Government of India
Ministry of Human Resource Development

GIAN
GLOBAL INITIATIVE OF ACADEMIC NETWORKS

Multiphase Computational Fluid Dynamics and Heat Transfer

Overview

Multiphase flows are encountered in nature (e.g. raindrops or snowflakes moving through the atmosphere) and in a wide variety of industrial applications such as nuclear reactors (bubbly flows), turbomachinery and pumps (cavitation), internal combustion engines (spray combustion) etc. They include all flows with at least two phases e.g. suspensions, slurry and debris flows, aerosols and dusty gases, cavitating flows, fluidized and bubbly beds etc. They are usually classified by the state of different phases and therefore are referred to as gas/solids flows or liquid/solids flows or gas/particle flows or bubbly flows etc. There are two general topologies of multiphase flows known as the ‚disperse flows' and the ‚separated flows.' The disperse flows characterize flows which consist of finite particles, drops or bubbles (the dispersed phase) distributed in a connected volume of the continuous phase. The separated flows consist of two or more continuous streams of different fluids separated by interfaces. Over half a century, there has been extensive analytical and experimental work done on various types and categories of multiphase flows for a variety of industrial applications including biological flows. However the computational analyses of multiphase flows are of relatively recent origin. With enormous computing power presently available, it is now possible to solve the fundamental equations describing various phases and their interactions and get a full picture of the flow physics and use it effectively in product design. The goal of this short course is to describe the essential elements of multiphase computational fluid dynamics and heat transfer accompanied by the tutorials and in class demonstrations of their implementation to solve problems using the commercially available software.

The course will begin with a brief introduction to various types of multiphase flows and their industrial applications. It will be followed by a description of the mathematical models and governing equations for both disperse and separated multiphase flows. Some models examples will be presented in tutorials to demonstrate how to solve the equations for simple geometries and interpret the results. The key components of the course will involve both the Eulerian and Lagrangian modelling approaches and their implementation to solve practical problems using a commercial CFD solver Ansys-Fluent. All the needed mathematical models and the numerical methods, and the detailed numerical set up will be presented. Volume of Fluid (VOF) method and fast interface tracking method will be discussed. Discrete Element (DEM) method and Parcel method with scaling laws will be discussed for gas/solid interaction flows. A lecture on stratified and segregated flow modelling will also be presented with example problems solved in the tutorials. Finally, the idea of multiscale modelling and its implementation to solve a particular class of multiphase problems will be presented in a lecture.

The foreign faculty member is an internationally known academic, researcher and practitioner with proven knowledge, experience, and demonstrable ability in teaching, consultancy, research, and training in the field of Computational Fluid Mechanics and Heat Transfer including the Multiphase CFD and Heat Transfer. The host faculty will assist in the tutorials/demonstrations who teaches Applied Mathematics and Computation, and Computational Fluid Dynamics courses at PG level regularly.

Course Objectives

The primary objectives of the course are as follows:

i) Expose the participants to multiphase flow modelling and numerical simulations.
ii) Build the confidence and capability amongst the participants in solving multiphase flow problems using both the Eulerian and Lagrangian modelling approaches.
iii) Provide exposure to practical problems and the numerical methodology for obtaining the solutions to multiphase flow problems on computers
iv) Enhance the capability of the participants to formulate, analyze and numerically solve the complex multiphase flow and heat transfer problems.

