SYLLABUS

Name of the course:	**Introduction to modeling of multiphase flows**			
Level of studies:	MSc., Ph.D.			
Direction/specialization:	all			
Code:			**Semester:**	**ECTS: 3**
Level: intermediate/advanced			**Type:** elective	
Total volume: 70 h	Lecture: 30 h Tutorial: 0 h Project: 15 h Consultations: 5		Self-study: 20 h	
Lecturer: dr inż. Tomasz Wacławczyk				

Educational objectives:

C1. Learning of foundations of the physical, mathematical and numerical modeling of multiphase flows
C2. Getting familiar with available models for quantitative prediction of multiphase flows in different regimes: separated, dispersive and mixtures
C3. Getting familiar with physical and mathematical foundations as well as phenomenology, advantages and limitations of the models supported in the commercial package ANSYS/Fluent

Assumed competences:

1. Basic knowledge in fluid mechanics and CFD
2. Basic knowledge in mathematical analysis and differential geometry
3. Basic skills in the ANSYS-FLUENT software

Learning outcomes:

Knowledge:

EW1 – Student understands main differences between modeling of single- and multiphase flows in the context of continuum mechanics.
EW2 – Student knows classification of multiphase flows based on different flow regimes, understands limitations imposed on mathematical models, understands why numerical modeling is required.
EW3 – Student knows and understand assumption behind derivation of Young-Laplace equations, based on geometric analysis and thermodynamical reasoning (equation for free surface energy)
EW4 – Student understands difference between small, medium and large-scale models of two-phase flows, understands their mathematical classification (division into Euler-Euler and Lagrange-Euler models), can choose a proper model to considered flow regime and identify such model in the commercial simulation software.
EW5 – Student knows when to use models for dispersive flows, understands physical assumptions and derivation of the transport equation of point particles.
EW6 – Student understands, in able to derive, is aware of limitations of the models of mixtures and multi-components fluids. In particular, student understands necessity of application of closure models based on experimental data.
EW7 -Student recognizes assumptions of a single-fluid model, knows its numerical implementations and is aware of the problems related with modeling of a deformable phase interface
EW8 – Student knows and understands assumptions and principles of physical and numerical modeling of phase interfaces; student knows the single-fluid model and its numerical implementation, including problems related to modeling of separated flows with phase interfaces.

Skills

EU1 – Student is able to identify regime of a multiphase flow and to use an appropriate numerical model.

EU2 – Student is able to explain differences between different flow regimes and specify features of proper numerical models

EU3 – Student is able to formulate the multiphase flow problem, including appropriate boundary conditions, and perform a computer simulation in ANSYS/Fluent.

Content of the course

Lecture	**Hours**
Introduction to multiphase flow modeling; significance of multiphase flows in technical applications and fundamental research; presentation of main differences between single- and multiphase flow based on criterial numbers; historic perspective: derivation of the Young-Laplace equation, discussion of special solutions and the scope of applicability of the Y-L eq.	4
Multiphase flow regimes, mathematical model based classification, introduction to large-scale multiphase flows: drift flux model and its applications.	2
Mesoscale multiphase models: mixture and two-fluid models; closure of mathematical models based on experimental data; phenomenological models in computer simulations.	4
Small-scale models – modeling of turbulent flows with a dispersive phase; closure of the point particle model; physical interpretation of the Stokes number. Discussion of the main numerical problems in modeling of dispersive flows, integration of the particle trajectories.	3
Small-scale models – modeling of the viscous liquid flow in a separated mode; numerical models of a deformable interphase and topological changes. Discussion of main differences in comparison to single-fluid model, especially difficulties with numerical solution of conservation equations.	2
Derivation of the transport equation for the probability density function for localization of a sharp interphase. Presentation of relation of this equation with phase-field models and modified Ginzburg-Landau functional. Physical interpretation of sharp (Gibbs) and diffused (Van der Waals) models of an interphase.	2
Introduction to probabilistic description of the phase indicator function and the level-set function. Physical interpretation of the distance-to-interphase function.	2
Boundary conditions of a sharp interphase, single-fluid model of a two-phase flow; closure law for the capillary tensor in sharp- and diffuse-interphase models. The problem of motion of a contact line - Hugh-Scriven paradox.	3
Modeling of surface tension in sharp and diffusive models of phase interphase. The model of continuum surface force, the method of the gradient of chemical potential. Conditions for Marangoni flow and its numerical modeling.	3
Numerical schemes and methods for modeling of a separated-phase flow: the volume-of-fluid , phase-field and level-set methods.	3
Introduction to statistical modeling of a two-phase flows in a separated mode; behavior of the model near critical regime, non-equilibrium effects in a separated flow.	2

Project	
Home projects realized – dependently on their complexity – individually or in pairs.	15

References

1. Generally available sources (books, papers) indicated in the lecture presentations.
2. Dedicated materials prepared by the lecturer.

Student's workload

Form of activity	Hour
Contact hours (lectures)	30
Contact hours (consultancy)	5
Work on a home project	15
Self-study and other forms of individual work	20
SUMM	**70**

Didactic tools:

1. Lecture presentations (PDF, Power Point)
2. Lecture summaries and project instructions (PDF).
3. Individualized problems for computers simulations.
4. Access to the course website, GiTHub repository, resources of the WUT main library, other instructions.

Evaluation methods

Written tests from the theoretical material resented in the lectures, evaluation of the results and report from the home project.

Realization of learning outcomes

Learning outcome	Relation to the whole program	Teaching objectives	Didactic tools	Evaluation
EW1		C1,C2	Lectures, self-study, consultations	Numeric marks (from 2 to 5)
EW2		C1,C2	Lectures, self-study, consultations	as above
EW3		C1,C2	Lectures, self-study, consultations	as above
EW4		C1,C2	Lectures, self-study, consultations	as above
EW5		C1,C2	Lectures, self-study, consultations	as above
EW6		C1,C2	Lectures, self-study, consultations	as above
EW7		C1,C2	Lectures, self-study, consultations	as above
EW8		C1,C2	Lectures, self-study, consultations	as above
EU1		C3	Self-study, project	as above
EU2		C3	Self-study, project	as above
EU3		C3	Self-study, project	as above