GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Finite Element Modeling, PG_00070358		
Field of study	Naval Architecture and Offshore Structures		
Date of commencement of studies	February 2026	Academic year of realisation of subject	2026/2027
Education level	second-cycle studies	Subject group	Specialty subject group Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	Polish English
Semester of study	2	ECTS credits	3.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Department of Marine Structures Mechanics and Technology -> Institute of Naval Architecture -> Faculty of Mechanical Engineering and Ship Technology -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. inż. Beata Zima	
	Teachers	dr inż. Maciej Kahsin prof. dr hab. inż. Arkadiusz Żak	

Lesson types

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	30.0	0.0	0.0	30.0	0.0	60

E-learning hours included: 0.0

eNauczanie source addresses:

Moodle ID: 9001 Finite Element Modeling
https://enauczanie.pg.edu.pl/2025/course/view.php?id=9001

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	60	5.0	10.0	75

Subject objectives

The aim of the course is to familiarise students with the theoretical foundations of the Finite Element Method (FEM) and to develop their practical skills in applying it to advanced structural analysis: both linear and non-linear. The course aims to prepare students to independently and correctly build numerical models of complex engineering structures (from the idealisation of geometry and mesh selection, through the definition of specific loads and boundary conditions, to complex static, buckling and dynamic analyses), including the use of commercial CAE engineering software. An important aspect of the course is the development of skills in the critical evaluation, verification and interpretation of simulation results, based on engineering knowledge and current guidelines for the design of engineering structures.
Translated with DeepL.com (free version)

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K7_W01] explains and describes, based on general knowledge in the field of scientific disciplines forming the theoretical foundations of Naval Architecture and Ocean Engineering, the construction and principles of operation of marine systems, processes and their components, as well as methods and means of their design and operation	The student knows and understands the mathematical and physical foundations of the Finite Element Method (FEM), including variational formulations, characteristics of various element types (1D, 2D, 3D), and computational procedures used in linear static, buckling, and modal analyses.	[SW1] Assessment of factual knowledge [SW2] Assessment of knowledge contained in presentation [SW3] Assessment of knowledge contained in written work and projects
[K7_U01] applies acquired analytical, simulation, and experimental methods, as well as mathematical models for analysis and evaluation of shipborne and offshore systems and processes	The student is able to independently perform the full numerical analysis procedure (pre-processing, computation, post-processing) of a complex engineering component using CAE software, and critically evaluate, verify, and interpret the simulation results.	[SU2] Assessment of ability to analyse information [SU4] Assessment of ability to use methods and tools [SU5] Assessment of ability to present the results of task
[K7_W04] demonstrates knowledge encompassing selected issues in the field of advanced knowledge, particularly in the scope of methods, techniques, tools, and algorithms specific to Naval Architecture and Ocean Engineering	The student knows and understands advanced principles of engineering structural idealization, proper mesh density selection, and formulation of complex boundary conditions and loads in FEM analyses.	[SW1] Assessment of factual knowledge [SW2] Assessment of knowledge contained in presentation [SW3] Assessment of knowledge contained in written work and projects

Subject contents

Course content – lecture

- Introduction to FEM in Engineering: Overview of CAE workflow (pre-processing, solving, post-processing); historical context and application in structural analysis.
- Mathematical Foundations & Energy Methods: Variational formulations; Principle of Virtual Work; direct stiffness method for 1D elements (trusses and beams).
- Element Formulations & Isoparametric Mapping: Characteristics, shape functions, and derivation of stiffness matrices for 1D, 2D (shell/plate), and 3D (solid) elements.
- Structural Idealization & Modeling Strategies: Discretization principles; mesh convergence and refinement criteria; stress concentrations vs. numerical singularities.
- Boundary Conditions & Structural Loads: Types of constraints (kinematic supports, symmetry/ antisymmetry); representation of operational and structural loads.
- Structural Stability (Buckling Analysis): Linear buckling theory; evaluation of critical buckling loads and mode shapes.
- Dynamic Analysis (Modal Foundations): Basics of structural dynamics; formulation of mass matrices; determination of natural frequencies and mode shapes.
- Verification & Validation: Methods for critical evaluation of FEM simulation results; comparison with analytical models and design guidelines; case study presentations.

