Rheology, tribology, and acoustic lubrication of dense non–Brownian suspensions

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Suspensions are dispersions of solid particles in a fluid. Their rheology [1] implies a linear dependence of the shear stress σ on the shear rate, as a function of the microscopic friction μ_p between the particles. The coupling between the flow, the normal forces, and μ_p, induces a strong dependence of the rheology on σ. While the theoretical framework is well-established, measurements of the microscopic properties are missing.

In this presentation, I will show how one can use Tuning-Fork Microscopy (TFM) to measure μ_p between solid polystyrene (PS) particles immersed in a solvent, and how our results compare with the numerical simulations found in the literature [2,3], and moreover, provide novel insights on the origin of the rheological behaviors of suspensions [4]. This study focuses on three typical solvents : I will show that both PEG and water lead to constant values for μ_p (resp. 0 and 0.13), while Silicon (Si) oil leads to a decrease of μ_p with increasing load σ. The TFM results are consistent with the rheology : for Si oil, μ_p depends on the contact elasticity and thus on the applied load ; PS-water exhibits a constant viscosity up to a critical shear stress from which a shear-thickening behavior is observed. Because the applied stress is less than the critical value at which electrostatic repulsive forces are overcome in the inter-particle contacts, the observed transition in the rheology is not due to a change in the nature of particle contacts (from frictionless to frictional) but instead finds its origin in a change of regime from viscous to inertial, as suggested by Fall et al. [5]. PS-PEG has a Newtonian behavior but exhibits shear-thinning when the volume fraction ϕ gets close to Random Loose Packing : the swelling of the beads induces a repulsive force preventing particle contact, except at high ϕ.

Following these experiments, I will also present recent results from a new experiment in which ultrasounds activate a PS-Si oil suspension. While in this suspension μ_p can decrease with increasing shear stress, I will show that it is also possible to tune it down by propagating ultrasounds into the suspension : in the presence of ultrasound, at constant stress, the microscopic friction coefficient is replaced by a lower effective microscopic coefficient. This leads to a decrease in the viscosity of the system at fixed imposed stress and solid fraction.

Références

1. F. Boyer, E. Guazzelli, O. Pouliquen, *Physical Review Letters*, **107**, 1–5, (2011).
2. L. Lobry, E. Lemaire, F. Blanc, S. Gallier, F. Peters, *Journal of Fluid Mechanics*, **860**, 682-710, (2019).
3. W. Chèvremont, B. Chareyre, H. Bodiguel, *Physical Review Fluids*, **4**, 1-17, (2019).
4. A-V. Nguyen Le, A. Izzet, G. Ovarlez A. Colin, *Journal of Colloid and Interface Science*, **629**, 438-450, (2023).
5. A. Fall, A. Lemaitre, F. Bertrand, D. Bonn, G. Ovarlez, *Physical Review Letters*, **105**, 268303, (2010).