IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Complex fluid dynamics of viscoelastic polymer solutions**	
Project Number	**IMURA0966**	
Monash Main Supervisor (Name, Email Id, Phone)	Prabhakar Ranganathan Prabhakar.ranganathan@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name,Email)	Prof. Julio Soria Julio.soria@monash.edu	*Full name, email*
Monash Department:	Mechanical & Aerospace Engineering	
Monash ADGR (Name,Email)	Prof. Timothy Scott timothy.scott@monash.edu	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Jason Ryan Picardo jrpicardo@che.iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)	---	*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Madhu Vinjamur, head.che@iitb.ac.in	*Full name, email*
IITB Department:	Chemical Engineering	

Research Clusters:

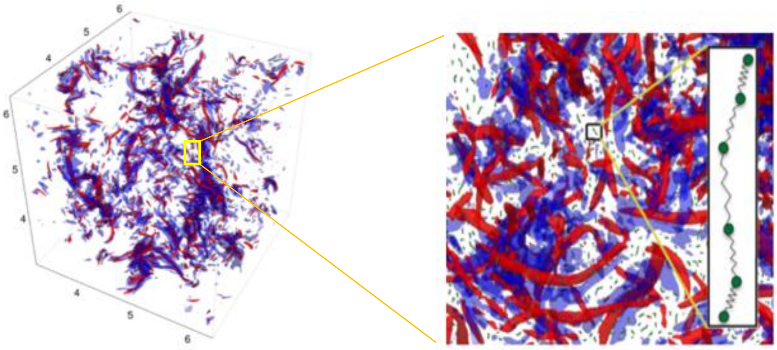
Research Themes:

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

The research problem

Turbulent friction in transporting fluids through pipes and ducts represents a huge cost globally and contributes enormously to global energy consumption. In the 1940s, it was discovered that, under certain circumstances, dissolving minute amounts polymers can reduce turbulent friction by as much as 80%! This is exploited to transport liquids like water or oil across large distances. The Trans-Alaska Pipeline, for example, uses dissolved polymers to reduce pumping costs. If we can understand the mechanisms behind this phenomenon, we can potentially use polymeric additives to manipulate turbulence in many processes, not just in pipes. **But the reasons for this turbulent drag reduction (TDR) by polymers are still, however, largely unknown.**

Project aims



If you are interested in a long-term career in **computational fluid dynamics** (CFD), this project is for you! It will provide you with deep knowledge and strong skills in fluid mechanics, numerical methods, code development and data analysis. CFD of complex flows of fluids with complex viscoelastic properties is a hot research area with commercial opportunities in India and across the world.

In this project, you will perform computer simulations with models of turbulent flows understand and accurately predict how the presence of polymers modifies flow structures and reduces frictional losses. Dissolved polymer molecules behave like nano-springs; they get stretched-out by fluid drag forces and then exert an equivalent feedback force when they relax and contract. As shown in the figures above, these nano-springs move through the eddies in a turbulent flow and get stretched to suck up the kinetic energy from the vortices. This causes the flow to become more laminar, reducing turbulent losses. Thus, the flow influences the polymers, and the polymers modify the flow.

We also have long-standing experience with CFD of polymer chains in turbulent flows. We have recently developed a new model to more accurately predict how polymers behave in such flows. **We are looking for a PhD candidate interested in CFD who can implement this new model in CFD simulations to obtain more accurate predictions of changes to turbulent flows and frictional losses by polymeric additives.**

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

The Monash PI is an expert in modelling the flow behaviour of polymer solutions. The IITB PI works on computational fluid dynamics of turbulence, on understanding the dynamics of flexible filaments in turbulent flows, and the analysis of such flows. The two PIs, therefore, bring the ideal set of complementary skills and expertise in complex dynamics of polymer solutions, fluid dynamics, computational techniques and data analysis.

Expected outcomes

On obtaining your PhD, you will be an expert in both rheological modelling as well as computational fluid dynamics (CFD). 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: Advanced computational engineering, simulation and manufacture</u>

The project will produce new computational methods and simulation software that will significantly improve our ability to predict the flow of polymer solutions, with a wide range of possible applications, from transport of oil in pipelines to underground oil recovery, and from microchip reactors to polymer processing.

Potential RPCs from IITB and Monash

IITB:

1. Prof. Rochish Thaokar (expertise in fluid dynamics and polymer physics)
2. Prof. Partha Goswami (expertise in the turbulent flow of suspensions)

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 Chemical or Mechanical Engineering, or Physics, or Mathematics.

Necessary Courses

CL601	Advanced Transport Phenomena	(6 credits)
CL602	Mathematical and Statistical Methods in Chem Engg.	(6 credits)
CL701	Computational Methods in Chem Engg.	(8 credits)

Potential Collaborators

The work is a collaboration between Prabhakar Ranganathan (Monash), Jason Picardo (IITB) and Dario Vincenzi (Université Côte d'Azur, Nice, France: https://math.unice.fr/~vincenzi/). Dario Vincenzi has contributed extensively to our current understanding of how polymer molecules behave in a turbulent flow. We will explore opportunities for the student to visit Dario Vincenzi in France in order to benefit from his expertise and guidance.

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