Steady and unsteady shear rheology of dense granular suspensions

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ABSTRACT

Densely packed suspensions of granular particles in the form of pastes and slurries are abundant in fields such as speciality chemical manufacture and food production, industries worth billions of pounds annually. In order to characterise and optimise the processing of such materials, it is essential that their fundamental flow behaviour, which is often highly surprising and complex, is thoroughly understood. In this work we aim to shed light on the relationships between microscale particle phenomena and bulk paste rheology by simulating shear flow of suspensions using the discrete element method, taking particle contact and hydrodynamic lubrication into account.

Under steady shear flow, viscous and inertial bulk rheology is observed as a function of Stokes number, while quasistatic flow is observed above a critical volume fraction at low and moderate shear rates. Soft particle rheology, viscous or shear thinning dependent on material properties, is observed at very high shear rates. Transitions in microscopic phenomena, such as interparticle force distribution, fabric, and correlation length are found to correspond to those in the macroscopic flow. A constitutive model that can capture the transitions between steady shear flow regimes is proposed.

The unsteady flow behaviour of dense suspensions is probed by studying their response to shear reversal. Bulk stress and pressure data agree with those of classical experiments, while evolving microscale structures demonstrate that the resulting non-Newtonian behaviour can, in part, be ascribed to direct contacts between frictional particle surfaces.