Rheology of dense granular flows: regime bridging and implications for kinetic theory

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Using the discrete element method, simulations of simple shear flow of dense assemblies of soft, frictional particles have been carried out over a range of shear rates and volume fractions in order to characterize the rheology of granular flows in the inertial, quasi-static, and intermediate regimes. In agreement with previous results for frictionless spheres [1], the pressure in each regime is found to obey an asymptotic power law relation with shear rate. These relations are then used to construct a blended pressure model bridging the three regimes. Additionally, we model the shear stress ratio variation using two dimensionless groups: 1) the inertia number [2], which collapses inertial regime data at different volume fractions and shear rates, and 2) the ratio of the particle binary collision time to the macroscopic deformation timescale, which further corrects for the departure from inertial behavior. The pressure and shear stress ratio relations form a rheological model that, in the hard-sphere limit, can be written as a modified kinetic theory for dense granular flows. The primary features of this kinetic theory are the inclusion of (1) a critical volume fraction that depends on the interparticle friction coefficient and (2) a 'chain-length' correction factor to the energy dissipation equation to account for multi-body interactions [3], and (c) a correction factor to the shear stress equation to account for the development of a yield stress at close packing.

References

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