Computational Modelling of Turbulent Flow and Scalar Transport

Overview

Turbulence is ubiquitous in nature, and most industrial flows are predominantly turbulent. However, the analysis of turbulent mass, momentum and scalar transport remains one of the most challenging areas of thermo-fluid mechanics due to the wide range of length and time scales encountered in typical turbulent flows. This scale separation is a strong function of turbulent Reynolds number, and the complex interactions that occur due to non-linearity of governing Navier-Stokes equations. A complete physical understanding of turbulent flows necessitates the resolution of a rich variety of multi-physics phenomena. To date, none of the existing experimental and analytical methods is able to cover the full range of scales and associated phenomena occurring in the turbulent flows.

The proposed course will discuss the current state-of-art of turbulence modelling in the context of both RANS and LES, and the fundamental physical principles which underpin these model developments. It will also be demonstrated in this course how the fundamental understanding obtained from DNS feeds into the development of high-fidelity RANS and LES turbulence models. It is important to recognize that this area is extremely dynamic, and continuously evolving with time. This is not meant to be a CFD course, but it focuses on the science of turbulence modelling, which is necessary for computational simulations of turbulent mass, momentum and scalar transport in engineering applications. The topics, which will be covered in the proposed course, will not only provide an exposure to the conventional methods of turbulence modelling but also to some of the newly developed methodologies which have started to yield promising results.

Lectures in this course will be prepared based on the materials from a range of different courses which ran successfully in the past under the guidance of the course instructor in the University of Cambridge, University of Liverpool and Newcastle University. The proposed course will draw heavily on the course instructor's own research papers, and the book chapters authored by him.The course is planned to have a duration of 5 days comprising 10 hours of lectures and 6 hours of tutorial including assignment and discussion.

Modules	**Tentative Lecture Schedule: March 27th – 31st, 2023** **1st Day: Module A: Motivation and relevance. Bibliography. Introduction to governing equations and their significances.** **March 27, 2023, Monday** ***Lecture 1 : 11:00 AM to 12:00 Noon*** **Motivation and relevance. Bibliography. Introduction to governing equations and their significances.**

	Lecture 2 : 12:30 PM to 1:30 PM **Recapitulation of the structure of turbulent boundary layer and scalar transport in turbulent boundary layers.** ***Lab/Problem Session: 3:00 PM to 4:00 PM*** **Problem solving session on the principles of fluid motion.** **2nd Day** **March 28, 2023, Tuesday** ***Lecture 3 : 11:00 AM to 12:00 Noon*** **Introduction to Reynolds decomposition and Favre decomposition, their interrelation and necessities, Introduction to LES filtering** ***Lecture 4: 12:30 PM to 1:30 PM*** **Introduction to different simulation methods for turbulent flows, their strengths and limitations** ***Lab/Problem Session: 3:00 PM to 4:00 PM*** **Problem solving session on the principles of fluid turbulence, Reynolds and Favre decomposition.** **3rd Day: Module B: Physics of turbulence transport and its modelling** **March 29, 2023, Wednesday** ***Lecture 5 : 11:00 AM to 12:00 Noon*** **Closure problem of turbulence and the need for turbulence modelling** ***Lecture 6: 12:30 PM to 1:30 PM*** **Computational modelling of Reynolds stress/sub-grid turbulent stress closures.** ***Lab/Problem Session: 3:00 PM to 4:00 PM*** **Problem solving session on the derivation of Reynolds averaged and LES filtered transport equations**. **4th Day** **March 30, 2023, Thursday** ***Lecture 7 : 11:00 AM to 12:00 Noon*** **Essential concepts of molecular mixing and turbulent mixing** ***Lecture 8: 12:30 PM to 1:30 PM*** **Length scales of mixing and the significance of scalar variance and dissipation rate** ***Lab/Problem Session: 3:00 PM to 4:00 PM*** **Problem solving session with examples from molecular and turbulent mixing.** ***5th Day*** **March 31, 2023, Friday**

	Lecture 9 : 11:00 AM to 12:00 Noon **Computational modelling of scalar variance and scalar dissipation rate** ***Lecture 10: 12:30 PM to 1:30*** **Closure of Reynolds scalar flux/sub-grid scalar flux** ***Lab/Problem Session: 3:00 PM to 4:00 PM*** **Problem-solving session with examples from molecular and turbulent mixing.** ***6th Day:*** **April 1, 2023, Saturday** ***11:00 AM to 12:00 Noon*** ***Final Examination:*** Syllabus – Materials covered during the course
You Should Attend If…	▪ you are a researcher from government/private organizations/industry including the R&D sector ▪ you are a faculty from reputed academic institutions and technical institutions ▪ you are a student (B. Tech. / M. Sc./ M. Tech. / Ph.D.)
Fees	The participation fees for taking the course are as follows: **Participants from abroad** **US $200** **Indian Participants** **Industry/ Research Organizations** **INR 3,000** **Research Scientists/ Faculty** **INR 2,000** **Students** **INR 1,000/-** *(Bonafide Letter is required from the Head of the Department/Institute)* The above fee includes all instructional materials, computer use for tutorials & and assignments, accommodation, and meals. **The number of participants for the course will be limited to fifty.**
The time frame of the course & Venue	**March 27th – 31st, 2023** National Institute of Technology Durgapur Mahatma Gandhi Avenue, Durgapur, West Bengal, India https://www.nitdgp.ac.in

Faculty

Prof. Nilanjan Chakraborty is currently a Professor of Fluid Dynamics at the School of Mechanical and Systems Engineering of Newcastle University. Previously he was a senior lecturer at the School of Engineering of the University of Liverpool. He joined University of Liverpool as a lecturer in 2005 and was promoted to a senior lectureship in 2008. He moved to his current position in 2011 where he heads the Fluid Dynamics and Thermal Systems research group. His research interests include Direct Numerical Simulation (DNS) of turbulent combustion, turbu-lence and combustion modelling, Reynolds Averaged Navier Stokes (RANS) and Large Eddy Sim-ulations (LES), turbulent convection, natural convection of non-Newtonian fluids, Melt-ing/solidification related heat transfer problems in classical manufacturing (e.g. Casting, Welding) and laser aided manufacturing applications (e.g. Laser Surface Alloying).

Course Coordinator

Dr. Rabindra Nath Barman is Assistant Professor in the Mechanical Engineering Department, NIT Durgapur. He received his B, Tech., M. Tech and Ph. D. from Jadavpur University. He has over 12 year's research experience in the water resources & hydraulic Engineering. He has published more than 40 papers in reputed journals and serving as a reviewer on several reputed journals. He is the principal co-author of the two Springer monographs. He is also a project investigator of research projects granted by DST, IEI and AICTE. His research are includes transport phenomena, fluid flow and heat transfer applications.

Course Co-Coordinator

Dr. Partha Sarathee Bhowmik is Associate Professor in the Electrical Engineering Department, NIT Durgapur. He received his Ph. D. from Jadavpur University. He is also a project investigator of research projects from DST and MHRD. His research interest includes Signal Processing, Soft Computing, and Power Systems stability, FACTS Devices, Smart Grid/Micro Grid, Renewable Energy and Instrumentation.

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