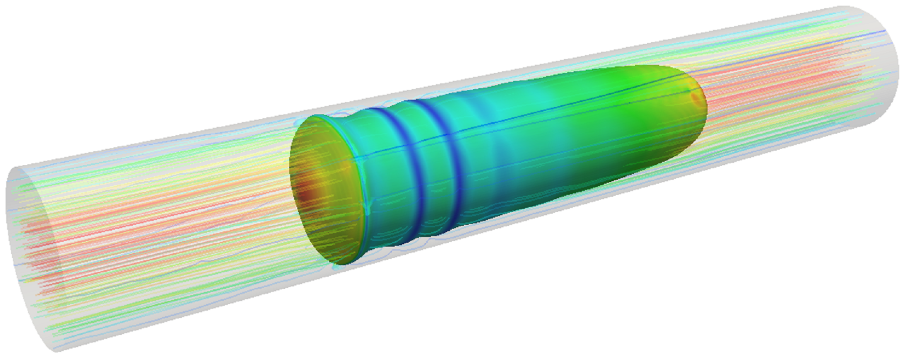


3rd Workshop on Advances in CFD and LB Modeling of Interface Dynamics in Capillary Two-Phase Flows

October 8-12, 2018, Kobe, Japan

École Polytechnique Fédérale de Lausanne
Graduate School of Engineering, Kobe Univerisity
The Japanese Society for Multiphase Flow

Workshop description

We are happy to present this workshop on the latest advances in the computational modelling of the interfacial dynamics of capillary two-phase flow phenomena using Computational Fluid Dynamics (CFD) and Lattice Boltzmann (LB) methods. In addition, experimental two-phase flow visualization techniques will presented. The Workshop is now at its 3rd edition, following the first two editions in 2016 and 2017 that took place at the EPFL in Lausanne, Switzerland.

The international team of lecturers is as follows: Prof. A. Tomiyama, S. Hosokawa and Prof. K. Hayashi (Kobe University), Prof. T. Seta (Toyama University), Prof. J.R. Thome (EPFL), Prof. G. Anjos (State University of Rio de Janeiro) and Dr. M. Magnini (Imperial College London).

Direct numerical simulation of two-phase flows is an active field of research since the beginning of the computational fluid dynamics in the early sixties. However, thanks to the exponential increase of the computer performance observed in the latest decades, the computational modelling of two-phase flows is advancing rapidly towards more complex and heterogeneous approaches, thus yielding unprecedented insight into the essential aspects of the flow. CFD techniques model the flow at the continuum scale and consider a sharp gas/liquid interface with zero thickness. Intermolecular forces determining the interface physics are not directly captured, but their effect is modelled by introducing a surface tension force concentrated at the sharp interface. This workshop tackles in detail the most popular CFD techniques to capture the interface dynamics across a fixed computational mesh, i.e. Volume Of Fluid and Level Set method, and a novel Arbitrary Lagrangian-Eulerian moving mesh methodology. Lattice Boltzmann methods, instead of solving the Navier–Stokes equations, solve the discrete Boltzmann equation to simulate the flow of a Newtonian fluid using collision models to investigate the interfacial region's thermophysics, and are thus also the focus of the present workshop. Quantitative flow visualization techniques will be presented, which are pertinent to the experimental validation of numerical methods.

The global tendency towards miniaturization driven by micro-electronics, as well as by the pharmaceutical and fuel cell industries to name but a few, is bringing ever greater attention to microscale two-phase flows. In this context, surface tension and phase change represent important aspects that require ad-hoc numerical modelling and are encompassed in this course. The present workshop is addressed to Ph.D. students and postdoctoral researchers involved in both experimental and numerical investigation of two-phase flows, i.e. all those who wish to get acquainted with the traditional background and the most recent developments on the heterogeneous interface modelling strategies mentioned above for capillary two-phase flows. These will be elaborated by the leading scientists who will lecture on the field of CFD and LB modelling of interfacial flows. The workshop is designed to promote interaction during and after the lectures: the participants are invited to present their research in a dedicated session which will take place at the beginning of the week; practical "hands-on" sessions are scheduled on four afternoons, where the participants will apply and develop the codes provided by the lecturers to simulate benchmark flow configurations.

