Syllabus
Course Program

Computer Modeling of Dynamics and Vibration Protection of Rotary Machines

Specialty
113 – Applied Mathematics

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer and Mathematical Modelling

Department
Mathematical Modeling and Intelligent Computing in Engineering (161)

Level of education
Master's level (1 year 4 months

Course type
Special (professional), Elective

Semester
1

Language of instruction
English

Lecturers and course developers

Anton Vasiliev

Anton.Vasiliev@khpi.edu.ua
Ph.D., senior researcher, assistant professor
Experience – 20+ years. Author of 100+ scientific papers. Lecturer of the disciplines: «Computer Aided Design and Engineering», «Computer modeling of dynamics and vibration protection of rotary machines», «Modeling of nonlinear processes in CAE»
More about the lecturer on the department's website

General information

Summary

The Course describe the inevitability of vibration in rotating machinery due to imperfections in rotor balancing, emphasizing the crucial role of setting appropriate vibration limits for machine durability. It highlights the technical complexity of addressing vibration issues across various industries and aims to enhance understanding and competence in managing rotating machinery vibration.

Course objectives and goals

Aims to underscore the significance of establishing suitable vibration limits crucial for machine durability while shedding light on the technical intricacies of managing rotating machinery vibrations across diverse industries. It endeavors to enhance in-house competency in dealing with rotor vibrations, addressing the need for diagnosis and correction to resolve excessive vibration incidents. The Course is structured into four parts to guide and inform on these aspects.

Format of classes

Lectures, laboratory classes, consultations, self-study. Final control in the form of a credit.

Competencies

PC1. Ability to solve tasks and problems that can be formalised, require updating and integrating knowledge, in particular in conditions of incomplete information.

PC2. Ability to conduct scientific research aimed to develop new and adapt existing mathematical and computer models to study various processes, phenomena and systems, conduct appropriate experiments and analyse the results.
PC4. Ability to develop and research mathematical and computer models, conduct computational experiments and solve formalised problems using specialised software.
PC9. The ability to mathematically formalise the formulation of scientific and practical problems, to choose a mathematical analytical or numerical method of its solution, which ensures the required accuracy and reliability of the result.
PC10. Ability to develop mathematical methods and algorithms for computer modelling of nonlinear physical phenomena and processes in innovative technological systems.
PC11. Ability to mathematically describe various dynamic processes that can occur in systems of design objects.

Learning outcomes

LO4. Build mathematical models of complex systems and choose methods of their research, implement the built models in software and check their adequacy using computer technologies.
LO14. To have the knowledge to mathematically formalise the formulation of scientific and practical problems, to choose a mathematical analytical or numerical method of its solution, which ensures the required accuracy and reliability of the result.
LO17. Possess knowledge of the mathematical description of various dynamic processes that can occur in systems of design objects.

Student workload

The total volume of the course is 120 hours (4 ECTS credits): lectures - 32 hours, laboratory classes -16 hours, self-study - 72 hours.

Course prerequisites

Basic knowledge of Math (trigonometry, matrix, differential and integral equation, numerical methods, FEM), Mechanics (kinematics, dynamics, structural analysis, theory of vibrations), mechanical design, CAD. Skills in CAD.

Features of the course, teaching and learning methods, and technologies

Not applicable

Program of the course

Topics of the lectures

Topic 1. Introduction to course. Rotary machines. Vibration in Rotary Machines.
General Description, types, main features. List of CAE software for simulating Rotary Machines and vibration processes.
Topic 2. Short descriptions about vibrations.
2.1 Oscillations and Vibrations.
2.2 Kinematics of vibrations. Harmonic oscillation. Synchronous harmonic oscillation.
2.3 Vibro-translation, vibro-velocity, vibro-acceleration.
2.4 Polyharmonic vibration. Modulated oscillation.
2.5 Oscillation of system with 1 degree of freedom (1 DoF). Oscillation of 2 DoF system.
2.6 Forced oscillations of Multi-DoF System. Rotating Machines as oscillation system.
2.7 Math methods for modeling behavior of 1 DoF - Multi-DoF systems.
2.8 Numerical simulation of 1 DoF - Multi-DoF systems with Computer Software.
Topic 3. Main source of vibrations.
3.1 Mechanical disbalance.
3.2 Rotor (Shaft) Deflection.
3.3 Tolerance of producing and assembly.
3.4 Couplings. Defects of Couplings. Rigid, Semi rigid, Flexible, Movable Coupling. Coupling misalignment.

