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**	
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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:

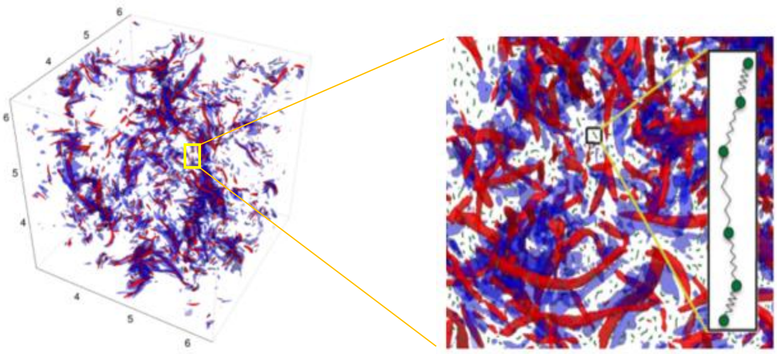
	Highlight which of the Academy's Theme(s) this project will address? *(Feel free to nominate more than one. For more information, see www.iitbmonash.org)*
1	*Advanced computational engineering, simulation and manufacture*
2	*Infrastructure Engineering*
3	*Clean Energy*
4	*Water*
5	*Nanotechnology*
6	*Biotechnology and Stem Cell Research*
7	*Humanities and social sciences*
8	Design

The research problem

Turbulence is often considered one of the last great unsolved problems in classical mechanics. 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 particularly important where liquids like water or oil must be pumped across large distances. The Trans-Alaska Pipeline, for example, uses dissolved polymers to reduce pumping costs. It is also suspected that the polymers in the mucus layer on the skin of marine animals such as dolphins enable them to have lower drag.

The reasons for this turbulent drag reduction (TDR) by polymers are still, however, largely unknown. If we can understand the mechanisms behind this phenomenon, we may able to choose the right kind and amount of polymer to be dissolved to reduce pipe friction in any given application.

Project aims



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. This flow-polymer coupling is very challenging because of the multi-scale nature of the problem. The polymers extend over nano- to micro- scales while turbulent flow eddies can span meters.

We have developed a new class of models that address this challenge. In this project, you will perform computer simulations with these new models of turbulent flows with polymers embedded in them to better understand how the elasticity and concentration of the polymeric nano-springs modify flow structures and reduce frictional losses.

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

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?

Major theme: Advanced computational engineering, simulation and manufacture

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.

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