COURSE DESCRIPTION CARD - SYLLABUS

Course name

Design of dynamics and durability of machine parts [S1MiBM2>PDTCM]

Course

Field of study
Mechanical Engineering

Year/Semester
4/7

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
15

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

KNOWLEDGE: Knows the basics of machine construction, knows the methods of computer aided design, knows the basics of material strength and metal science, knows the basics of structural mechanics (statics, stability and dynamics). SKILLS: Can use CAD software to generate models of virtual parts and assemblies. Can build simple FEM calculation models, including: can run a calculation solver and generate results in the form of stress maps. SOCIAL COMPETENCES: Ability to independently formulate problems of mechanical analysis of structures and to resolve related dilemmas. The ability to correctly plan and timely perform activities in the implementation of computational projects. In addition, students understands the need and knows the possibilities of continuous training.

Course objective

Provide students with knowledge of the use of modern CAE systems to simulate the dynamic response of load-bearing structures of machines and devices subjected to time-varying forces, as well as processing simulation results for the purpose of fatigue life estimation.

Course-related learning outcomes

Knowledge:

1. Knows the theoretical basis of computational methods used to evaluate the dynamic behavior of parts of machines and devices. [K_W06]
2. Knows the theoretical basis of fatigue analysis methods. [K_W04]

Skills:
1. Has knowledge of the NX Siemens software interface and can utilize it to develop virtual models of machine and device components. [K_U16]
2. Can utilize the finite element method for designing the instantaneous and fatigue strength of machine and device components. [K_U16]
3. Is capable of performing dynamic simulations, including generating the mechanical structure response to time-varying loads, as well as preparing visualizations of simulation results. [K_U16]
4. Can specify boundary and initial conditions and define loads when conducting analyses using computerized computational methods. [K_U16]
5. Can conduct engineering analysis and accurately interpret the results of computer simulations. [K_U12]
6. Can select fatigue analysis methods and draw conclusions towards determining the resistance of structures to the effects of time-varying loads. [K_U12]

Social competences:
1. Is aware of the importance of using computer methods to optimize the design processes of machines and devices. [K_K02]
2. Understands the need for continuous updating of knowledge in the field of CAD software. [K_K01]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Lecture: Written exam to verify the knowledge of fatigue analysis methods and procedures for the implementation of dynamic analyzes using FEM.
Laboratory: Current assessment of the progress of work after each completed unit on the basis of reports and completion of the simulation and fatigue calculations for a selected case.

Programme content

Lectures:
Lecture 1 - The role of fatigue analysis in shaping the load capacity of the structure
Discussion of the role and importance of fatigue analysis in the assessment of the strength of machine parts and devices. Also discussion of the role of dynamic analyzes in the process of generating information necessary to estimate fatigue life.
Lecture 2 - Response dynamics analyzes - modeling of loads (kinematic and force excitations)
Discussion of the basic concepts of the analysis and systematization of loads that varying in time and their definition for the purposes of performing dynamic tests with the use of FEM. Acquainting with basic concepts, including: determined and stochastic load, stationarity and spectral characteristics.
Lecture 3 - Response dynamics analyzes in a modern computer system - part 1
Overview of computer dynamic analysis procedures using the "step by step" method on a selected example in the NX Siemens system. Acquainting with basic techniques for defining boundary conditions, building a computational model and generating results.
Lecture 4 - Methods of defining damping in dynamic response simulations.
Discussion of the issues of defining damping in dynamic response simulations. Familiarization with basic concepts, including viscous damping, hysteresis damping and the Raylegh model. Introduction to modal analysis as a tool for determining the actual damping coefficients.
Lecture 5 - Response dynamics analyzes in a modern computer system - part 2
Discussion of the methods of processing the results of dynamic analyzes and their role in fatigue life estimation.
Lecture 6 - Fatigue analysis - basic concepts
Overview of the phenomenon of metal fatigue. Acquainting with basic terms and concepts, including: types of stresses and deformations, fatigue material characteristics, elements of fracture mechanics, sources of intensification of the wear process (notch, temperature, frequency of loads, etc.)
Lecture 7 - Fatigue analysis methods
Discussion of modern methods of fatigue analysis, including: counting fatigue cycles from a time history (Rainflow method), failure accumulation hypotheses, methods of capturing the influence of average

