Syllabus

Course Program

Modern Methods of Modeling the Mechanics of Fracture of Materials and Structures

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

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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", "Modern Methods of Modeling the Mechanics of Fracture of Materials and Structures"

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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 purpose of studying the discipline is to acquire the ability to analyze the operating conditions of materials and structures and predict their possible destruction, which is necessary when designing new equipment.
Objectives: learning the theoretical foundations of the mechanics of the destruction of materials and structural elements, formulating their mathematical models and being able to apply them to predict the destruction of materials and structural elements.

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

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. The role of fracture studies in structural design
Design definition. The main problem. Some design goals.
Topic 2. Types of mechanical destruction
Determination of the type of destruction. Types of destruction observed.
Topic 3. Strength and deformation of metals
Stressed state at a point. Elastic and plastic deformation. Destruction. Introduction to the theory of dislocations. Introduction to the mechanics of linear elastic failure. Use of fracture mechanics during design. Mechanics of elastoplastic failure
Topic 4. Physical addictions
Dependencies between conventional and real stresses and strains. Dependence between stresses and

deformations in the elastic region. Dependence between stresses and strains in the plastic region.
Topic 5. Hypotheses of failure under complex stress state and their use in calculations
Hypothesis of maximum normal stress (Rankin's hypothesis). Hypothesis of maximum tangential stress (Triska-Gest hypothesis). Hypothesis of maximum linear deformation (Saint-Venant hypothesis). Hypothesis of total specific energy of deformation (Beltrami's hypothesis). The hypothesis of the specific energy of a change in form (hypothesis of Huber - Mises - Genki). Comparison of different hypotheses of failure under biaxial tension. Mohr's strength hypothesis. Pysarenko-Lebedev strength hypothesis. Hypotheses of destruction under a complex stress state in design.
Topic 6. Multicycle fatigue
The nature of fatigue. Tired load. Laboratory fatigue tests. Fatigue curves of equal probability of failure are the main source of information used in calculations. Factors influencing fatigue curves of equal probability of failure. Consideration of various factors during design. The influence of the average stress of the cycle. Fatigue in a multiaxial tense state. The application of fatigue failure hypotheses under multiaxial stress conditions.
Topic 7. Issues of damage accumulation, durability assessment and destruction control
Hypothesis of linear damage accumulation. Hypotheses of injury accumulation. Construction of damage equations. Durability assessment based on the analysis of the local dependence of stresses on deformations and the use of fracture mechanics. Study of crack propagation by methods of fracture mechanics. Simulation of operational loads and full-scale fatigue tests. Allowable damage and failure control.
Topic 8. Application of statistics in fatigue research
Distribution of aggregates. Selective distributions. Statistical hypotheses. Confidence limits. Properties of good grades. Sample size for the required level of confidence. Probability paper. Comparison of mean values and variances.
Topic 9. Fatigue test methods and statistical processing of test results
Standard method. Constant Amplitude Cycle Voltage Test, Dual Outcome Method, or Survival Evaluation Method. Stepped load method. Method About. The "ladder" method. Method of limiting values.
Topic 10. Low-cycle fatigue
Cyclic deformation. The curve of dependence of deformation on durability and the correlation of the theory of short-cycle fatigue. The influence of the average deformation of the cycle. and average voltage of the cycle. Accumulation of short-cycle fatigue damage. The influence of the multiaxiality of the stressed state. The relationship between thermal and low-cycle fatigue.
Topic 11. Stress concentration
Consequences of stress concentration. The coefficient of stress concentration in the elastic. region Coefficients of stress concentration and deformations in the plastic region. Stress concentration coefficients for multiple cutouts. Fatigue stress concentration coefficients and notch sensitivity index.
Topic 12. Creep, creep rupture, and fatigue
Prediction of behavior during prolonged creep. Dependencies for predicting creep behavior. Creep under uniaxial stress. Creep under multiaxial stress conditions. Accumulated creep formation. Joint action of creep and fatigue.
Topic 13. Fretting, fretting fatigue and fretting wear
Factors affecting the fretting process. Fretting fatigue. Fretting wear. Fretting corrosion. Minimizing or preventing fretting damage.
Topic 14. Wear, corrosion and other types of destruction
Wear. Empirical model of zero attrition. Corrosion. Stress corrosion cracking.

Topics of the laboratory classes

Topic 1. Stress state at a point
Topic 2. Mechanics of linear elastic failure
Topic 3. Hypotheses of destruction under a complex stress state
Topic 4. Multicycle fatigue
Topic 5. Accumulation of damage
Topic 6. Application of statistics in fatigue research
Topic 7. Short-cycle fatigue
Topic 8. Creep, creep rupture and fatigue

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. Collins J.A. Failure of materials in mechanical design. New York, John Wiley and Sons. 1993. – 672 p.
2. Bansal R. K. Strength of Materials / R. K. Bansal. – Laxmi Publications, 2010. – 1106 p.
3. Case J. Strength of Materials and Structures / J. Case, C.T.F. Ross. Butterworth-Heinemann, 1999. 720 p.
4. Fedorov V. Theory and methods of constructing equations for the evolutionary damageability of materials. International Journal of Damage Mechanics. 2023, Vol. 32, Iss. 10, pp. 1144–1163. DOI: 10.1177/10567895231191149.

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