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Dates	**12th March to 17th March 2019**	
Location	**Motilal Nehru National Institute of Technology (MNNIT) Allahabad, U.P., India.**	
Course Schedule	12th March 2019 (Tuesday)	Inauguration: 3.00 PM-3.30 PM High Tea: 3.30 PM-4.00 PM **Lecture-1: 4:00 PM –5.00 PM** Topic: Introduction to Multiphase Flows and their Industrial Applications. Tea Break: 5.00 Noon-5.15 PM **Lecture-2: 5.15 PM-6.15 PM** Topic: Mathematical Models for Dispersed Multiphase Flows and Governing Equations. **Tutorial-1: 6.15 PM-7.15 PM** Topic: Simple Model Problems of Dispersed Multiphase Flows and their Solutions. **Tutorial-2: 7.15 PM-8.15 PM** Topic: Complex Benchmark Problems of Dispersed Multiphase Flows and their Solutions.
	13th March 2019 (Wednesday)	**Lecture-3: 4 PM –5PM** Topic: Mathematical Models for Separated Multiphase Flows and Governing Equations. Tea Break: 5PM-5.15 PM **Lecture-4: 5.15 PM-6.15 PM** Topic: Interfacial Heat and Mass Transfer Models. **Tutorial-3: 6.15 PM-7.15 PM** Topic: Simple Model Problems of Separated Interfacial Multiphase Flows and their Solutions. **Tutorial-4: 7.15 PM-8.15 PM** Topic: Complex Benchmark Problems of Interfacial Multiphase Flows with Heat and Mass Transfer and their Solutions.
	14th March 2019 (Thursday)	**Lecture-5: 4PM –5 PM** Topic: Eulerian Modeling (Granular Flow Modeling) of Dispersed Multiphase Flows with Phase Interaction Models. Tea Break: 5PM-5.15 PM **Lecture-6: 5.15 PM-6.15 PM** Topic: Volume of Fluid (VOF) Method and Multiple particles size Group Modeling. **Tutorial-5: 6.15 PM-7.15 PM** Topic: Application of Eulerian Flow Modeling of a Fluidized Bed Reactor. **Tutorial-6: 7.15 PM-8.15 PM** Topic: Application of Eulerian Flow Modeling of a Fluidized Bed Reactor (Continued).
	15th March 2019 (Friday)	**Lecture-7: 4PM –5 PM** Topic: Lagrangian Modeling of Dispersed Multiphase Flows with Solid/Gas Interactions in a Fluidized Bed Reactor. Tea Break: 5 PM-5.15 PM **Lecture-8: 5.15 PM-6.15 PM** Topic: Discrete Element Method (DEM), Parcel Method, and Scaling Laws (to address large number of particles). **Tutorial-7: 6.15 PM-7.15 PM** Topic: Application of Lagrangian Flow Modeling of Solids/Gas Flow in a Fluidized Bed Reactor. **Tutorial-8: 7.15 PM-8.15 PM** Topic: Application of Lagrangian Flow Modeling of Solids/Gas Flow in a Fluidized Bed Reactor (continued).
	16th March 2019 (Saturday)	**Lecture-9: 4PM –5 PM** Topic: Stratified and Segregated Flow Modeling with Interfacial Area Density Models.

		Tea Break: 5 PM-5.15 PM **Lecture-10: 5.15 PM-6.15 PM** Topic: Introduction to Multi-Scale Modeling Techniques. **Tutorial-9: 6.15 PM-7.15 PM** Topic: Model Problems of Stratified Multiphase Flows and their Solutions. **Tutorial-10: 7.15 PM-8.15 PM** Topic: Model Problems of Segregated Multiphase Flows and their Solutions.
	17th March 2019 (Sunday)	Evaluation of Learning Outcomes (Examination/Test, Feedback) & Certificate distribution. 9.30 AM-12 Noon.
Who should attend?	UG and PG Students, Research scholars, Faculty members, Practicing Engineers, Scientists.	
Course Fee	**One-Time GIAN Registration:** Please visit http://www.gian.iitkgp.ac.in/GREGN/ and register by paying Rs. 500/- (those who have already been paid, need not pay again). The participation fees for attending the course is as follows:	

Participants from abroad:	US$ 100
Industry/ Research Organizations:	Rs. 2000
Academic Institutions (Faculty members):	Rs. 1000
Academic Institutions (Students/Research scholars):	Rs. 500

- The above fee includes all instructional materials, computer use for tutorials & assignments (if any).
- Minimum 90% attendance necessary to be eligible for certificate of participation/attendance.
- Appearing for evaluations/examinations during the course is necessary for certificate of grades in the course.
- Accommodation in the campus can be provided subject to availability and on 'first come first served' basis. Payment for accommodation is extra.

Bank Details

Account Name: Multiphase Flow-2019. **Account No.:** To be announced soon.
Bank Name: Vijaya Bank. **Branch:** MNNIT Allahabad. U.P. India.
IFSC Code: VIJB0007184.
Last Date of Registration: 5th March 2019.

