Syllabus
Course Program

Computer Solution of Coupled Problems

Specialty
113 – Applied Mathematics

Educational program
Computer and Mathematical Modeling

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

Semester
2

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Department
Mathematical Modeling and Intelligent Computing in Engineering (161)

Course type
Special (professional), Elective

Language of instruction
English

Lecturers and course developers

Lyudmyla ROZOVA (lecturer and practical lessons)

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PhD, Associate Professor of the Department of Mathematical Modeling and Intelligent Computing in Engineering of NTU "KhPI"

More about the lecturer on the department's website

General information

Summary

The discipline "Computer solution of coupled problems" is aimed at studying the main approaches for solving coupled problems of computational fluid dynamics, heat transfer and structural strength analysis using modern multi-purpose software systems for design and analysis with a view to further application in professional activities. The discipline is presented in the 2nd semester and provides: 32 hours of lectures, 16 hours of laboratory classes, 72 hours of independent work.

Course objectives and goals

The goal of the discipline is to obtain knowledge on approaches to formulating coupled problems of computational fluid dynamics, heat transfer, structural analysis, modern approaches and tools for numerical modeling, skills and abilities to apply them in solving practical problems of a computational and research nature.
The goals of teaching the discipline are to provide students with in-depth knowledge about the features of using software for computer solving coupled problems of computational fluid dynamics, heat transfer and structural strength analysis, interpretation of calculation results and their further use. The acquisition of skills and abilities to apply the received knowledge occurs when solving practical problems by the use of the ANSYS software package, its interactive platform ANSYS Workbench, a special module for flow modeling ANSYS Fluent and a structural analysis module ANSYS Mechanical, in their realization in the student version in free access.

Format of classes

Lectures, laboratory classes, independent work. Final control in the form of 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.
PC3. Ability to develop methods and algorithms for the construction, research and software implementation of mathematical models in engineering, physics, biology, medicine and other fields and to analyse them.
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 course is 120 hours (4 ECTS credits): lectures - 32 hours, laboratory classes - 16 hours, self-study - 72 hours.

Course prerequisites

Methods of mathematical modeling and data analysis, Modeling in CAE systems, Nonlinear processes and models.

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

Classes are provided interactively using multimedia technologies. To master practical skills, the following software components are used: the ANSYS software package, its interactive platform ANSYS Workbench, a special module for flow modeling ANSYS Fluent and the structural analysis module ANSYS Mechanical, in their realization in the student version in free access. The student is required to attend all scheduled classes and perform laboratory work. Maintain ethical behavior. In order to master the necessary quality of education in the discipline, attendance and regular preparation for classes are required.

Program of the course

Topics of the lectures

Topic 1 Introduction to modeling in the ANSYS Workbench software package.
Basic approaches and features. Graphical user interface (GUI) ANSYS Workbench. ANSYS Workbench Modules. Approaches for constructing model geometry.
Topic 2. Setting material properties.
Using existing ANSYS material libraries. Materials database. Material properties specified by the user. Properties of materials, depending on the physical model. Features of setting the properties of materials as functions of temperature, mass fraction, pressure.
Topic 3. An introduction to fluid and gas flow modeling in ANSYS Fluent.
Features of modeling liquid and gas flow. Transport equation for liquid. Introduction to the finite volume method for modeling liquid and gas flow. ANSYS Fluent graphical user interface (GUI).
Topic 4. The steps of modeling in ANSYS Fluent.
Basic stages of modeling in ANSYS Fluent. Selecting the modeling area. 2D or 3D modeling approach.

Features of creating flow geometry. Creating a mesh. Selecting an element type. Features. Setting material properties.

Topic 5. The steps of modeling in ANSYS Fluent. Continuation

Selection of a physical flow model. Setting initial and boundary conditions, operating conditions for the flow. Specifying the decoupler type and convergence accuracy for calculation. Studying of the obtained results (post-processing). Conclusions from the calculations.

Topic 6. Creation of a mesh of finite volumes.

Meshing. Creation of Cell zones. Fluid cell zones, solid cell zones. Creating boundary zones.