Workshop location and travel information

The workshop will be held at the Graduate School of Engineering, Kobe University, Japan, which is located on the Rokkodai 2nd Campus. The lectures will be in Room D1-201 on the 2nd floor of Section D1. Computers will be set up in the room for "hands-on" sessions. See the university web site: http://www.kobe-u.ac.jp/en/campuslife/campus_guide/campus/index.html for more information.

Workshop registration and inscription fee

The workshop does not have any registration fee in order to promote the participation of students/researchers. The link to the registration page can be found on the website of the Virtual International Research Institute of Two-Phase Flow and Heat Transfer (VIR2AL). When registering, participants will be invited to submit a brief personal overview of their research and interests in two-phase flow. The registration deadline is July 1st, 2018. You are encouraged to register as soon as possible. A maximum number of 30 participants will be accepted. As this is an advanced course, it is expected that participants already have a working knowledge of numerical fluid mechanics.

Schedule and Contents of the lectures

MONDAY, 8 October

8:30-10:00 – Introduction to multiphase flow, Prof. A. Tomiyama. Fundamental equations for predicting multiphase flows within the context of continuum dynamics are introduced in this lecture. Local instantaneous mass, momentum and energy equations and jump conditions at interfaces are derived from conservation laws and some integral theorems, and kinematic equations for interface tracking are deduced from a geometric equation of surface, and averaged field equations for multi-fluid and Euler-Lagrange models are derived from the local instantaneous equations and phase-definition functions. A simple method to derive semi empirical correlations and relevant dimensionless groups from local instantaneous equations and jump conditions is also introduced as a useful tool for developing a correlation from experimental or numerical data.

10:30-12:00 – Interface capturing methods, Prof. K. Hayashi. Interface capturing methods, i.e. the VOF and level set methods are introduced. Numerical schemes for the advection and viscous terms and the Poisson equation commonly used in single and multiphase flow simulations are briefly explained. The bases of the interface capturing methods are given in detail: especially, this lecture focuses on how to track the interface and to evaluate the surface tension force. Immersed boundary methods for particulate flows and flows in complex channel geometries are also introduced.

13:00-17:00 – Hands-on session, Prof. K. Hayashi. Exercises with sample programs in C++ are provided for better understanding of the concepts outlined in the previous theoretical sessions.

17:30-19:00 – "My research in 150 s" and apero. Participants are invited to present their research in 150 seconds (timing will be strictly enforced) in front of the class in a clear, concise and straightforward manner, with the support of a two slides preloaded on our computer.

TUESDAY, 9 October

8:30-10:00 – Phase change modelling in interface capturing frameworks, Dr. M. Magnini. This lecture present an overview of the most popular models for including phase change within interface capturing frameworks. The background theory, temperature boundary condition at the interface, and numerical implementation which are peculiar of each model are discussed. The differences between microscale and macroscale oriented formulations are debated. Mathematical techniques for the smoothing of the phase change source terms are introduced. Some typical validation benchmarks to assess the phase change models accuracy are illustrated. Results of CFD simulations aimed to investigate flow boiling within microchannels are described.

10:30-12:00 – Advection schemes and surface tension in VOF methods, Dr. M. Magnini. This lecture presents an overview about the most employed advection schemes for VOF methods, i.e. the Piecewise Linear Interface Construction (PLIC) for sharp interfaces and the Compression scheme for slightly diffuse interfaces. Theoretical background and numerical implementation of both methods are presented. Afterwards, different methods for the curvature evaluation in the Continuum Surface Force (CSF) framework are introduced. The attention will be focused in particular to the advantages and disadvantages of the classical implementation, smoothing techniques, height function method and higher order interface reconstruction method. Finally, the VOF method implemented in the solver InterFOAM of the open-source CFD toolbox OpenFOAM will be illustrated, as an introduction for the afternoon "hands-on" session.