stresses, number of cycles and multidimensionality of the stress tensor. Conducting a discussion on the source and scale of errors in the sustainability estimation process. Presentation of the fatigue life determination procedure.
Laboratories:
Laboratory 1 - NX Siemens software interface
Familiarization with the NX Siemens software interface and its operation methods. Discussion of the basic functions of the program, including sketch creation and applying constraints. Development of simple geometries through extrusion, rotation, and surface generation from a system of lines. Handling program messages and acquiring basic skills in their proper interpretation.
Laboratory 2 - Building a virtual model
Deepening knowledge and expanding skills in the use of the program. Developing three-dimensional geometry for the chassis frame of a buggy-type vehicle according to the student's own idea. Discussing synchronous modeling options as an efficient method to accelerate the generation of the solid model. Exploring the assembly creation module.
Laboratory 3 - Modeling of a virtual model of an vehicle.
Continuation of work on developing the three-dimensional chassis frame of a vehicle. Implementation of screw connections, pin joints, and contact couplings. Refinement of the structural form of the frame, as well as the development of a simple suspension model.
Laboratory 4 - Preparation of a geometric model for computer calculations.
Preparing a virtual model for mesh application by removing irrelevant and insignificant features of the model. Simplifying geometry: removing fillets, notches, redefining and stitching surfaces, cutting and dividing surfaces, and converting the solid model into a surface model.
Laboratory 5 - Generating a computational model for structural calculations.
Discussing types of finite element meshes and their generation using automatic meshing options. Evaluating finite elements, including understanding basic parameters determining their quality and discussing the influence of mesh imperfections on calculation results. Discussing methods for repairing finite element meshes.
Laboratory 6 - Defining of boundary conditions for strength simulations.
Discussing types of boundary conditions, including restraining degrees of freedom and applying loads. Conducting initial computer simulations in the static domain. Discussing the effects of improper model support and errors in implementing force and kinematic loads. Discussing types of computational solvers and software post-processor handling. Generating results in the form of stress maps, displacement fields, and reading reactions at supports.
Laboratory 7 - Computer simulations in the static domain.
Conducting computer simulations in the static domain for the worst-case loading scenario. Assessing the impact of changing the model support method on results. Proper interpretation of results, searching for "numerical" stress concentration locations (method error), comparing stress maps with permissible stresses, and preliminary refinement of the vehicle frame design.
Laboratory 8 - Evaluation of weld strength using the Hot Spot method.
Discussing the assumptions of the method. Processing the computational model to enable reading representative stresses. Building a "calculator" for extrapolating stresses in welds. Discussing methods for interpreting stresses in welds.
Laboratory 9 - Preparation for structural dynamics calculations part 1.
Discussing computational solvers for implementing calculations using the modal superposition method and the direct integration method. Generating modal characteristics of the structure, discussing damping models (including Rayleigh's model and hysteresis and viscous damping). Interpreting numerical calculation results, including the form and frequencies of natural vibrations.
Laboratory 10 - Preparation for structural dynamics calculations part 2.
Generating kinematic and force excitations as harmonic, polyharmonic, and random functions. Assessing the stationarity of load profiles and discussing basic functions describing the random process, relevant for correct preparation of excitation spectra. Implementing time profiles in the software for selected computational nodes.
Laboratory 11 - Processing dynamic simulation results.
Generating time-dependent stress fields. Visualizing structural behavior. Processing stress profiles using the Rainflow method and the Palmgren-Miner cumulative damage hypothesis. Generating the basic Rainflow matrix and determining the damage ratio using a spreadsheet.
Laboratory 12 - Estimating the fatigue life of selected structural nodes, part 1.
Conducting fatigue analyses using processed stress profiles and basic fatigue characteristics, such as the Wöhler curve. This includes further processing of profiles using a selected method of mean stress influence on fatigue strength and implementing the Palmgren-Miner damage accumulation hypothesis.

Laboratory 13 - Estimating the fatigue life of selected structural nodes, part 2.
Conducting fatigue analyses using processed stress profiles and two-parameter fatigue characteristics, such as the fatigue plane. Identifying sources of discrepancies and quantitatively estimating inference errors.
Laboratory 14 - Design upgrade.
Introducing structural changes to increase fatigue strength and re-conducting calculations. Reinforcing knowledge and discussing the impact of implemented design solutions on durability.
Laboratory 15 - EXAM
Independent student work involving estimating fatigue strength for a fragment of a selected machine as chosen by the instructor.

Course topics

none

Teaching methods

1. Lecture with multimedia presentation
2. Laboratories - own design and analytical work with the use of NX Siemens software

Bibliography

Basic:
1. Reiner Anderl, Peter Binde Simulations with NX, Hanser Publications, 2018
2. Łodygowski T., Kąkol W., Metoda elementów skończonych w wybranych zagadnieniach mechaniki konstrukcji inżynierskich, Poznań, WPP 1994
3. Kocańda S., Szala J.: Podstawy obliczeń zmęczeniowych. Wydawnictwo Naukowe PWN, Warszawa, 1997.
4. Bendat J.S., Piersol A.G.: Random Data: Analysis and Measurement Procedures, 4th Edition 2010
5. User manual NX Siemens 2020

Additional:
1. Kleiber M., Wprowadzenie do metody elementów skończonych, Poznań, WPP 1984
2. Kleiber M., Numeryczna analiza statycznych i dynamicznych zagadnień stateczności konstrukcji, Poznań, WPP 198

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	45	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	55	2,00