COURSE DESCRIPTION CARD - SYLLABUS

Course name

Modeling and simulations of mechanical systems

Course

Field of study

Mechatronic

Area of study (specialization)

Level of study

Second-cycle studies

Form of study

full-time

Year/Semester

1/1

Profile of study

general academic

Course offered in

Polish

Requirements

compulsory

Number of hours

Lecture

30

Tutorials

Laboratory classes

30

Projects/seminars

Other (e.g. online)

Number of credit points

5

Lecturers

Responsible for the course/lecturer:

Tomasz Stręk, D.Sc., Univ. Prof.

Institute of Applied Mechanics

Faculty of Mechanical Enginneering

ul. Piotrowo 3, 60-965 Poznań

ul. Jana Pawla II 24 (CMBiN - room 438)

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Responsible for the course/lecturer:

Roman Starosta, D.Sc. Eng.

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Prerequisites

Knowledge of mathematics, mechanics, fluid mechanics, strength of materials, heat transfer and differential equations, numerical methods. Skills of logical thinking, the use of information obtained from the library and the Internet.

Course objective

Knowledge of theoretical knowledge and acquisition of computational practice using the finite element method to solve linear and nonlinear problems in heat transfer problems in mechanical engineering. Acquiring the ability to take into account the thermal and / or thermal-mechanical properties of materials in the design of devices and structures.

Course-related learning outcomes

Knowledge

1) The student has an ordered, theoretically founded knowledge of building computational models in mechanics and the application of the most popular computer computational methods. 2) The student understands the complexity of modeling mechanical systems, including simplifying assumptions, formulating a physical and mathematical model, as well as methods of solving and verifying the model. 3) The student has knowledge of computer-aided design with the use of MES systems and CAD / CAE systems. The student is able to explain the basic concepts of analytical mechanics concerning the disfree material system and give appropriate examples of their application, is able to explain the meaning and applicability conditions of the virtual work principle and the Dirichlet principle as well as Lagrange equations of I and II type.

Skills

1) The student is able to use CAD / CAE software to carry out design tasks and computational analysis of mechanical systems. 2) The student is able to successfully carry out the process of modeling and computer simulation, verify the correctness of the adopted model, interpret the obtained results and draw conclusions. 3) The student is able to prepare short scientific studies and reports on the conducted simulation studies. 4) The student is able to determine the positions of permanent equilibrium of a system with several degrees of freedom around which small linear vibrations of the system occur. 5) can derive the equations of motion of a system with several degrees of freedom using the Lagrange equations and solve them with the aid of a computer algebra system and analyze motion both on the basis of graphs of temporal changes of position and velocity, as well as the trajectory of motion in the phase space.

Social competences

1) Student understand the need for learning and acquiring new knowledge; can organize lerning process an dwork in a team 2) Student can appropriately determine priorities to achieve the assumed goal.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: Credit in writing on the basis of general questions or scores (credit in the case of obtaining 51%

of points:> 50% - 3.0,> 60% - 3.5,> 70% - 4.0,> 80% - 4.5,> 90 % of points - 5.0) carried out at the end of the semester. In the case of remote work, it may be implemented in the form of a technical problem developed and solved (using FEM) described in the selected scientific publication.

Laboratory / project: Assessment on the basis of the project of the developed problem / issues in the field of content of issues performed in the laboratory exercises. The form and quality of prepared materials is assessed (description of issues, theory, method, results, analysis and literature). The prepared data will allow calculations and graphical representation of the calculations.

Programme content

Lecture (A): Heat transfer by conduction, convection and radiation. Fluid heat transfer. Basic laws of heat conduction and thermal stresses. Mathematical models of heat transfer and thermal stresses. Boundary and initial conditions. Finite element method in heat transfer problems. Design of devices and structures taking into account heat transfer and thermal stresses. Construction, principle of operation and modeling of heat exchangers (e.g. shell and tube, cross-flow type). Modeling and analysis: temperature fields in the cooling collar, laser heating of materials, insulating properties of materials and structures, heat transfer and thermal stresses in composites and metamaterials, composite thermal barrier. Design of materials with zero or negative coefficient of thermal expansion. Reverse engineering issues in heat transfer. Identification of thermal properties of materials and structures. Presentation of other computing systems.