Topic 7. Setting boundary and operating conditions for the flow.

Types of boundary conditions. Internal and external boundary conditions. Selection of boundary conditions zone. Flow input and output. Changing boundary conditions. Setting the boundary layer. Conditions of symmetry. Features of setting operating pressure and flow speed.

Topic 8. Postprocessing in ANSYS Fluent.

Possibility of presenting analysis results. Type of results. Isosurfaces, isolines, vectors of quantities. Creating a flow animation. Obtaining results for user-defined quantities. Create a report.

Topic 9. ANSYS Fluent Solvers.

Pressure-based solver. Density-based solver. Selection and features. Algorithms used in the solvers. Calculation convergence. Acceleration of convergence.

Topic 10. Flow turbulence.

Features of specifying turbulence in a flow model. Turbulence models, used in ANSYS Fluent.

Topic 11. Heat transfer modeling in ANSYS Fluent.

Transport energy equation for heat transfer task, its components. Types of Heat Transfer in Computational Fluid Mechanics.

Topic 12. Solve a coupled fluid-solid heat transfer problem using ANSYS Fluent.

Setting of boundary conditions at the fluid-body interface (wall conditions). Types of wall modeling. Heat transfer in the fluid-body, fluid-liquid interface.

Topic 13. ANSYS Fluent Heat Transfer.

Convention modeling. Natural and forced convention. Boiling convention.

Topic 14. Heat transfer post-processing in ANSYS Fluent.

Thermal analysis results. Types of quantities, abilities to represent them. Further export to the structural strength analysis module.

Topic 15. Static structural finite element analysis in ANSYS Mechanical.

Basic equations. Stages of performing the analysis. Creation of a finite element model. Importing a load model from the ANSYS Fluent module. Setting boundary conditions. Carrying out the solution of thermoelasticity analysis. Post-processing of results.

Topic 16. Conclusions about the course.

Summary of computer modeling of coupled problems using the ANSYS software package. Brief overview of the main topics of the course. Conclusions.

Topics of the laboratory classes

Topic 1. Laboratory work 1.

Simulation of 3D laminar flow in a pipe.

Topic 2. Laboratory work 2.

Simulation of 3D turbulent flow in a pipe.

Topic 3. Laboratory work 3.

Modeling heat transfer in fluid. Part 1.

Topic 4. Laboratory work 4.

Modeling heat transfer in fluid. Part 2.

Topic 5. Laboratory work 5.

Coupled Analysis Solution. Simulation of a building fan with a heat source. Part 1.

Topic 6. Laboratory work 6.

Coupled Analysis Solution. Simulation of a building fan with a heat source. Part 2.

Topic 7. Laboratory work 7.

Coupled Analysis Solution. Modeling of heat flow in a pipeline Part 1.

Topic 8. Laboratory work 8.

Coupled Analysis Solution. Modeling of heat flow in a pipeline Part 2.

Self-study

Processing of lecture material. Preparation for laboratory classes. Independent study of topics and questions not covered in lecture classes. Performing individual tasks for laboratory works.

Course materials and recommended reading

1.°Lee H.H. Finite Element Simulations with ANSYS Workbench 2021.-SDC Publications, 2021. (https://www.sdcpublications.com/Textbooks/Finite-Element-Simulations-ANSYS-Workbench/ISBN/978-1-63057-456-7/)
2.°Currie, I.G. Fundamental mechanics of fluids / I.G. Currie. –New York ; Basel: Marcel Dekker, Inc., 2003. – 525 p.
3.°Shaughnessy, Edward J., Jr. Introduction to fluid mechanics / Edward J. Shaughnessy, Jr., Ira M. Katz, James P. Schaffer. – New York ; Oxford: Oxford University Press, 2005. 1018 p.
4.°Rajput R.K. A Textbook of Heat and Mass Transfer . - S Chand Publishing, 2015. 771 p.
5.°Ansys Student - Free Software Download. ANSYS, Inc., 2023.
URL: https://www.ansys.com/academic/students

Assessment and grading

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

Points for the test are added according to the rating:
Completing laboratory works – 80 points
Theoretical survey – 20 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