インターナショナルレクチャーコース

二相流における界面動力学の数値流体力学及び
格子ボルツマン法の進展に関するワークショップ

主　催　国際二相流・伝熱協会、神戸大学大学院工学研究科、日本混相流学会

趣　旨　本国際ワークショップでは、二相流数値シミュレーション分野の最前線で活躍する国内外の研究者を迎え、５日間の集中的講義と実践的演習、討論を行います。国内外の研究者によるプレゼンテーションと、より理解を深めるための計算機を用いた実習でプログラムが構成されており、効率的に二相流数値シミュレーションの知識・技能を講師との議論を交えながら習得できます。さらに、海外から博士課程学生やポスドク等の若手研究者も参加しますので、国際交流の場としても最適です。取り上げる話題は VOF 法やレベルセット法のほか、ALE-FEM や格子ボルツマン法、さらに数値計算の妥当性検証のための光学計測、二相流のための実験・画像処理技術まで多岐にわたり、幅広い知識を基礎から応用までしっかりと習得できます。学生や研究機関の若手研究者の方はもちろんのこと、企業の方も是非ふるってご参加ください。なお、本ワークショップは英語で行います。

日　程　２０１８年１０月８日（月・祝）～１２日（金）

場　所　神戸大学工学部　工学研究科 D1 棟 201 室（http://www.kobe-u.ac.jp/guid/access/rokko/rokkodai-dai2.html）

プログラム（内容詳細は案内末尾に記載）

【10 月 8 日（月・祝)】

8:30-10:00	Introduction to multiphase flow, Prof. A. Tomiyama (Kobe University)
10:30-12:00	Interface capturing methods, Prof. K. Hayashi (Kobe University)
13:00-17:00	Hands-on session, Prof. K. Hayashi (Kobe University)

【10 月 9 日（火)】

8:30-10:00	Phase change modelling in interface capturing frameworks, Dr. M. Magnini (Imperial College)
10:30-12:00	Advection schemes and surface tension in VOF methods, Dr. M. Magnini (Imperial College)
13:00-16:30	Hands-on session, Dr. M. Magnini (Imperial College)
16:30-18:00	Short presentations by participants: “My research in 150 s”

【10 月 10 日（水)】

8:30-10:00, 10:30-12:00	ALE-FEM formulation for two-phase flow, Prof. G. Anjos (State University of Rio de Janeiro)
13:00-16:30	Hands-on session, Prof. G. Anjos (State University of Rio de Janeiro)

【10 月 11 日（木)】

8:30-10:00, 10:30-12:00	Two-phase flow simulations using Lattice Boltzmann method, Prof. T. Seta (Toyama University)
13:00-16:30	Hands-on session, Prof. T. Seta (Toyama University)

【10 月 12 日（金)】

8:30-10:20	Optical measurements for validation of numerical simulation of two-phase flow, Prof. S. Hosokawa

(Kobe University)

10:40-12:30 Measurement and image processing techniques for quantifying two-phase flows, Prof. J. R. Thome (EPFL)

定　員　30 名程度。先着順とさせていただきます。

参 加 費

学生（日本混相流学会員）	10,000 円
学生（非会員）	20,000 円
一般	50,000 円
正会員（維持会員）	30,000 円

参加費は当日現地にてお支払いください。現金払いのみ。

＊原則として参加登録された方は 5 日間全てご出席いただきますが、企業の方で業務上全日程に都合がつかない場合は予め不参加の日程をご連絡いただければ受け付けます。ただし参加費の減額は致しませんのでご注意ください。

申込〆切　9 月 14 日(金)

申込方法　下記申込先に、「インターナショナル WS 参加申込」と題記し、氏名、会員資格（日本混相流学会正会員/学生会員/非会員(一般)/非会員(学生)）、連絡用メールアドレス、所属、部署、電話番号を明記のうえ、電子メールにてお申し込みください。

申し込み・問い合せ

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内容の詳細

MONDAY, 8 October

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.

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 basis 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.

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.

TUESDAY, 9 October

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.

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.

Hands-on session, Dr. M. Magnini: This practical session shows how to set-up 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.

Short presentations by participants: "My research in 150 s": 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.

WEDNESDAY, 10 October

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.

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

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.

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

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.

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.