Particle-Phase Stress in a Dense Suspension

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We attempt to reproduce the results of numerical simulations of a dense, random monolayer of identical, neutrally buoyant spheres that is subjected to a steady, homogeneous, shearing flow within a viscous fluid (e.g., Singh and Nott, J. Fluid Mech. 412, 279, 2000). We consider rigid spheres that interact through hydrodynamic lubrication forces and a short-range repulsive force. These forces and their associated moments sum to zero for each particle in the suspension. We focus on a typical pair of particles and use the balances of force and moment to determine their translations and rotations as functions of their orientation with respect to flow. In doing this, we assume that the neighbors of the pair translate and rotate with the mean flow. The determination of the relative motion of the pair permits the calculation of the force between them. Summing the first moment of this force over all orientations gives the stress as a function of the average shearing. We calculate the dependence of the effective viscosity on the area fraction of the particles and determine the rate-dependent particle pressure that results from the anisotropy in their separation associated with the presence of the repulsive force.