IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Advanced CFD of viscoelastic flows**	
Project Number	**IMURA1075**	
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Research Clusters:

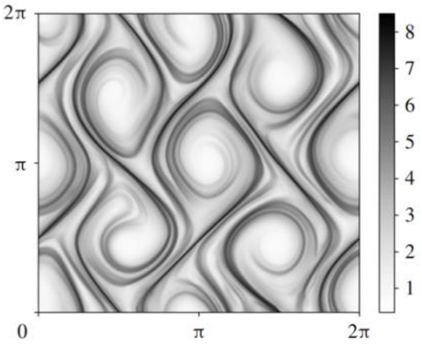
Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*	
1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research Themes:

Highlight which of the Academy's Theme(s) this project will address? *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*	
1	*Artificial Intelligence and Advanced Computational Modelling*
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	*Sustainable Societies*
7	*Infrastructure*

The research problem

Viscoelastic fluids, like polymer solutions and melts, are encountered in a wide range of scenarios—from the plastic industry to the mucus film in human lungs. These flows are prone to instability and difficult to control. For instance, viscoelastic effects can cause turbulence even when the Reynolds number is very small. To understand and optimize the functioning of these systems, we must be able to accurately predict the flow of viscoelastic fluids. However, standard CFD methods fail when it comes to simulating strong viscoelastic flows. Such flows spontaneously generate extremely large elastic stresses in highly confined zones (figure on the right); these shock like stresses feedback onto the flow and determine their behaviour. With traditional finite difference/volume/element methods, one must use very complex, *ad hoc* schemes with large grid resolutions to capture these stress-gradients.



Contour-plot of the log of the polymer stretch field in a fine-grid (1024^2) simulation of 2D elastic turbulence.

Project aims

We aim to devlop an advanced CFD code for strong viscoelastic flows by using a sophisticated technique called the Discontinuous Galerkin method. This fundamentally different way of solving PDEs has been developed specifically to capture shocks in compressible flows. This method exhibits higher accuracy and faster convergence compared to traditional techniques. By applying the Discontinuous Galerkin method to viscoelastic flows, for the first time, we will be able to simulate flows with much higher elasticity than has been previously possible, and at reasonable computational cost. Such a code is expected to have a major impact on our understanding of phenomenon like elastic turbulence (used to enhance oil recovery and mixing in micrchannels), the breakup of jets (ink jet printing), as well as the flow of biological fluids like mucus.

If you are interested in a long-term career in computational fluid dynamics, this project is for you. You will work in a very exciting area with research and commercial opportunities in India and across the world. It will provide you with deep knowledge and strong skills in fluid mechanics, numerical methods, code development and data analysis.

What is expected of the student when at IITB and when at Monash?

You will learn the necessary concepts and methods by spending time with the PIs, at IITB and Monash. At IITB, the focus will be on learning the basics of CFD and then mastering the Discontinuous Galerkin method. You will also get an introduction to viscoelastic fluid dynamics. Then, the first stay at Monash will provide the opportunity to understand in detail the equations governing viscoelastic fluids and the interesting phenomena they predict. Importantly, the stay at Monash will expose you to the important experimental work being done on polymer solutions which will motivate our simulations. Importantly, there are strong faculty groups in CFD and polymer dynamics at IITB and Monash respectively, so you will greatly benefit by interacting with peers at both institutes.

Expected outcomes

On obtaining your PhD, you will be an expert in advanced computational fluid dynamics. You will be an expert in the Discontinuous Galerkin method which is rapidly growing as the technique of choice for a wide range of Newtonian as well as non-Newtonian flows. You will also be an expert in modelling and simulations of viscoelastic flows. This skill set is in high demand in research groups across the world, as well as at research and development wings of companies involved in polymer processing (e.g. Saint-Gobain, Chennai), as well as at CFD consultancy and software companies (ESI Group, Bangalore and Pune; SankhyaSutra Labs, Bangalore).

How will the project address the Goals of the above Themes?

<u>Major theme: Artificial Intelligence and Advanced Computational Modelling</u>

The project will produce new computational methods and simulation software that will significantly improve our ability to predict the flow of viscoelastic fluids, like polymer solutions, with a wide range of possible applications, from microchip reactors to polymer processing and beyond to fluids in the human body.

Potential RPCs from IITB and Monash

IITB:
1. Prof. Avijit Chaterjee, Aerospace Engineering (computational methods in aerodynamics)
2. Prof. Partha Goswami, Chemical Engineering (expertise in CFD and turbulent flows)

Monash:
1. Prof. Murray Rudman (CFD of non-Newtonian fluids)
2. Prof. Greg Sheard (spectral-element methods and CFD of thermal convection and magneto-hydrodynamic flows
3. Prof. Ravi Jagadeeshan (statistical mechanics and Brownian Dynamics simulations of polymer solutions)

Capabilities and Degrees Required

The ideal candidate for this project should meet the following criteria:
1. Strong interest in fluid dynamics, mathematical and numerical methods, evidenced by good grades in the corresponding courses, and having done projects in these areas.
2. Comfort with programming and code-development using languages such as C/C++, Fortran, Python, Matlab or Mathematica. (Just using a CFD package such as COMSOL, FLUENT, etc., does not count as experience with coding.)
3. Good verbal and written communication skills.
4. Bachelor's or Master's degree in Mechanical or Chemical Engineering, or related fields.

Necessary Courses

ME757	Galerkin Methods for fluid dynamics	(6 credits)

Potential Collaborators

A potential partner in this work is Dario Vincenzi (Université Côte d'Azur, Nice, France: https://math.unice.fr/~vincenzi/) who is an expert in the turbulent flow of polymer solutions. He is currently collaboration with the IITB co-PI and the Monash PI.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Computational Fluid Dynamics and Mechanics; Maths; Computer Simulation; Modelling and Simulation