Laboratory (A): Solving engineering problems in the content of the lecture in the FEM program. Computer and mathematical models (equations with initial-boundary conditions) of practical problems will be prepared for the laboratory content presented in the lecture. Issues: (1) basic problems of heat transfer, stationary (fixed) problems in heat exchange, (2) analysis of the temperature field in the cooling collar, (3) heat transfer in the heat exchanger (heat sink), (4) flow heat exchanger analysis, (5) thermal stresses in the heat exchanger, the effect of thermal stresses on the construction of a composite layer, (6-7) design of a heat exchanger for mechatronic applications and analysis of its thermal-mechanical properties, (8) completion of a final project.

Lecture (B): Free and non-free material systems. Classification and analytical form of constraints. Structural analysis of complex mechanical systems. Specify the number of degrees of freedom in a system. Two-sided geometric constraints: gradient of constraints at a point, conditions imposed on velocities and accelerations of system points. Possible positions, speeds and shifts as well as virtual shifts of system points. Perfect bonds. Generalized coordinates and generalized velocities. Generalized forces. The principle of virtual work. Equilibrium conditions in a conservative force field. The Dirichlet principle. Lagrange's equations of the second kind. Type II Lagrange equations in the potential and conservative force field. Lagrange's equations of the first kind. The law of variation in kinetic energy of a system bounded by non-stationary constraints.

Laboratory (B): Solving tasks in technical mechanics in a computer computational system in the area of: (1) introduction to the computer system of symbolic transformations and solving advanced tasks on material point dynamics, (2) studying the motion of nonlinear mechanical systems - Duffing's equation,

(3) determination of equilibrium positions of mechanical systems under the action of conservative forces and assessment of their stability - the Dirichlet principle, (4) analytical statics - the principle of virtual work, (5) dynamics of mechanical systems under the action of potential forces - Lagrange equations of the second type, (6) dynamics planetary gears, (7) dynamics of non-potential systems, (7) final test.

Teaching methods

Lecture: lecture / problem lecture / lecture with multimedia presentation. The content presented at the lecture is provided in the form of a multimedia presentation combined with a classic blackboard lecture enriched with demonstrations related to the presented issues and computer simulations.

Computer laboratory: project method (research, implementation, practical project) / group work / problem solving; solving problems in a computer system of symbolic transformations, numerical calculations, discussion.

Bibliography

Basic

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O.C. Zienkiewicz, R.L. Taylor , The Finite Element Method, Volume 1-3, 5th edition, Butterworth-Heinemann, Oxford, 2000. (7th edition - 2013: https://www.elsevier.com/books/the-finite-element-method-its-basis-and-fundamentals/zienkiewicz/978-1-85617-633-0)

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M.Łunc, A.Szaniawski, Zarys mechaniki ogólnej, PWN, Warszawa, 1959.

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Additional

J. Taler, P. Duda, Rozwiązywanie prostych i odwrotnych zagadnień przewodzenia ciepła, WNT, Warszawa 2003.

Mechanika techniczna. Komputerowe metody ciał stałych, pod red. M. Kleibera, PWN, Warszawa, 1995.

Andriy Milenin, Podstawy metody elementów skończonych. Zagadnienia termomechaniczne, Wydawnictwo AGH, 2010.

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E. Ott, Chaos w układach dynamicznych, WNT, Warszawa, 1997.

G.K. Susłow, Mechanika teoretyczna, PWN, Warszawa 1960.

W. Rubinowicz, W. Królikowski, Mechanika teoretyczna, PWNTaler J., Duda P.: Rozwiązywanie prostych i odwrotnych zagadnień przewodzenia ciepła, WNT, Warszawa 2003.

Mechanika techniczna. Komputerowe metody ciał stałych, pod red. M. Kleibera, PWN, Warszawa, 1995.

Breakdown of average student's workload

	Hours	ECTS
Total workload	125	5,0
Classes requiring direct contact with the teacher	62	2,5
Student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation) [1]	63	2,5

[1] delete or add other activities as appropriate