Syllabus

Course Program

Mathematical Models of Composite Materials

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
2

Language of instruction
English

Lecturers and course developers

Victor Fedorov (responsible lecturer)

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PhD, Associate Professor of the Department " Mathematical modeling and intelligent computing in engineering "

Author of more than 40 scientific and methodical publications.
Courses: "Computational methods", "Nonlinear models of a deformed body", "Mathematical Models of Composite Materials"
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More about the lecturer on the department's website

Serhii Misiura (assistant)

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PhD, Associate Professor of the Department " Mathematical modeling and intelligent computing in engineering "

Author of more than 60 scientific and methodical publications.
Courses: "Frontend development", "Backend development", "Computer networks and distributed computing", "Fundamentals of WEB technologies", "Technologies and tools for teamwork on projects", "System administration", "Development of server applications"
More about the lecturer on the department's website

General information

Summary

Composite materials have the best mechanical properties and are an important factor in technical progress. This discipline provides knowledge of the behavior of composite materials and structural elements under the influence of loads, which allows predicting the possible destruction of structures. This is a mandatory component of the design of modern technology.

Course objectives and goals

The goal of studying the discipline is to acquire the ability to study the stressed and deformed state (SDS) of composite elements of structures and predict their possible destruction, taking into account their anisotropy and heterogeneity.
Objectives: assimilation of knowledge from the theoretical foundations of the mechanics of anisotropic and non-homogeneous materials and structural elements, formulation of their mathematical models and the ability to apply them to the study of SDS and rupture conditions of composite elements of structures.

Format of classes

Lectures, laboratory classes, independent work, consultations, calculation work. Final control in the form of credit.

Competencies

GC3. Ability to master modern knowledge, formulate and solve problems.
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.
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 course is 120 hours (4 ECTS credits): lectures - 32 hours, laboratory classes - 16 hours, self-study - 72 hours.

Course prerequisites

The student may have knowledge of the theory of elasticity and the theory of shells.

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

Presentation of theoretical material in lectures is supplemented by laboratory classes, in which students solve practical problems with computing tools available to them. The results are drawn up in the form of reports, which should contain the conditions of the problem, its mathematical model, the sequence of calculations and the results in numerical and (or) graphic form. All actions must be accompanied by short comments. Appropriate work is graded after a short survey on this topic.

Program of the course

Topics of the lectures

Topic 1. Introduction to Composite Materials

General History. Composite Material Description. Types of Composite Materials. Constituent. Properties.

Composite Manufacturing, Fabrication and Processing. Uses of Composite Materials. Design and Analyses with Composite Materials. Journals.

Topic 2. Anisotropic elasticity and composite laminate theory

The anisotropic elastic stiffness and compliance matrices. The physical meaning of the components of the orthotropic elasticity tensor. Methods to obtain composite elastic properties from fiber and matrix properties. Thermal and hygrothermal considerations. Time-temperature effects on composite materials. High strain rate effects on material properties. Laminae of composite materials. Laminate analyses. Piezoelectric effects.

Topic 3. Plates and panels of composite materials

Plate equilibrium equations. The bending of composite material laminated plates: classical theory. Classical plate theory boundary conditions. Navier solutions for rectangular composite material plates. Navier solution for a uniformly loaded simply supported plate – an example problem. Levy solution for plates of composite materials. A static analysis of composite material panels including transverse shear deformation effects. Boundary conditions for a plate using the refined plate theory which includes transverse shear deformation. Composite plates on an elastic foundation. Solutions for plates of composite materials including transverse-shear. Dynamic effects on panels of composite materials. Natural flexural vibrations of rectangular plates: classical theory. Natural flexural vibrations of composite material plate including transverse-shear deformation effects. Buckling of a rectangular composite material plate – classical theory. Buckling of a composite material plate including transverse-shear deformation effects. Methods of analysis for sandwich panels with composite material. Governing equations for a composite material plate with mid-plane asymmetry. Governing equations for a composite material plate with bending- twisting coupling.

Topic 4. Beams, columns and rods of composite materials

Development of classical beam theory. Composite beams with abrupt changes in geometry or load. Solutions by green’s functions. Composite beams of continuously varying cross-section rods. Vibration of composite beams. Beams with mid-plane asymmetry. Advanced beam theory for dynamic loading including mid-plane asymmetry. Advanced beam theory including transverse shear deformation effects. Buckling of composite columns.

Topic 5. Composite material shells

Analysis of composite material circular cylindrical shells. Some edge load and particular solutions. A general solution for composite cylindrical shells under axially symmetric loads. Response of a long axi-symmetric laminated composite shell to an edge displacement. Sample solutions. Mid-plane asymmetric circular cylindrical shells. Buckling of circular cylindrical shells of composite materials subjected to various loads. Vibrations of composite shells.

Topic 6. Energy methods for composite material structures

Theorem of minimum potential energy. Analysis of a beam using the theorem of minimum potential energy. Minimum potential energy for rectangular plates. Use of the theorem of minimum potential energy to determine buckling loads in composite plates. Reissner’s variational theorem and its applications. Static deformation of moderately thick beams. Flexural vibrations of moderately thick beams.

Topic 7. Strength and failure theories

Failure of monolithic isotropic materials. Anisotropic strength and failure theories. Lamina strength theories. Laminate strength analysis.

Topics of the laboratory classes

Topic 1. Anisotropic elastic matrices of stiffness and compliance

Topic 2. Methods of obtaining the elastic properties of the composite from the properties of the fiber and the matrix

Topic 3. Research of SDS of plates from composite materials

Topic 4. Intrinsic bending vibrations of a plate made of composite material

Topic 5. Study of SDS of beams

Topic 6. Study of SDS of axisymmetric shell

Topic 7. Analysis of the strength of composite elements of structures

Self-study

Elaboration of lecture material.

Preparation for laboratory classes.
Independent study of topics and issues that are not taught in lectures.
Execution of individual calculation works.

Course materials and recommended reading

1. Vinson J. R., Sierakowski R. L. The Behavior of Structures Composed of Composite Materials. New York, Boston, Dordrecht, London: Kluwer Academic Publishers, 2004. 435 p.
2. Altenbach H., Altenbach J., Kissing W. Mechanics of Composite Structural Elements. Singapore: Springer, 2018. 503 p.
3. Jones R. M. Mechanics Of Composite Materials. – Boca Raton: CRC Press, 2018. – 538 p.
4. Low I. M., Dong Y. Composite Materials: Manufacturing, Properties and Applications. Elsevier Science, 2021. 688 p.
5. Christensen R. M. Mechanics of Composite Materials. New York: John Wiley and Sons, Inc., 1979

5. Kaw A. K. Mechanics of composite materials. Boca Raton : CRC Pres, Taylor & Francis Group, 2006. – 457 p. https://sarrami.iut.ac.ir/sites/sarrami.iut.ac.ir/files/files_course/01-mechanics_of_composite_materials_sbookfi.org_.pdf

Tasks and methodical instructions for solving them will be sent when studying the relevant topics

Assessment and grading

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

Currently, the successful completion of nine tasks is assessed at 10 points.
The results of theoretical knowledge training are valued at 10 points, for a total of 100 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 Oleksiy VODKA
	Date August 30, 2023	Guarantor of the educational and professional program (1 year 4 months) Oleksiy LARIN