Syllabus
Course Program

Contact Mechanics and Numerical Modeling of Impact

Specialty
113 – Applied Mathematics

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer and Mathematical Modeling

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

Gennadiy Lvov

Gennadiy.Lvov@khpi.edu.ua
professor, doctor of technical sciences
Scopus: Scopus Author ID: 6506190655
ORCID: http://orcid.org/0000-0003-0297-9227
ResearcherID: U-8774-2017

More about the lecturer on the department's website

General information

Summary

The basics of the general theory and methods of calculation of impact problems in mechanical systems are given, as well as methods of calculation of fast dynamic processes, in which the starting point is the impact interaction of two bodies.

The application of impact theory, based on the methods of theoretical mechanics and mechanics of a rigid deformed body, is considered. Mathematical models of the propagation of shock waves in three-dimensional bodies and thin-walled structural elements have been constructed. In practical classes, students gain experience in using modern software complexes for calculating impact phenomena..

Course objectives and goals

The purpose of teaching the academic discipline "Contact problems of the mechanics of a rigid deformed body" is the formation of students' abilities:
- identify cases of the need to use certain methods and algorithms of the contact mechanics of a deformed solid body; - set a mathematical problem (write out a system of equations with initial and boundary conditions), which will be adequate for solving the actual problem;
- appoint an effective method and algorithm, or choose an existing program that will allow solving the given contact task on a PC;

- perform calculations, analyze their results and make a decision about the sufficient quality of the obtained results or about the need to make changes in the formulation of the boundary value problem or the method and algorithm of its solution;
- prepare the results of calculations in the form of a report, using the relevant standards, recommendations and requirements of the customer interested in solving the current problem
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Format of classes

Lectures, practical 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.

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.
LO16. Be able to develop mathematical methods and algorithms for computer modelling of nonlinear physical phenomena and processes in innovative technological systems.

Student workload

The total volume of the discipline is 120 hours. (4 ECTS credits): lectures – 32 hours, laboratory work – 16 hours, independent work – 72 hours.

Course prerequisites

To study the course, students need basic knowledge of
- theoretical mechanics;
- linear theory of elasticity;
- theories of oscillations
- skills in using software tools for solving mathematical problems.

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

The educational process includes: lectures using computer and information tools; practical classes, independent work. When teaching the lecture course, methods of problem-based learning are applied by applying such forms of learning as thematic and problem-based lectures. The purpose of such lectures is to develop students' logical and independent understanding of material.

Practical classes of meaningful modules are planned for each topic, include preparation for practical classes according to the specified plan; execution of control tasks; review of scientific publications on the selected issue. The following forms and methods of teaching are used: explanation, discussion, debate, writing theses, creating presentations, forming individual components of scientific works.

Students' independent work includes: preparation for practical classes, study of recommended scientific literature, writing reports, preparation for modular tests and assessment. Tasks of students' independent

work are considered completed if they: are submitted within the specified time and are fully completed (reveal the topic of the task); do not have logical and calculation errors.

Program of the course

Topics of the lectures

Topic 1. Introduction
Peculiarities of statements of contact problems of the mechanics of a deformed body.
Topic 2. Flat contact problem of elasticity theory.
- Action of a concentrated force on the edge of a half-plane.
- Integral equation for contact pressure.
- A solution for the contact of bodies with smooth edges and a flat stamp.

Topic 3. Spatial contact problems.
- Action of a concentrated force in an unlimited space
- Elementary solutions of the first and second type
- The tense state of the half-space. Bussenesque's problem.
- Hertz's solution.

Topic 4. Elements of impact theory
- Basic definitions
- Newton's hypothesis about the coefficient of recovery
- Direct central impact of two balls
- The Ostrogradsky-Carnot theorem
- Appel's classification

Topic 5. The action of given impulses on an absolutely solid body
- Free body blow
- Body kick with one fixed point
- A blow to the body with a fixed axis

Topic 6. Sudden superimposition of ideal bonds on an absolutely solid body
- Stop point of the free body
- Sudden stop of a body that rotates around a fixed axis
- Sudden stopping of a point of a body that performs spherical motion.

Topics of the workshops

Topics of the laboratory classes

LABORATORY WORK No. 1. COMPLETELY INELASTIC IMPACT OF TWO BODIES

LABORATORY WORK No. 2. ABSOLUTELY ELASTIC CO-IMPACT OF TWO BALLS

LABORATORY WORK No. 3. IMPACT OF AN ELASTIC ROD AGAINST A RIGID OBSTACLE

LABORATORY WORK No. 4. TORSIONAL IMPACT OF A ROD

LABORATORY WORK No. 5. ELASTO-PLASTIC IMPACT OF A CYLINDER AGAINST A RIGID OBSTACLE

LABORATORY WORK No. 6. AN INDELISTIC IMPACT ON A BEAM WITH PINCHED EDGES

LABORATORY WORK No. 7. ELASTIC IMPACT OF A BULLET ON A ROUND PLATE

LABORATORY WORK No. 8. IMPACT ON AN ELASTIC ROD.

Self-study

Preparation for practical classes. Completion of mandatory homework

Course materials and recommended reading

Basic literature

1 A.I. Lurie. Theory of elasticity. Springer-Verlag Berlin Heidelberg.
2. S. Timoshenko, S. Woinuwsky-Krieger. Theory Plates and Shells. New-York, 1987.-635 p.– 10202p.
3. Jan Awrejcewicz. Theory of impact. https://www.researchgate.net/publication/302222277

Assessment and grading

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

To assess a student's performance, a point accumulation system is used. Maximum number of points for:
- independent work 5 points,
- control work 10 points,
- modular test 15 points.
- mandatory homework 20 points.

As an alternative to the cumulative point system, it is possible to take a written exam

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