3.5 Stiffness of bearings and supports. Reduction of stiffness. Anisotropic and Nonlinear behavior. Vibration from rolling bearings. Axial vibration in bearings. Defects in bearings.
3.6 Mechanical cracks in different parts.
3.7 Dual stiffness of shaft.
3.8 Thermal debalance.
3.9 Gears as source of vibration.
3.10 External forces.
3.11 Computer modeling of defects and factors to a rotor behavior and vibration.
Topic 4. Vibrational diagnostic
4.1 General Information. Tasks and Targets. Tools and Methods. Methodology.
4.2 Vibrosignal processing. Harmonics Analysis. Spectral Analysis. Examples.
4.3 Automated diagnostic Systems.
4.4 Computational Diagnostic of vibrational Characteristic.
4.5 Computational Diagnostic of Fatigue.
Topic 5. How to balance Rotating Machines.
5.1 Experimental approaches in rotor balancing process.
5.2 Computational Simulation of rotor balancing process with CAE software.
Topic 6. Campbell diagram.
Numerical methods used for obtaining Campbell diagram for rotating machines. Computer Simulation of rotor machines behavior on critical speed. Comparison of influence of math models description of rotor machines to process of error estimation and methods convergences.

Topics of the workshops

Non Applicable

Topics of the laboratory classes

Topic 1. Analyzing CAD models of Rotary machines.
Topic 2. Modeling examples of simple vibrations.
Oscillation of system with 1 degree of freedom (1 DoF).
Oscillation of 2 DoF system.
Forced oscillations of Multi-DoF System.
Rotating Machines as oscillation system.
Topic 3. Simulating influences of different source of vibrations in Rotary Machines to its Behavior using CAE Software.
3.1 Mechanical disbalance.
3.2 Rotor (Shaft) Deflection.
3.3 Tolerance of producing and assembly.
3.4 Couplings. Defects of Couplings.
3.5 Stiffness of bearings and supports. Reduction of stiffness. Anisotropic and Nonlinear behavior.
3.6 Mechanical cracks in different parts.
3.7 Dual stiffness of shaft.
3.8 External forces.
Topic 4. Vibrational diagnostic.
4.1 Computational Diagnostic of vibrational Characteristic.
4.2 Computational Diagnostic of Fatigue.
Topic 5. How to balance Rotating Machines.
5.1 Balancing a rotor.
Topic 6. Campbell diagram.
5.1 Obtaining a Campbell diagram for different rotor Machines.

Self-study

Information on self-study and individual assignments (reports, course projects, etc.), if it is necessary according to the plan. Also, methods of control and assessment of self-study.
Students need to learn machine structure of different type of rotating machines:
1. General Machines

2. Steam Turbine and Generators
3. Critical Machines
4. Gas Turbines
5. Hydro Turbine
6. Reciprocating Machinery
7. Pump
8. Reciprocating Compressors
9. Onshore Wind Turbines with Gearbox
And write essay about this machines

Course materials and recommended reading

Compulsory materials
1. Giancarlo Genta. Dynamics of Rotating Systems. Springer. 2004 674p. ISBN 0-387-20936-0
2. Adams, Maurice L. Rotating machinery vibration: from analysis to troubleshooting / author, Maurice L. Adams. 2010. 478p ISBN 978-1-4398-0717-0
3. Alok Sinha. Vibration of mechanical systems. The Pensylvania State University. 2010. 330p. ISBN-13 978-0-511-77527-7
4. Allen S. Hall. Machine Design. Allen S. Hall., Alfred R. Holowenko, Herman G. Laughlin. McGraw-Hill Inc. 1961. 351 p. ISBN 07-025595-4
5. Ullman, David G. - The mechanical design process / David G. Ullman. - 4th ed. McGraw-Hill Inc. 1944. 448 p. ISBN 978-0-07-297574-1
6. the Jet engine. Rolls-Royce plc. 1986. 292 p. ISBN 0902121 235
7. Mechanical vibrations. Theory and applications. S. Graham Kelly. 2011. 898 p. ISBN-13: 978-1-4390-6214-2
8. http://courses.ansys.com

Additional materials
1. ISO/TC 108/SC 2 Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures
2. ISO 10816-1: General Machines
3. ISO10816-2: Steam Turbine And Generators
4. ISO10816-3: Critical Machines
5. ISO10816-4: Gas Turbines
6. ISO10816-5: Hydro Turbine
7. ISO10816-6: Reciprocating Machinery
8. ISO10816-7: Pump
9. ISO10816-8: Reciprocating Compressors
10. ISO10816-21: Onshore Wind Turbines With Gearbox

Assessment and grading

Criteria for assessment of student performance, and the final score structure

Criteria for assessment of student performance, and the final score structure

Total mark (100 points) consists of three parts:
1. Test on theory (50 points)
2. Practice (lab) passing (40 points)
3. Essay 10 points

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.
Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by	Date August 30, 2023	Head of the department Oleksii VODKA
	Date August 30, 2023	Guarantor of the educational and professional program (1 year 4 months) Oleksiy LARIN