, Physics of explosive processes

Learning resources

1. Jaramaz, S.: Warheads Design and Terminal Ballistics, Faculty of Mechanical Engineering, Belgrade, 2000.
2. Stamatovic, A.: Projectile design, Ivexy, Belgrade, 1995 (in Serbian)
3. Krsic, N.: Design of fuzes, VINC, Belgrade, 1986 (in Serbian)
4. Elek, P.: Manuscript for lectures, Faculty of Mechanical Engineering, Belgrade, 2010.

NUMBER OF HOURS

Total number of hours: 45

ACTIVE TEACHING	
active teaching (theoretical)	**18**
lectures	12
elaboration and examples (revision)	6
active teaching (practical)	**18**
auditory exercises	5
laboratory exercises	0
calculation tasks	11
seminar works	2
project design	0
discussion and workshop	0
research	**0**

OTHER	
knowledge checks	**9**
assessment of calculation tasks	0
check and assessment of lab reports	0
check and assessment of seminar works	3
check and assessment of projects	0
colloquium, with assessment	3
test, with assessment	0
final exam	3

Assessment of knowledge (maximum number of points - 100)

feedback during course study	10	seminar works	30
test/colloquium	30	project design	0
laboratory exercises	0	final exam	30
calculation tasks	0		

Requirements to take the exam (number of points) 35

References

Backman, M.E.: Terminal Ballistics, NWC China Lake, California, 1976.
Carleone, J.: Tactical Missile Warheads, Progress in Astronautics and Aeronautics, AIAA, Vol. 155, Washington, 1983.
Meyers, M.A.: Dynamic Behavior of Materials, Wiley-Interscience, 1994.
Elek, P.: Terminal ballistics, Faculty of Mechanical Engineering, Belgrade, 2018. (in Serbian)
Elek, P., Jaramaz, S., Micković, D.: Fragmentation of the case od HE projectiles: Fragment mass distribution laws and physically based fragmentation models, MTI, 2011, ISBN 978-86-81123-23-2, pp.105