COURSE DESCRIPTION CARD - SYLLABUS

Course name

Optimization of mechatronic structures

Course

Field of study

Mechatronics

Area of study (specialization)

Level of study

Second-cycle studies

Form of study

full-time

Year/Semester

1/2

Profile of study

general academic

Course offered in

Polish

Requirements

compulsory

Number of hours

Lecture

15

Tutorials

15

Laboratory classes

15

Projects/seminars

Other (e.g. online)

Number of credit points

3

Lecturers

Responsible for the course/lecturer:

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Responsible for the course/lecturer:

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Prerequisites

Knowledge: Basic knowledge of mathematics, materials science, mechanics, the basics of machine design, theory of machines and mechanisms as well as the strength of materials acquired during the 1st and 2nd degree studies.

Skills: The ability to independently formulate a technical problem, develop a construction record in accordance with the rules of a technical drawing, calculate the strength of machine elements and shape the design features of machine components.

Social competences: Understanding the necessity of expanding one's competences, being ready to cooperate within the team.

Course objective

The aim of the course is to familiarize the student with the idea of optimal design and the construction of an optimization model based on a mathematical model of construction using analytical methods and computer programs (ABAQUS and ISIGHT).

Course-related learning outcomes

Knowledge

Has an extended knowledge of the strength of materials related to the safety and reliability of mechanical structures, calculation of composite elements, frames and curved bars as well as thin-walled tanks and thick-walled vessels. Has knowledge of the basics of optimal structure design. [K2_W03]

Has knowledge of computer structure analysis including advanced operations in the CAD environment, regarding 3D visualization and analysis of the cooperation of mechanical elements. [K2_W15]

Has an extended knowledge of mechatronics, knowledge of the analysis and design of complex mechatronic systems, systems theory and technology, and the application of modeling and simulation in mechatronic design. [K2_W09]

Skills

He can visualize a mechanical element in a 3D environment and analyze the cooperation of elements shown in the drawing. [K2_U19]

He can perform strength calculations allowing to determine the safety and reliability of selected mechanical structures. Is able to determine the strength of basic composite elements, frames and curved bars as well as thin-walled tanks and thick-walled vessels. [K2_U09]

Can design complex mechatronic devices and systems, using modeling and simulations. He can plan and carry out experiments, including measurements and computer simulations, interpret the obtained results and draw conclusions. [K2_U14]

He can use computer systems to design and operate mechatronic devices. Can implement control systems in the real-time operating system. He can use the basic methods of image processing and analysis. He can prepare software documentation. [K2_U15]

Social competences

Understands the need for lifelong learning; can inspire and organize the learning process of other people. [K2_K01]

Can set priorities for the implementation of a task set by oneself or others. [K2_K04]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: Written exam from the lecture containing a few open theoretical questions. Duration: 90 minutes.

Evaluation criteria: there is a certain number of points to be scored for each task (1-5 points), points are awarded with an accuracy of 0.25 points, there is a total of 10 points.

Rating scale: below 50% - 2.0, from 50% - 3.0, from 60% - 3.5, from 70% - 4.0, from 80% - 4.5, from 90% - 5.0.

Classes: Written test from exercises including 2-3 calculation or design tasks during the last class. Duration: 90 minutes.

Evaluation criteria: there is a certain number of points to be scored for each task (1-5 points), points are awarded with an accuracy of 0.25 points, there is a total of 10 points.

Rating scale: below 50% - 2.0, from 50% - 3.0, from 60% - 3.5, from 70% - 4.0, from 80% - 4.5, from 90% - 5.0.

Laboratory: Final assignement in the form of verification of practical skills to optimize a given construction example and to operate the ABAQUS and Isight programs. Assessment takes place during the last laboratory class and lasts 90 minutes. Ongoing verification of acquired skills during laboratory exercises.

Evaluation criteria: the correctness of the construction of the optimization model is assessed (75% of the rating) and its implementation in the ABAQUS / Isight program (25% of the rating)

Rating scale: below 50% - 2.0, from 50% - 3.0, from 60% - 3.5, from 70% - 4.0, from 80% - 4.5, from 90% - 5.0.

Programme content

Lectures:

Lecture 1 - Optimal design. Basic optimization concepts. Classification of optimization problems.

