IITB-Monash Research Academy

An Indian-Australian research partnership

Project Title:	**Solid settling in sheared non-Newtonian fluids**
Project Number	**IMURA0329**
Monash Supervisor(s)	Prof Murray Rudman Dr Andrew Chryss (CSIRO)
Monash Primary Contact:	murray.rudman@monash.edu, 9905 4627
Monash Head of Department:	Prof Chris Davies chris.davies@monash.edu
Monash Department:	Mechanical and Aerospace Engineering — *Full name*
Monash ADRT:	Prof Emanuele Viterbo — *Full name, email*
IITB Supervisor(s) IITB Co-Supervisor	Prof.Shivasubramanian Gopalakrishnan Prof.Rajneesh Bhardwaj — *Full names and titles*
IITB Primary Contact:	sgopalak@iitb.ac.in Rajneesh.bhardwaj@iit.ac.in — *Email, phone*
IITB Head of Department:	R P Vedula — *Name, Email,*
IITB Department:	Mechanical Engineering — *Full name*

Research Academy 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

The research problem

The transport of multi-phase mixtures by pipeline or open channel is a major component of many industrial and naturally occurring processes. In many mining and tailings disposal applications, environmental factors (notably water recovery, tailings stability and disposal site footprint) are inevitably leading to the use of higher solids loadings. For a purely fine-particle suspension, the suspension is often

well modelled by a (possibly thixotropic) shear thinning material – often with a yield stress. When this suspension also contains large dense particles (greater than about 50 microns), the system can be approximated as a non-Newtonian carrier fluid containing a suspension of coarse particles. As the solids concentration increases, usually so does the yield stress. This typically leads to pumping in the laminar flow regime. This apparently straightforward approach is complicated by the lack of turbulent eddies that normally suspend solid particles, and hence to the inevitable settling of the suspended phase in the pipe or channel, vastly reducing efficiency or even causing pipe blockages. Settling will occur under shear even for a suspension that has a sufficient yield stress to support the particles under static conditions (Pullum *et al.* 2002).

When a non-Newtonian fluid (or generalised Newtonian fluid) is sheared the local apparent viscosity is changed and that viscosity modification in turn modifies the flow field (compared to the Newtonian case) which then feeds back to the forces on the particle surface, affecting the settling velocity. The non-linearity of the viscosity in generalised Newtonian fluid ensures that this feedback is not trivial and scaling cannot be done on the basis of a Reynolds number alone (additional non-dimensional parameters such as the Bingham number or flow index become relevant).

The manner in which shear affects the settling of coarse solids in a non-Newtonian suspension is an open question. This is the research problem that this project will address.

Project aims

The aims of this project is to develop an understanding of solid particle settling in sheared flows and develop techniques for the prediction of settling rates in processes involving non-Newtonian fluids and coarse particle suspensions.

Expected outcomes

We expect the following outcomes from this project

- A computational model of the settling behaviour of particles in sheared non-Newtonian fluids, including yield stress materials, validated with companion experiments done by CSIRO outside of this project
- A method to predict the development lengths for coarse solids transported in minerals tailings applications
- Determination of the limiting ratio of particle size to pipe, duct or channel geometry where wall effects become significant
- Quality Ph.D. graduate with an ability to understand and model complex fluid flows of practical relevance

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

This project will provide answers to one of the key questions in high concentration solids suspension: Can we predict coarse particle settling? It will develop fundamental understanding and suggest new design guidelines for solids transport in non-Newtonian carrier fluids. These solutions will be derived via the mathematical and engineering-based models that will be used in the project. This project will be ideally suited to a Mechanical and/or Chemical Engineering student, with expertise in Fluid Mechanics, Mathematics and a sound physical intuition.

The knowledge generated in this Ph.D. project will form part of the understanding on which applications and potentially inventions based on solids transport in non-Newtonian fluids are developed.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These

The student for this project will require the following skills

- Good mathematical background, with a good understanding of numerical methods
- Some experience with computer programming, either with a high level language (such as C, C++,

FORTRAN) or expertise in developing applications with MATHEMATICA or MATLAB.

- A good background in Fluid Mechanics
- Good communication skills and an ability to interact with people from different scientific backgrounds.
- Some general understanding of non-Newtonian rheology is desirable
- Experience with ANSYS Fluent, ANSYS CFX or Open FOAM desirable. If not, a willingness to learn is essential.