GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Fundamentals of Numerical Modelling of Fluid Flows, PG_00061839		
Field of study	Design and Construction of Yachts		
Date of commencement of studies	October 2023	Academic year of realisation of subject	2025/2026
Education level	first-cycle studies	Subject group	
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	3	Language of instruction	Polish
Semester of study	6	ECTS credits	6.0
Learning profile	general academic profile	Assessment form	assessment
Conducting unit	Institute Of Naval Architecture -> Faculty Of Mechanical Engineering And Ship Technology -> Wydziały Politechniki Gdańskiej		
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. inż. Paweł Dymarski	
	Teachers		

Lesson types and methods of instruction						
Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	45.0	0.0	0.0	45.0	0.0	90
E-learning hours included: 0.0						

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	90	0.0	0.0	90

Subject objectives

The aim of the course is to familiarize students with the methods of numerical fluid mechanics. Both methods used to model potential flow and RANSE-CFD methods based on the finite volume method will be discussed.

During project classes, students will learn to prepare computational tasks, perform calculations and analyze the obtained results. In particular, students will learn how to perform flow calculations with a free surface.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[K6_K02] can work in a team, assuming various roles, can act in a rational and ethical way	The student is able to work in a team to solve a numerical fluid dynamics task using an appropriate CFD tool	[SK5] Assessment of ability to solve problems that arise in practice [SK1] Assessment of group work skills
[K6_W02] has knowledge in the field of technical mechanics, fluid mechanics, strength of materials, necessary to understand the basic physical phenomena occurring in ocean engineering	The student has knowledge in the field of fluid mechanics necessary to understand and model basic physical phenomena in the field of FM occurring in ocean engineering.	[SW3] Assessment of knowledge contained in written work and projects
[K6_U04] has skills that allow for self-education and preparation for work in an industrial environment, including the application of occupational health and safety rules	The student is able to self-educate using a manual (tutorial) dedicated to specific CFD software.	[SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject [SU1] Assessment of task fulfilment

Subject contents	1. Basic equations governing the movement of fluids 1.1 Basic (simplified) mathematical models used in FM - incompressible fluids - non-viscous liquids - potential flows 2. Introduction to numerical methods 2.1 What is CFD 2.2 Classification of methods - methods of solving potential flows - methods for solving viscous flows: -- finite CD method, -- FVM finite volume method, 3. Methods of modeling potential flows 3.1 Laplace's equation 3.2 Formulating boundary conditions: - Neumann problem, - Dirichlet problem. 3.3 Functions satisfying Laplace's equation - hydromechanical singularities 3.3.1 Modeling simple flows using hydrodynamic singularities - Rankin oval, - flow around a circular cylinder, - flow around the sphere 3.4 General method for determining potential non-circulating flows - source-sink method 3.5 Methods for determining the flow on a hydromechanical sheet - circulation flows - 2D flows, Kutta condition, - vortex fiber in 3D space - Biot-Savart equation, - flow around an airfoil with a finite span 3.6 Hydrodynamic reactions in stationary potential flow. Discussion 3.7 Unstationary potential flow 3.7.1 Water wave motion potential 3.7.2 Flow around bodies in wave motion 3.7.3 Bernoulli equation. Determination of the hydrodynamic reaction 4. Methods for determining viscous flows. Finite volume method 4.1 Definition of mesh element (CV control volume) 4.2 Surface and volume integrals within CV 4.3 Interpolation schemes and their impact on the accuracy/stability of calculations 4.4 Formulating boundary conditions 5. Computational grids 5.1 Types of computational grids and their impact on calculation accuracy 5.2 Techniques for "thickening" the mesh. Why do we use different densities? 5.2.1 Mesh refinement near the "wall". Problem y+ 5.3 Special/non-standard nets 5.3.1 non-machining grid 5.3.2 Moving grids: - sliding mesh - "overset" mesh (overlapping meshes) 5.4. Examples of "good" and "bad" mesh. 5.5. Analysis of the influence of mesh density on the solution 6. Techniques used to solve systems of linear and nonlinear equations 6.1 Exact methods 6.2 Iterative methods. The problem of "empty" matrices 6.3 Systems of nonlinear equations. 7. Methods used for non-stationary calculations 7.1 Discussion of "basic" time integration methods - Euler methods (explicit and implicit) - trapezoidal method - midpoint method 7.2 Predictor-corrector integration methods 7.3. Runge-Kutta methods and others 7.4. The impact of the methods used on the accuracy/stability and speed of the obtained solution. 8. (optional) Issues related to solving the N-S equation 9. Turbulence models 10. Special and practical issues 10.1 Testing the convergence of calculations 10.2 Calculation of the hydrodynamic reaction 10.3 Calculation of object dynamics - fluid-rigid body interaction 10.4 Boundary conditions for calculations of a ship/object subjected to wave action 10.5 Hull-propeller systems.

<table>
<tr><td>Prerequisites
and co-requisites</td><td colspan="2">Knowledge of fluid mechanics,
Knowledge of the basics of numerical methods:
- the concept of interpolation,
- basics of numerical integration
Knowledge of 3D object modeling software,
Knowledge of basic mechanics:
- understanding the concept of reaction force, understanding the second law of dynamics,
- knowledge of vector calculus</td></tr>
<tr><td>Assessment methods
and criteria</td><td colspan="2">

Subject passing criteria	Passing threshold	Percentage of the final grade
Lecture	60.0%	50.0%
Project	70.0%	50.0%

</td></tr>
<tr><td rowspan="3">Recommended reading</td><td>Basic literature</td><td>Ferziger J.H., Perić M. Computational Methods for Fluid Dynamics. Springer 2002
Gryboś Ryszard: Podstawy mechaniki płynów. Wydawnictwo Naukowe PWN 1998
John D. Anderson: Fundamentals of Aerodynamics. Mc Graw Hill 2011</td></tr>
<tr><td>Supplementary literature</td><td>H K Versteeg and W Malalasekera: An Introduction to Computational Fluid Dynamics. Pearson Education Limited 2007
O.M. Faltinsen: Sea Loads On Ships and Offshore Structures . Cambridge 1990
M. Krężelewski: Hydromechanika ogólna i okrętowa część II. Skrypt PG</td></tr>
<tr><td>eResources addresses</td><td>Adresy na platformie eNauczanie:</td></tr>
<tr><td>Example issues/
example questions/
tasks being completed</td><td colspan="2"></td></tr>
<tr><td>Work placement</td><td colspan="2">Not applicable</td></tr>
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