13:00-16:30 – Hands-on session, Dr. M. Magnini. This practical session shows how to setup and run a two-phase flow simulation using the VOF method implemented in InterFOAM. Two benchmark configurations will be simulated by the participants: (1) the breaking of a dam and (2) the rise of a Taylor bubble in a vertical tube.

WEDNESDAY, 10 October

8:30-10:00, 10:30-12:00 – ALE-FEM formulation for two-phase flow, Prof. G. Anjos. These lectures aim to present the principles behind the Arbitrary Lagrangian-Eulerian Finite Element Method formulation (ALE-FEM) for solving two-phase flows with a moving interface. An overview of the conservation equations for two-phase flows written in a generalized formulation and the modelling of the interfacial forces will be presented followed by an introduction to the FEM theory and the solution of a practical handmade 1D test case.

13:00-16:30 – Hands-on session, Prof. G. Anjos. The participants will follow a demonstration with the lecturer's 2D ALE-FEM code for two-phase flows (based on the JCP's article "A 3D Moving Mesh Finite Element Method for Two-Phase Flows").

THURSDAY, 11 October

8:30-10:00, 10:30-12:00 – Two-phase flow simulations using Lattice Boltzmann method, Prof. T. Seta. The Lattice Boltzmann method (LB) allows simple numerical codes, easy parallel implementations, and fast computation of the multiphase flows with complicated boundary conditions. The overview of the LB is given, followed by the theoretical fundamentals including the Chapman-Enskog expansion employed to derive the Navier-Stokes equations. The comprehensive review of the popular multiphase Lattice Boltzmann methods and the boundary conditions dealing with wettability are introduced. The accuracy and robustness of the models are explained in detail to enable the students to construct the LB model to address problems they are interested in.

13:00-16:30 – Hands-on session, Prof. T. Seta. Some FORTRAN codes for multiphase LB models are presented in a hands-on session for understanding the advantages and disadvantages of each model.

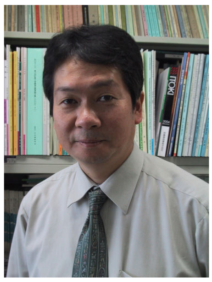
FRIDAY, 12 October

8:30-10:20 – Optical measurements for validation of numerical simulation of two-phase flow, Prof. S. Hosokawa. Experimental data are required for validation of models used in numerical predictions of two-phase flows. Since optical measurement methods such as laser Doppler velocimetry and image processing methods are invasive and do not affect flow characteristics, they are frequently used for the validation. In this lecture, fundamentals of the measurement methods are explained and examples of validations of numerical predictions are presented to discuss the points to note in comparison between measured and predicted values. Advanced methods such as a small LDV probe and spatiotemporal filter velocimetry are also introduced to demonstrate their potential for validating numerical simulations.

10:40-12:30 – Measurement and image processing techniques for quantifying two-phase flows, Prof. J. R. Thome. This lecture will give an overview of several experimental techniques developed within the LTCM lab for two-phase flow visualization and image processing. The 1st technique is for the measurement of dynamic void fractions in stratified and slug flows in horizontal tubes, using a laser sheet and high speed camera together with image processing to overcome the refractive index effect of the channel to the test liquid (refrigerants). The 2nd technique is for characterizing micro channel two-phase flows to determine: flow pattern, bubble frequency, bubble length, bubble velocity, bubble coalescence rates and indirectly the void fraction (bubbly and slug flows only), using a pair of lasers and diodes with signal processing. The 3rd technique in referred to as the "time-strip" method, that is an image post-processing method for high speed videos of two-phase flows, particularly suited for characterizing bubbly and slug flows. The 4th technique is micro-Particle Shadow Velocimetry, in which the shadows of particles are tracked from behind using LED lighting, rather than micro-PIV with front lighting by a laser requiring fluorescent particles, to obtain: bubble shapes, velocity flow fields, etc. Quantitative measurements are obtained for creating test cases for numerical validations and for the building of mechanistic models.