Introduction to optimal design. Basic optimization concepts: construction parameters, design assumptions, decision variables, objective function, optimization criteria, boundary conditions, weight functions. Classification of optimization problems.

Lecture 2 - Construction of the optimization model.

Development of a mathematical model of the structure. Building an optimization model. Examples of optimization of mechanical structures.

Lecture 3 - Procedures for static optimization.

Division of static optimization procedures. Graphical methods. Analytical methods (Lagrange multipliers method, Kuhn-Tucker conditions). Methods of mathematical programming. Variation methods. Numerical methods (Monte Carlo statistical method). Deterministic methods. Choosing the optimization procedure.

Lecture 4 - Modern optimization procedures.

Genetic algorithms and simulated annealing in optimization - basic concepts, principle of operation, advantages and disadvantages and examples.

Lecture 5 - Multi-criteria optimization.

Characteristics of multi-criteria optimization. Mathematical foundations. Multi-criteria optimization according to the Pareto concept. Application of multi-criteria optimization in engineering design. An example of multi-criteria optimization.

Lecture 6 - Optimization in mechatronics.

Optimization of mechatronic devices. Optimization when selecting the drive. Optimization in control systems.

Lecture 7 - Sensitivity analysis - Design of Experiment (DOE)

Planning the experiment. Analysis of the influence of design variables on the value of the objective function.

Lecture 8 - Exam

Written exam from the lecture containing a few open theoretical questions

Exercises:

Classes 1 - Parameterization of mechanical structures. Mathematical modeling of structures.

Exercises 2 - Building an optimization model for selected mechanical structures.

Exercises 3 - Solving single-criteria optimization problems.

Classes 4 - Solving multi-criteria optimization problems.

Classes 5 - Optimization of the selection of a mechatronic device drive

Exercises 6 - Optimization of the geometry of the working system of the machine.

Exercises 7 - Optimization of machine steering and control.

Classes 8 - Test

Written test for exercises containing 2-3 calculation or design tasks.

Laboratories:

Laboratory 1 - Introduction to ABAQUS and ISIGHT software

Laboratory 2 - Parametric optimization in ABAQUS software

Laboratory 3 - Topological optimization in the ABAQUS program

Laboratory 4 - Design of Experiment (DOE) analysis in the ISIGHT program

Laboratory 5 - Optimization in the ISIGHT program

Laboratory 6 - Modern optimization procedures in the ISIGHT program

Laboratory 7 - Approximation methods in optimization in the ISIGHT program

Laboratory 8 - Final assignement

Completion of the laboratory in the form of verification of practical optimization skills for a given construction example.

Teaching methods

Lecture: Lecture with multimedia presentation.

Classes: Blackboard exercises with a multimedia presentation, using the case study method - analysis of a solution to real construction problems.

Laboratory: Workshop methods of practical computer classes.

Bibliography

Basic

1. Ostwald M.: Podstawy optymalizacji konstrukcji. Wyd. Politechniki Poznańskiej, Poznań 2005.

2. Kusiak J., Danielewska-Tułecka A., Oprocha P.: Optymalizacja: Wybrane metody z przykładami zastosowań. Wyd. Naukowe PWN, Warszawa 2009.

3. Venkata Rao R., Savsani V.J.: Mechanical Design Optimization Using Advanced Optimization Techniques, Springer, Surat 2011.

4. Amborski K.: Podstawy metod optymalizacji. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2009.

Additional

1. Rothwell A.: Optimization Methods in Structural Design. Springer, Delft 2017.

2.Wojtkowiak D., Talaśka K., Fierek A.: The application of the Finite Element Method analysis in the process of designing the punching die for belt perforation, IOP Conferences: Materials Science and Engineering 776: 012057, 2020.

3. Wojtkowiak D., Talaśka K., Wilczyński D. i inni: Determining the Power Consumption of the Automatic Device for Belt Perforation Based on the Dynamic Model, Energies 14:1, 317, 1-15, 2021.

Breakdown of average student's workload

	Hours	ECTS
Total workload	75	3,0
Classes requiring direct contact with the teacher	45	2,0
Student's own work (literature studies, preparation for tutorials, preparation for tests, project preparation) [1]	30	1,0

[1] delete or add other activities as appropriate