THE COURSES

Multiphase flows and heat transfer with phase change are of interest to researchers, scientists and engineers working in a multitude of industries. Courses similar to this one have been offered in the past at Stanford University, the University of California-Santa Barbara, in Washington D.C. and elsewhere. The courses have taken place at ETH Zurich since 1984 with over 2100 participants so far. Over the years, the courses have continuously evolved, reflecting on-going progress, interests, and developments; parallel sessions were introduced in 1989.

The Zurich courses not only offer the opportunity to meet and interact with outstanding lecturers, but also with colleagues working worldwide on similar topics but in different industries. The courses are organized in a modular form as an intensive introduction for persons having basic knowledge of fluid mechanics, heat transfer, and numerical techniques (introductory tutorial texts are provided to the participants before the course), but also serve as advanced courses for specialists wishing to obtain the latest information.

Part I, Basics, covers the common background material and emphasises the latest empirical and mechanistic modelling, computational and instrumentation aspects of multiphase flows. A tutorial text is provided to the participants before the course to introduce the very basic concepts and fill any basic gaps in their background, so that they can participate in the most effective way.

Part IIA, New Reactor Systems and Methods, covers multiphase flow topics of particular interest to the nuclear industry. Some of the most recently proposed advanced reactor designs and the main multiphase phenomena of importance to the nuclear industry are treated. The state-of-the-art and beyond in modelling and simulation methods (including CFD and CMFD applications) for core design and accident analysis is introduced. An article introducing Light Water Reactors will be provided to the participants as tutorial material before the course.

Part IIB, Computational Multi-Fluid Dynamics (CMFD), reflects the growing interest in the application of CMFD techniques to multi-phase flows and covers the most common computational techniques. The introductory chapters from a book authored by Tryggvason, Scardovelli and Zaleski will be provided to the participants to prepare for the lectures.

Part III, CMFD with Commercial Codes, is attached to both Parts IIA and IIB. The participants will hear commercial code developers discuss their products for both nuclear and other applications.

The emphasis in these courses is on
• A condensed, critical and updated view of basic knowledge and future developments, in relation to systems and phenomena encountered in industrial applications
• Trends in modelling, design, analysis, CFD / CMFD methods and experimentation
• Sources of information, data and correlations
• Availability as well as limitations of modern modelling and computational techniques and codes
• Interdisciplinary transfer of knowledge from one area of applications to another

These limited-enrolment courses feature
• 23 well-coordinated lectures by experts and excellent lecturers
• Movies, videos, animations, and computer simulations illustrating the physical phenomena and the numerical techniques
• A complete set of all the lecture materials (including extensive notes) will be available for download from our website
• Tutorials as introductory texts for all parts of the course
• Handout-format hard copies of all the standardized PowerPoint presentations for use in the classroom
• Discussion time and discussions with the lecturers during and between lectures

FEES
Full course (I, IIA or IIB and III): CHF 1’950
Part I: CHF 1’400
Parts IIA or IIB and III: CHF 1’100

INFORMATION
All practical information about the course and hotel reservations can be obtained from the course web site http://www.lke.mavt.ethz.ch/shortcourse

REGISTRATION
https://ethzurich.eventsair.com/scomf20/reg

CONTACT
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COURSE VENUE
ETH Zurich, Monday – Wednesday: main building, D floor, room 1.1 (HG D 1.1), Thursday-Friday: ML building, F floor, room 34 and 36 (ML F 34 and ML F 36)

The course organizers reserve the right to cancel the course on short-term notice, with full refund of the fees, in case of force majeure.
1. Introduction to multiphase flows (09:00–10:30): M. Corradini. Definition of multiphase flows; types of flow (two-phase, three-phase, single component, multi-component). Applications: power generation, hydrogen recovery, chemical processing, etc. Differences to single phase flows; examples of characteristic multiphase phenomena (Counter Current Flow Limitation, Departure from Nucleate Boiling, Dry out, instability). History of development of the subject; principal sources of information.


Tuesday, 11 February 2019 (9:12:30 and 14:00-17:00)

5. Instability of the gas-liquid interface and flow regime maps (09:00–10:00): M. Corradini. Basic theory of the interfacial instability (Rayleigh-Taylor and Kelvin-Helmholtz instability) and numerous applications. Flow regime maps based on phenomenological modelling; stability of stratified flow as basis of flow regime maps.


8. Empirical and phenomenological models for flows with phase change (16:00–17:30): M.L. Corradini. Single component systems; heat transfer regimes, heat transfer in slug flow (equilibrium, non-equilibrium); heat transfer in annular flow, correlations, mechanisms, models (overall, detailed, effect of nucleate boiling). Multicomponent systems (droplet effects). Dryout (critical) heat flux; low quality ( bubbly) and high quality (annular) flows.

Wednesday, 12 February 2019 (9:12:30 and 14:00-17:30)


PART IIA. NEW REACTOR SYSTEMS AND METHODS

Thursday, 13 February 2019 (8:30-13:00 and 14:00-17:30)


Coffee Break: 11:20-11:40


17A. Instabilities in two-phase flow (16:00–17:30): B. Askari. Two-phase system instabilities. BWR Stability, stability maps, computational tools, practical applications.

