Multiphase Flow, Master course, TME160-2020

PM – course info

Responsible teacher

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Multiphase flows

Multiphase flows exist in a great number of natural and technological systems. The term *multiphase flow* refers to any flow situation in which there is a simultaneous presence of multiple phases (gas, liquid or solid) or components in a domain of interest. The components are well mixed above the molecular level. The most straightforward classification of multiphase flows is according to the state of different phases or components and, therefore, one may refer to gas-solid, liquid-solid, liquid-liquid or gas-liquid flows. Alternatively, one uses terms such as gas-particle flows, bubbly flows etc. Understanding multiphase flows includes dealing with a wide spectrum of spatial and temporal scales, working within a broad range of engineering disciplines and using a multitude of different modelling and computational approaches. Challenges arise from complex interactions of many entities (e.g. bubbles, drops, or solid particles) suspended in a fluid, but also from phenomena such as a possible change of phase within a system (typically present in gas-liquid systems), turbulence etc.

Learning outcomes

After completion of this course, the student should be able to:

- comprehend the phenomenology and the underlying physics of flow problems involving a simultaneous presence of multiple phases in a flow domain.
- critically review the state-of-the-art of modelling and computational methods and procedures for studying multiphase flows.
- reflect on governing equations and underlying assumptions for a wide range of different techniques studied throughout the course.
- explain and apply on realistic situations specific numerical aspects related to performing computations of multiphase-flow problems.
- solve a number of industrially-relevant multiphase-flow problems using commercial or open-source CFD codes.

Qualifications for the enrolment

The course is intended for students with prior knowledge in fluid mechanics. If you are in one of the categories given below, you most likely fulfil the qualifications for the enrolment:

- you are already a master student at MPAME (Applied Mechanics), MPISC (Innovative and Sustainable Chemical Engineering) or MPSES (Sustainable Energy Systems) at Chalmers.
- you are enrolled at another master programme, but you have passed basic courses in Fluid Mechanics and/or Computational Fluid Dynamics (CFD) at the department of Applied Mechanics at Chalmers, or similar at other schools.
- you have studied at another school where you passed courses in the field of Fluid Dynamics and/or Computational Fluid Dynamics (CFD).

In case of any questions, please contact the responsible teacher.

Teaching material

- *Lecture notes* – to be given to students before the lectures.
- *Textbook* 'Multiphase Flows with Droplets and Particles' by Crowe, Sommerfeld and Tsuji. Other textbooks will also be mentioned.
- *Scientific articles*: to be suggested (and made available) to students for various topics studied in the course.
- *Matlab, Python* or similar packages
- *Commercial and open-source computational codes (no preferences made)*.

Teaching methods

- Lectures and calculation exercises
- Computer assignments. Results to be presented and discussed by the students.

Note: due to special circumstances related to current pandemics, the lectures will be given online. Links in Zoom are created for every lecture and given in Canvas. Methods will be suggested to facilitate discussion related to and during the lectures.

Computers rooms are booked for two occasions (November 18 and November 29) to give you assistance related to Assignment 1. Measures will be taken to fulfil recommendations for such events in the current pandemics.

Changes in the course from the previous occasion

The material is always updated to include the latest developments in a number of modelling and simulation techniques.

Compulsory activities

- **Two out of three** computer assignments (**Assignments 1 and 2**) in the course are compulsory to be eligible for the exam. The students will write reports and defend their conclusions. The third assignment (**Assignment 3**) is not mandatory, but it will give credits for the exam. If the deadlines given below (see **Deliverables**) cannot be met due to objective reasons, the students should contact the responsible teacher. If the reasons are not deemed objective, a student will have to enrol to the course at another opportunity.

Individual and group work

Mandatory computer assignments and the related reports will be done individually (Assignment 1) or in groups (up to 4 for Assignment 2). Assignment 3 is also to be carried out individually.

Deliverables

- **Assignment 1 is mandatory**. Reports from **Assignment 1** should be handed in according to the dates indicated below.

Assignment	Hand-out date	Hand-in date
1	**Friday 13/11**	**Monday 30/11**

- **Assignment 2** is mandatory and will be given on **Friday, November 27**. The students will present their results on **Friday, December 18**. Written reports should be delivered on that day or upon agreement.