The lecturers

Prof. K. Hayashi is Associate Professor at the Graduate School of Engineering, Kobe University, Japan, since 2012. He was formerly Assistant Professor (2007-2008) and then Lecturer (2008-2009) at the Kobe City College of Technology, and Assistant Professor at the Kobe University (2009-2012). His research focuses on developing numerical methods for simulating complicated motions of bubbles and drops and correlations based on the bubble and drop mechanics.



Prof. A. Tomiyama is Professor at the Graduate School of Engineering, Kobe University, Japan, since 2003. He was formerly researcher at the Energy Research Laboratory at Hitachi Ltd. between 1984 and 1988, then Assistant Professor (1988-1991) and Associate Professor (1991-2002) at the Kobe University. In 2011 he became Vice Dean at the Graduate School of Engineering, Kobe University, and Dean since 2015. His research interests are experimental and numerical investigation of multiphase flows in nuclear reactors, chemical plants, fuel injectors and environmental systems.

Dr. M. Magnini was a postdoctoral research assistant at the LTCM at the EPFL, Switzerland, from 2012-2017 and is now a post-doc at Imperial College London. He received a M. Sc. degree in mechanical engineering in 2007 from the Alma Mater Studiorum - Università di Bologna, Italy, and a Ph.D. degree in Energy Engineering in 2012 from the same institution. His research focuses on numerical simulations of two-phase flows with phase change within macro and microchannels and theoretical modelling of evaporation in microchannel slug flow.

Prof. G. Anjos is Professor of Mechanical Engineering at the State University of Rio de Janeiro (UERJ), Brazil. He received his M.S degree in Mechanical Engineering from the Federal University of Rio de Janeiro (UFRJ) and the Ph.D. degree at the Swiss Federal Institute of Technology (EPFL). His doctoral thesis has been nominated for the EPFL best thesis award of 2012 and it has been published in the renowned Journal of Computational Physics in 2014. Additionally, Prof. Anjos has worked as Post-Doc at the Massachusetts Institute of Technology (MIT). His research interests include two-phase flows, scientific computing, fluid dynamics and heat and mass transfer. He is member of the Brazilian Society of Mechanical Sciences and Engineering (ABCM).

Prof. T. Seta is Associate Professor at the Graduate School of Science and Engineering for Research, University of Toyama, Japan, since 2007. He was formerly a researcher at the IBM T. J. Watson Research Center (1996-1997), researcher at the Institute of Applied Energy (1997), Lecturer at the Shizuoka Sangyo University (1998-2001), and Lecturer at the University of Toyama (2001-2006). His research interests include numerical modeling of dynamics of liquid water on hydrophobic and hydrophilic surfaces, and numerical investigation of the accuracy, stability, and efficiency of Lattice Boltzmann methods for heat and mass transfer.

Prof. J. R. Thome is Professor of Heat and Mass Transfer at the Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland, since 1998, where his primary research interests are two-phase flow and heat transfer, covering both macro-scale and micro-scale heat transfer (boiling and condensation). He is chair of the Virtual International Research Institute on Two-Phase Flow and Heat Transfer (VIR2AL). He was also the Director of the ERCOFTAC European Coordination Center (European Research Community On Flow, Turbulence And Combustion) with about 180 affiliated universities, research centers and industrial companies, resigning this position in 2011.

Prof. S. Hosokawa is Associate Professor at the Graduate School of Engineering, Kobe University, Japan, since 1998. He was formerly Assistant Professor at the Kobe University (1993-1998). His research interests include development of optical measurements for single and multiphase flows, turbulence in dispersed two-phase flows, motion of fluid particles, mass and momentum transfer at an interface and generation method and application of micro-bubbles.