Friday, 14 February 2019 (8:30-13:00)

18A. Multiphase phenomena in severe accidents (08:30–9:30): M.L. Corradini. Multiphase phenomena during severe accidents: vapour explosions, molten core conditions, pool boiling, etc. Severe accident code systems analyses and simulations.

19A. Applications of conventional and research-based CMFD techniques to complex nuclear safety problems: (10:00–11:20): D. Lakehal. Computational thermal-hydraulics in the practice using a variety of modelling techniques for different problem configurations. From statistical average models to scale-resolving strategies.

Coffee Break: 11:20-11:40

20A. CFD and CMFD modelling applied to reactor systems (11:40–12:30): S. Lo. A brief overview of CFD usage in the nuclear industry, including detailed modelling of a PWR, single-phase and two-phase flows in fuel bundles, critical discharge, pebble bed reactor, spent fuel transport and storage, and environmental flow around reactor buildings.

SCHEDULE AND CONTENTS OF LECTURES

PART IIB. COMPUTATIONAL MULTI-FLUID DYNAMICS (CMFD)

Thursday, 13 February 2019 (8:30-13:00 and 14:00-17:30)

13B. Introduction to CMFD (08:30-9:50): D. Lakehal. Overview: single fluid modelling (surface tracking by VOF, Level Set, etc.) and multi-fluid models in CMFD. Turbulence in multiphase flows: scale separation; averaging and filtering; methods for low and high Reynolds numbers – from RANS to LES; coupled sub-scale approaches.

14B. Introduction to Interface Tracking (10:00-11:20): G. Tryggvason. Need for numerical simulations and history. Overview of the governing equations and standard solution methods. Introduction to the various methods used to track sharp fluid interfaces.

Coffee Break: 11:20-11:40


Friday, 14 February 2019 (8:30-13:00)

17B. Embedded Interface Methods (08:30 – 9:50): G. Tryggvason. Interface tracking for direct numerical simulations (DNS) of multiphase flows. Applications to bubbly flows and flows with phase change and mass transfer. Multi-scale issues.

18B. Application of CFD codes to multiphase systems (10:00–11:20): S. Lo. Introduction to different modelling approaches for multiphase flows, including Lagrangian tracking, Discrete Element Method (DEM), Eulerian multiphase models and Multi-component multiphase models for species mass transfer and chemical reactions.

Coffee Break: 11:20-11:40


PART III. CMFD WITH COMMERCIAL CODES

Friday, 14 February 2019 (14:00-17:15)


22. Validation of two-phase flow models in ANSIYS CFD (15:00–15:55): M. Achzar. Solver technology; Overview of model portfolio: Euler/Euler two-phase flow, free surface flow, Euler/Lagrangian models, DDPM; Applicability and limitations, Applications and model validation including comparisons to data.

23. Modelling of industrial multiphase flows with STAR-CCM+ (16:00 – 16:55): S. Lo. A selection of examples illustrating some of the challenges and advanced multiphase models used in the oil & gas, chemical & process and nuclear industries.

24. General discussion (16:55 – 17:15)
Behrooz Askari is the managing director of SwissSafeTech LTD. He graduated from the Rome University La Sapienza, Nuclear Engineering Department and then received his PhD from ETH Zurich on Boiling Water Reactors (BWRs) stability analysis and design. He has been working closely with Professor Yadigaroglu and for the past 20 years, he studied methodologies for 2 phase flow system instabilities, especially for BWRs. As the result of this research, he has developed advanced tools to analyse instability issues in BWRs. The tools are based on core LPRM and APRM signal time series analysis and, alternatively, based on fully coupled 3D neutronics and thermal hydraulics. He has been serving the nuclear industry, as a senior consultant for the past 12 years.

Mohammed Azhar is a principal CFD Engineer in the chemical and process group at ANSYS Fluid Dynamics. He received his PhD in Chemical Engineering at the University of Leeds. He has worked as an Application Field Testing (AFT) lead for ANSYS FLUENT. As an Application Specialist, he develops and tests new industrial fluid dynamic applications. As a proxy customer, he is responsible for managing and communicating market requirements for multiphase flow and oil & gas industry sector.

Sanjoy Banerjee is Distinguished Professor of Chemical Engineering and Director of the Energy Institute at the City University of New York. Previously he was Professor of Chem. Engng. at the Univ. of California – Santa Barbara. Member of the US NRC Advisory Committee on Reactor Safeguards, ACRS. Earlier in Canada, he occupied the positions of Westinghouse Professor of Engng Physics at McMaster Univ. and of Acting Director of Applied Science in the Whiteshell Nucl. Research Est. He was a founding member of the Canadian Advisory Committee on Nuclear Safety and serves as a consultant to governmental and industrial organisations in several countries. He has received the ASME Melville Medal, the IChemE (UK) Danckwerts Lectureship, the AIChE Kern Award, and the ASME Heat Transfer Memorial Award. He has published extensively on multiphase fluid dynamics and turbulence. Fellow of ANS.

