DENSE GRANULAR RHEOLOGY FROM FIRST PRINCIPLES

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ABSTRACT

The flow behavior is an important aspect of granular dynamics in the non-linear regime, typically encoded in constitutive equations. While such constitutive equations for rheology may be established purely from macroscopic considerations, we demonstrate here how constitutive laws can be derived from microscopic interactions: Based on the homogeneously driven granular states discussed earlier [1-3], an approach known from colloids, the intergration through transients (ITT) method, is used to derive in the sheared case first transient correlation functions and finally flow curves. These flow curves show rich phenomena such as Newtonian viscosity, yielding behavior, shear thinning and thickening. Also, the well-known Bagnold law can be derived in this way from first principles, and the calculation also predicts the coefficient of proportionality between the shear stress and the square of the shear rate.

Similar phenomena as in rheology shall be discussed for active microrheology in granular media [4-6], where a probe particle (an intruder) is pulled through an agitated system. Dynamical regimes are identified reminiscent of the different flow regimes in rheology. Both for small pulling forces as well as for small imposed pulling velocities, the friction on the intruder is constant in the linear-response regime. For subsequent stronger pulling, a force-thinning regime is observed, followed by a thickening regime for large pulling.

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