Course content – project

- Introduction to the CAE Environment: Overview of the graphical user interface (GUI); workspace configuration; project template setup.
- Geometric Modeling and Clean-up: Importing external CAD geometry; mid-surfacing techniques for thin-walled structures; geometry simplification for meshing.
- Material Definition and Element Selection: Setting up linear elastic material properties; choosing appropriate element types (beam vs. shell vs. solid) for specific components.
- Meshing and Convergence Study: Generating structured and unstructured meshes; local mesh refinement in high-stress zones; conducting a mesh independence verification.
- Application of Loads and Boundary Conditions: Translating engineering constraints into numerical boundary conditions; applying distributed, hydrostatic, or point forces.
- Linear Static Analysis Execution: Setting up solver parameters; running the analysis; error tracking and troubleshooting convergence issues.
- Post-processing and Result Interpretation: Extracting and analyzing stress distributions (Von Mises, principal stresses), displacements, and reaction forces.
- Advanced Simulation Modules: Setting up and executing eigenvalue buckling and modal (natural frequency) analyses for the selected structure.
- Project Documentation and Defense: Compiling numerical findings into a formal technical engineering report; final presentation and discussion of results.

Prerequisites and co-requisites

- Mechanics background: Knowledge of the basics of strength of materials and structural mechanics at the undergraduate level.
- Field-specific knowledge: Basic understanding of ship structures, ocean engineering, or general engineering structures.
- Computer skills: Ability to use computers and basic proficiency in any CAD software for 3D geometry modeling.
- Language proficiency: Command of the English language sufficient for active participation in classes and independent study of technical literature.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
Lecture without grade	0.0%	0.0%
Project	100.0%	100.0%

<table>
<tr><td rowspan="3">Recommended reading</td><td>Basic literature</td><td>• Żak A., A Finite Element Approach for Wave Propagation in Elastic Solids, Springer Nature, 2024.
• Zienkiewicz O.C., Taylor R.L., The Finite Element Method. Volume 1: The Basis & Volume 2: Solid Mechanics, Elsevier / Butterworth-Heinemann.
• Cook R.D., Malkus D.S., Plesha M.E., Witt R.J., Concepts and Applications of Finite Element Analysis, John Wiley & Sons.</td></tr>
<tr><td>Supplementary literature</td><td>• Ostachowicz W., Kudela P., Krawczuk M., Żak A., Guided Waves in Structures for SHM: The Time-Domain Spectral Element Method, John Wiley & Sons, 2012.
• Bathe K.J., Finite Element Procedures, Prentice-Hall.
• Moaveni S., Finite Element Analysis: Theory and Application with ANSYS, Pearson.</td></tr>
<tr><td>eResources addresses</td><td></td></tr>
<tr><td>Example issues/ example questions/ tasks being completed</td><td colspan="2">1. Theoretical and Discussion Topics (Lecture):
• Discussion on the differences between stiffness matrix formulations for shell and solid elements in the context of thin-walled structure modeling.
• Mesh convergence study – how to identify discretization errors versus numerical singularities in stress concentration zones?
• Criteria for selecting appropriate boundary conditions for a partial structural model considering symmetric and antisymmetric conditions.
• Physical interpretation of eigenvalues in linear buckling analysis and structural modal analysis.
2. Tasks Realized within the Project (CAE):
• CAD geometry import, topology clean-up, and mid-surfacing generation for a selected structural component.
• Execution of a linear static analysis (computation of Von Mises stress distributions and displacements) for a stiffened plate structure subjected to pressure loading.
• Determination of the lowest natural frequencies and mode shapes (modal analysis) for a frame or mast structure to avoid resonance.
• Execution of a structural stability analysis to determine the critical buckling load multiplier for a stiffened panel under compression.</td></tr>
<tr><td>Practical activites within the subject</td><td colspan="2">Not applicable</td></tr>
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