- **Assignment 3** is to be given in **week 7** of the course. This assignment is not mandatory, but it is highly relevant for your training on modelling and simulations of multiphase flows. In addition, it will give credits for the final exam (up to 10 %).

Examination and grades

There is a written exam for the course, but due to the current situation its exact form is yet to be decided. The students will be informed in good time (during November) and prepared for the chosen form of the exam. The grades are failed, 3, 4 and 5.

Teaching assistants

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Course evaluation

A course evaluation group will be formed during the first teaching week. The course representatives will be randomly selected among the students enrolled in the course (if not given otherwise). Other students enrolled in the course can also participate in the group work. The exact dates and times for the meetings will be agreed between the responsible teacher and the group.

Detailed timetable, TME160 2020

Session		**Week 1** of the course; Calendar week 45, 2020
1	Tue Nov 3 8-12 Zoom	Course objectives. General guidelines. Introduction to multiphase flows – Lecture 1 • Characterization, Basic definitions, properties of phases • Flow regimes
2	Wed Nov 4 8-10 Zoom	Introduction to multiphase flows – Lecture 1 • Averaging techniques
3	Fri Nov 6 8-12 Zoom	Lecture 2 • Equation of motion of an individual particle • Forces on individual particles

Session	Week 2 of the course; Calendar week 46, 2020	
4	Tue Nov 10 8-12 Zoom	Lecture 2 • Equation of motion of an individual particle • Forces on individual particles
5	Wed Nov 11 8-10 Zoom	Lecture 3 • Multiscale modelling of multiphase flows
6	Fri Nov 13 8-12 Zoom	Lecture 4 • Lagrangian Particle Tracking – main principles and governing equations
Session	**Week 3** of the course; Calendar week 47, 2020	
7	Tue Nov 17 8-12 Zoom	Lecture 4 • Lagrangian Particle Tracking – models for particle-particle interactions
8	Wed Nov 18 8-10 SB-D042 SB-D080	• Computer lab
9	Fri Nov 20 8-12 Zoom	Lecture 5 • Multi-fluid modelling of multiphase flows – main principles and derivation of governing equations
Session	**Week 4** of the course; Calendar week 48, 2020	
10	Tue Nov 24 8-12 Zoom	Lecture 5 • Multi-fluid modelling of multiphase flows – formulation of closure models
11	Wed Nov 25 8-10 Zoom	Lecture 6 • Numerical modelling of multiphase flows – Lagrangian particle Tracking (numerical schemes, interpolation, collision models)
12	Fri Nov 29 8–12 HB105 HB110 Zoom	• Computer lab (8-10, HB105, HB110) • Lectures (10-12, Zoom)
Session	**Week 5** of the course; Calendar week 49, 2020	
13	Tue Dec 1 8-12 Zoom	Lecture 6 • Numerical modelling of multiphase flows – Lagrangian Particle Tracking and Multifluid modelling (numerical schemes, convergence, conservation of mass and momentum).

14	Wed Dec 2 8-10 Zoom	Lecture 6 • Numerical modelling of multiphase flows – Multifluid modelling (numerical schemes, convergence, conservation of mass and momentum).
15	Fri Dec 4 8-12 Zoom	Lecture 6 • Numerical modelling of multiphase flows –Multifluid modelling (numerical schemes, convergence, conservation of mass and momentum).

Session	**Week 6** of the course; Calendar week 50, 2020	
10	Tue Dec 8 8-12 Zoom	Lecture 7 • Direct Numerical Simulation (DNS) of multiphase flows – main principles and techniques. Volume of Fluid (VOF).
11	Wed Dec 9 8-10 Zoom	Lecture 7 • Direct Numerical Simulation (DNS) of multiphase flows –Volume of Fluid (VOF). Level Set and Front Tracking, Immersed Boundary
12	Fri Dec 11 8-12 Zoom	Lecture 7 • Modelling of multiphase flows using mesoscopic frameworks – Lattice Boltzmann method
Session	**Week 7** of the course; Calendar week 51, 2020	
13	Tue Dec 15 8-12 Zoom	Lecture 8 • Population balance modelling – principles and applications
20	Wed Dec 16 8-10 Zoom	Lecture 8 • Population balance modelling – principles, applications – focus on condensation and boiling
21	Fri Dec 18 8-12 Zoom	• Student presentations (Assignment 2)
Session	**Week 8**	
		Extra time