International Expert

Professor Ramesh K. Agarwal is the William Palm Professor of Engineering in the department of Mechanical Engineering and Materials Science at Washington University in St. Louis (USA). From 1994 to 2001, he was the Sam Bloomfield Distinguished Professor and Executive Director of the National Institute for Aviation Research at Wichita State University in Kansas (USA). From 1978 to 1994, he was the Program Director and McDonnell Douglas Fellow at McDonnell Douglas Research Laboratories in St. Louis (USA). Dr. Agarwal received PhD in Aeronautical Sciences from Stanford University (USA) in 1975, M.S. in Aeronautical Engineering from the University of Minnesota (USA) in 1969 and B.S. in Mechanical Engineering from Indian Institute of Technology Kharagpur (India) in 1968. Over a period of 40+ years, Professor Agarwal has worked in various areas of Computational Science and Engineering - Computational Fluid Dynamics (CFD) and Heat Transfer, Computational Electromagnetics (CEM) and Acoustics, Multidisciplinary Design and Optimization. Over the years he has also worked on all kinds of parallel and supercomputing platforms (both SIMD, MIMD) to perform large scale engineering computations for industrial applications. For past fifteen years he has been engaged in research in Active Flow Control (AFC) for drag reduction of aircraft wings and trucks using various AFC devices. He has conducted both basic research as well as AFC simulations for full scale industrial applications. His Research in AFC has been funded by NASA, AFOSR, NSF, Boeing and Ford Motor Company. He is the author and coauthor of over 500 journal and refereed

conference publications. He has given many plenary, keynote and invited lectures at various national and international conferences worldwide in over fifty countries. Professor Agarwal continues to serve on many academic, government, and industrial advisory committees. Dr. Agarwal is a Fellow eighteen societies including the American Association for Advancement of Science (AAAS), American Institute of Aeronautics and Astronautics (AIAA), American Physical Society (APS), American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers (IEEE), Royal Aeronautical Society, Chinese Society of Aeronautics and Astronautics (CSAA), Society of Manufacturing Engineers (SME) and American Society for Engineering Education (ASEE). He has received many prestigious honors and national/international awards from various professional societies and organizations for his research contributions.

Host Faculty:

Dr. Anuj Jain is Professor in the Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad (India). He served as Head in the Department of Applied Mechanics during 2013-15 and as Dean (Research & Consultancy) during 2010-12. Prof. Jain has obtained his Ph.D. degree in multiphase flows through cyclone separators from IIT Roorkee. He has more than 32 years of teaching and research experience. He has published over 100 research papers. Besides, he has co-authored one textbook on Strength of materials for undergraduate level students. Five students have been awarded Ph.D. degree under his guidance so far. He has guided 74 M. Tech. theses. Prof. Jain is presently working on three externally funded research projects in the area of Bio-Fluid Dynamics as the investigator. He conducts Faculty Development Programme on CFD regularly. His current research interests include application of CFD for various challenging problems. Prof. Jain was the Chair of 6th International & 43rd National Conference on Fluid Mechanics and Fluid Power (FMFP-2016) and is the Vice-President of the National Society of Fluid Mechanics and Fluid Power, India.

Dr. Akshoy Ranjan Paul is Associate Professor in the Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad (India). Dr. Paul has 16 years of combined teaching and research experience and is actively involved in research in the areas of fluid mechanics, especially flow control, turbulence and CFD. He obtained his Ph.D. in Aerodynamics in 2013 from MNNIT Allahabad. He has published over 90 research papers. Besides, he has written four textbooks on fluid mechanics and solid mechanics for undergraduate level students. Six Ph.D. students are presently working under his guidance. Besides, he has guided over 35 M.Tech. theses. Dr. Paul is a panel reviewer of many international journals and is presently working in four research projects sponsored by various Govt. Agencies in the area of Fluid Dynamics as an investigator. Dr. Paul was the Organising Secretary of 6th International & 43rd National Conference on Fluid Mechanics and Fluid Power (FMFP-2016).

Contact:

Principal Course Coordinator	Course Coordinator	Local GIAN Coordinator
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