Three dimensional rheology of soft granular particles under gravity

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ABSTRACT

We present a characterization of the steady shear rheology for an idealized granular material from slow quasi-static states up to inertial flows, under various gravity fields and contact stiffness conditions, where the response is conventionally assumed to be independent of both [1]. A series of Discrete Element Method simulations are performed on a frictional granular assembly in a split-bottom geometry. While traditionally the inertial number, the ratio of stress to strain-rate time-scales, is dominating the flow rheology [2], we find that a second dimensionless number, the ratio of softness and stress time scales, must be involved to characterize the bulk flow behavior. For slow, quasi-static flows, the density increases while the macroscopic friction decreases with increase in either particle softness or gravity. This trend is added to the $\mu(I)$ rheology and can be traced back to the anisotropy in the contact network, displaying a linear correlation between macroscopic friction and deviatoric fabric in the steady state. Interestingly, also when the external rotation rate is increased for a given gravity field and contact stiffness, the linear relations holds. With further increase in the external rotation rate, the system enters into dilute, almost gaseous regime, where many interesting phenomena like convective flow instability are observed and collisions are dominant. Finally, we compare the numerical data obtained by DEM simulations with the theoretical predictions of the modified kinetic theory proposed in [3].

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