Dominique Bestion is Research Director at CEA-Grenoble, in France, Professor at the Ecole Polytechnique, and Editor at Nuclear Engineering and Design. Has worked extensively in modelling two-phase flow for system and CFD codes, and has been project manager of the CATHARE code development. He coordinates two-phase flow modelling in the NEPTUNE French multi-scale thermalhydraulic platform and was coordinator of Thermalhydraulic activities of the NURESIM, NURISP and NURESAFE European Projects for a multi-disciplinary and multi-scale simulation platform. As a member of the OECD-CSNI-WGAMA, he coordinates a Task Group on the application of CFD to nuclear reactor safety issues.

Jacopo Buongiorno is the TEPCO Professor and Associate Department Head of Nuclear Science and Engineering at MIT. He has published over 70 journal articles in the areas of reactor safety and design, two-phase flow and heat transfer, and nanofluid technology. For his research work and his teaching at MIT won several awards, including the Ruth and Joel Spira Award (MIT, 2015), and the Landis Young Member Engineering Achievement Award (ANS, 2011). He is the Director of the Center for Advanced Energy Systems, which is one of eight Low-Carbon-Energy Centers of the MIT Energy Initiative. He is a consultant for the nuclear industry in reactor thermal-hydraulics, and a member of the Accrediting Board of the Natl Academy of Nuclear Training. He is also a member of ANS (and served on its Special Committee on Fukushima in 2011-2012), of ASME, and was a participant in the Defense Science Study Group (2014-2015).

Michael L. Corradini is Wisconsin Distinguished Professor of Nuclear Engng at the Univ. of Wisconsin-Madison. He is also a member of the US NRC Advisory Committee on Reactor Safeguards (ACRS), member of NRC safety review panels and of the DoE Generation IV Roadmap Project. He has published widely in areas related to vapour explosion and severe accident phenomena, jet spray dynamics and transport phenomena in multiphase systems.

Djamel Lakehal is founder and CEO of ASCOMP AG, an ETH Spin-off company specialized in industrial thermal-fluid dynamics. He obtained his PhD in Fluid Mechanics from Ecole Centrale of Nantes, France. After four years of research on turbulence at the Univ. of Karlsruhe and TU-Berlin, he joined the Laboratory of Nuclear Energy Systems at ETH as Group Leader and Lecturer. Dr Lakehal authored numerous papers in the area of thermal-fluid dynamics. He acts as an adjunct lecturer at ETH Zurich and ENS Paris.

Simon Lo was the Director for Multiphase Flow Models Development at CD-adapco, a Siemens business until he retired in July 2019. He is a Honorary Professor in CMFD at The University of Nottingham, UK. He received his PhD from Imperial College, London in 1984. Since then he has been actively involved in the development of commercial CFD codes (CFX, STAR-CD and STAR-CCM+) and their application to industrial multiphase flows.

Horst-Michael Prasser is Professor of Nuclear Energy Systems at ETH-Zurich and former Head of the Thermal-Hydraulics Laboratory at PSI. He graduated from the Moscow Institute of Power Engineering and obtained his PhD in 1984 in Zittau. During the German reunification, he took part in the foundation of the Res. Centre Dresden (Rossendorf), where he later headed the group “Experimental Thermal Fluid Dynamics.” He works on multiphase flow instrumentation and the closure relations necessary for CMFD codes, as well as on nuclear reactor safety studies.

Gretar Tryggvason is the Charles A. Miller Jr. Distinguished Professor and Head of the Department of Mechanical Engineering at the Johns Hopkins University. He is well known for the development of methods for direct numerical simulations of multiphase flows and their applications. He is an active member of several professional societies, a fellow of the American Physical Society and the ASME, and the former editor-in-chief of the J. Comp. Physics.

Stéphane Zaleski is Professor at Sorbonne Université in the Jean Le Rond d’Alembert Institute. He studied for his doctorate at the Physics Department of Ecole Normale Supérieure in Paris. In 1992 he joined the Laboratoire de Modélisation en Mécanique which later became the Jean Le Rond d’Alembert Institute. He investigates various numerical methods for the simulation of multiphase flow with applications for atomization, cavitation, porous media flow, boiling, hydrometallurgy and droplet impact. He currently investigates several variants of the Volume of Fluid method for interface tracking and the phase field method for interface tracking. He has written several computer codes for the simulation of two-phase flow including PARIS Simulator with R. Scardovelli and G. Tryggvason and he participates in the development of the Basilisk code. He is Associate editor of the Journal of Computational Physics and of Computers and Fluids. He created with Patrick Huerrre a PhD and Master degree program in Fluid Mechanics taught entirely in English, a rarity at a French University. He received the Victor Noury prize of the Paris Academy of Sciences and the Silver Medal of CNRS; he is a Fellow of the American Physical Society.

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