Local Stresses in Dense Suspensions

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Concentrated suspensions are ubiquitous in industrial applications – cements, chocolate and ceramic pastes etc., but their flow is notoriously difficult to manage. There has been a recent paradigm change in understanding the flow of such suspensions, with the realisation that direct particle contacts dominate their rheology at high densities.

This goes a long way towards explaining the capriciousness of dense suspensions. The small number of nearest neighbours in contact with any given particle means that local dynamics play a key role. Load-bearing networks of particles, arising from either adhesive bonds or frictional contacts, give rise to particle-level stresses that are highly heterogeneous in time and space. These extreme stress fluctuations can have disastrous consequences in industrial applications, so that it is critical to understand not only bulk flow, but also the local dynamics.

In this project, the student will develop and employ a variety of novel experimental techniques to directly measure and characterise local stresses in suspensions. These techniques will include boundary-stress microscopy to measure forces along container walls, as well as stress sensitive fluorophores (‘mechanophores’) to resolve individual particle contacts. Furthermore, magnetic tweezers can be used to explore how suspensions respond to local forces by doping index-matched suspensions with magnetic particles. This work will be key to developing robust models of suspension dynamics that go beyond bulk, steady-state behaviour to capture the full spatio-temporal dynamics.

This project forms part of a large grant held between P&A in Edinburgh and our Engineering School, as well as engineers at Strathclyde University. The project is supported by a number of blue-chip industrial partners, and the student will be encouraged to interact strongly with the whole academic and industrial project team to broaden his or her perspective on the subject and to gain in-depth understanding of how the emerging results may affect industrial practice.

Figure 1: (Left) Simulation showing load bearing ‘force chains’ (yellow lines) in a shear thickening suspension. (Right) Schematic setup for ‘boundary stress’ microscopy where local suspension stresses on a surface can be visualised and measured [adapted from Rathee, Blair and Urbach, PNAS (2017)].