Fluids at Brown, Division of Applied Mathematics
Fluids and Thermal Sciences, School of Engineering
Joint Seminar Series

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3:00 PM
Barus & Holley, Room 190

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EXPLORING COMPLEX COLLOIDAL DISPERSIONS BY NUMERICAL SIMULATION

Suspensions, formed by dispersing solids in liquids, are found in applications such as cement and concrete, coatings, and ceramics. These materials display a wide range of behaviors. The specific behavior seen depends on the particle volume fraction f, the size and shape of particles, and the forces between particles. For many years, and for reasons that I will discuss, computational simulations—and much of the more basic experimental study—focused on suspensions which were spheres at particle loadings far below the jamming (or maximum packing) limit, say at f_{max}. However, advances in both computational power and our understanding of microscopic processes at the scale of particle contacts, where surface charge and adsorbed material play a major role, have allowed simulational exploration of much more complex suspensions. Our work in this direction is motivated by the goal of developing understanding of mining residues and nuclear waste slurries. Here, we will discuss the behavior of suspensions at very large f, where the rheological phenomena of yield stress, discontinuous shear thickening and shear jamming are found in practice.

Over the last several years [1,2], we have shown using a hybridization of discrete-element modeling and hydrodynamic simulations (as in Stokesian Dynamics) that a transition from lubricated to frictional interactions between suspended particle surfaces can explain discontinuous shear thickening: the transition results from sudden development of a percolating frictional contact network when stabilizing repulsive interactions are overwhelmed by the shear forces. In this talk, new results obtained as we explore the relationship between this sudden change in properties to a phase change will be presented, and the full flow “phase behavior” will be described. We then turn to the influence of strong attractive forces, which lead to a yield stress behavior, which can obscure the shear thickening as prior experimental work has made clear. Finally, we consider particles which are distributed in size, as often seen in practical applications involving suspensions, and show that the classical Krieger viscosity relationship in which the effective viscosity diverges as $(1- f/f_{max})^{-2}$ provides a collapse of data provided that f_{max} is known for the distribution, and show how behavior of wide continuous distributions of particle size can, somewhat remarkably, be reproduced by bidisperse distributions of the same variance and skewness.

1. R. Mari, R. Seto, J. F. Morris & M. M. Denn “Shear thickening, frictionless and frictional rheologies in non-Brownian suspensions” J. Rheol. 2014
2. R. Mari, R. Seto, J. F. Morris & M. M. Denn 2015 Discontinuous shear thickening in Brownian suspensions by dynamic simulation. *Proc. National Acad. Sci.* **112**. 15326.

Contact network: shear thickening suspension