COURSE DESCRIPTION CARD - SYLLABUS

Course name
Computational fluid mechanics [S1Mech2>KMP]

Course

Field of study
Mechatronics

Year/Semester
3/5

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
15

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

3,00

Coordinators

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Lecturers

Prerequisites

A student has basic knowledge about computer graphics and CAD software, basics of computer programming and FEM (finite element method) to the extent necessary to understand the principle of software and to carry out the flow symulation. A student is able to integrate obtained data, interpret it, draw conclusions, formulate and justify opinions. A student is able to use a popular FEM system to carry out a simple numerical simulation of phenomena described by a system of differential equations, include the discretisation of domain.

Course objective

An introduction to computational fluid mechanics in the flow simulations area for selected structures. Acquisitioned of practical knowledge and skills in the use of specialised softwares.

Course-related learning outcomes

Knowledge:
The graduate hasa a basic, theoretically underpinned knowledge, including the key topics of fluid mechanics and computational fluid mechanics.
Has knowledge of flow classification and modelling options.

The graduate has basic knowledge of numerical methods in the computational fluid mechanics.

Skills:
Graduate is able to model the fluid flow using selected commercial software and analyse, visualise and critically evaluate obtained results.
Can formulate problems and knows how to use numerical methods and Informatics tools in engineering practice.
Can use mathematical apparatus to all major areas of mechatronics, in particular to the formulation of the governing equations of liquids and gases flow.
He can process of the CFD simulation data using external software, including the Python language.
Can obtain information from literature, databases and other properly selected sources (also in English) in the field of mechanical engineering and other engineering and technical areas in line with the studied field.

Social competences:
Understands the need for lifelong learning related to the development of technology.
It has the ability to self-learning, including "improving" professional competence.
He/she realizes the importance of non-technical aspects and effects of engineering activities.
A student understands a need for teamwork.
Is ready to recognise the importance of knowledge in solving practical problems and seek expert advice when finds it difficult to independently solve problems.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Knowledge acquired during the lecture is verified during the test written.
Computer laboratories are awarded based on the individually completed exercise/project tasks.

Programme content

Fluid properties. Fluid kinematics. Differential analysis of fluid flow. Fundamental flow equations. Flow classification based on selected criteria. Dimensional analysis and modeling. Introduction to Computational Fluid Dynamics (CFD).
Practical exercises include the application of the discussed concepts using selected commercial and/or open-source software commonly used in the industry.

Course topics

Fundamental equations describing fluid flow. Euler and Navier-Stokes equations. Laminar and turbulent flows, compressible and incompressible flows. Viscosity. Flow similarity. Reynolds number.
Introduction to Computational Fluid Dynamics (CFD). Overview of fundamental assumptions and flow modeling methods. DNS, LES, and RANS models. Turbulence modeling.
Governing equations. Formulation of Finite Volume Method (FVM).
Boundary layer. Issues related to the generation and quality of computational grids. y+ parameter.
Overset (chimera) grid methods.
Drag and Lift. Determination of aerodynamic forces. Drag and lift coefficients (CD and CL).
Analysis, interpretation and visualization of simulation results.
Unsteady flow computations. Choosing time step size. CFL condition.
Data processing in CFD using Python. Modal analysis, including Principal Component Analysis (PCA), in identification and analysis of coherent flow structures. Vortex visualization. Vorticity, Q-criterion, and Lambda-2 criterion. Streamlines and particle trajectories.
Basic aspects of Fluid-Structure Interaction (FSI) modeling. Aeroelasticity. Moving geometries. Arbitrary Lagrangian-Eulerian (ALE) formulation. Data interpolation and mesh deformation.
Basic aspects of multiphase flow modeling.

Teaching methods

Informative/problem-based lecture: multimedia presentation illustrated with examples given on a board, case study. Computer laboratory with project elements.

Bibliography

Basic:
T. J. Chung: Computational Fluid Dynamics. Cambridge Univesity Press 2002
Y. A. Çengel, J. M. Cimbala: Fluid Mechanics: Fundamentals and Applications. McGraw-Hill 2014
J.Tu, G.H. Yeoh, C. Liu: Computational Fluid Dynamics: A Practical Approach. Burlington, MA: Elsevier, 2024.

Additional:
O.C. Zienkiewicz: Metoda Elementów Skończonych. WNT Warszawa 1977
B.R. Noack, W. Stankiewicz, M. Morzyński, P.J. Schmid: Recursive dynamic mode decomposition of transient and post-transient wake flows. Journal of Fluid Mechanics 809, 2016. pp. 843-872
R. Roszak, M. Rychlik, W. Stankiewicz, K. Kotecki, H. Hausa, M. Morzyński, M. Nowak: Metoda numerycznej analizy aerosprężystości. Prace Instytutu Lotnictwa, 11 (220), 2011. pp. 148-160.
www.youtube.com/@fluidmechanics101

Breakdown of average student's workload

	Hours	ECTS
Total workload	75	3,00
Classes requiring direct contact with the teacher	45	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	30	1,00