Detachment of a concentrated suspension drop

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Many phenomena in nature involve liquid jets loaded with rigid particles, i.e., small capillary-shaped flows of a granular suspension. So far, these flows are understood for sufficiently thick and diluted jets, when the suspension behaves like a continuous Newtonian effective medium and the formalism of single-phase jets applies. However, for jet break-up or in the case of high particle volume fractions, Newtonian effective models breakdown and a new description involving finite size effects — in particular, interphase flows and capillary confinement at the particle scale — is needed.

To elucidate these finite size effects, we conduct experiments on the detachment of a pending drop in the highly concentrated regime (solid volume fractions approaching 0.60) using model suspensions of spherical, neutrally buoyant spheres suspended in a viscous Newtonian liquid. This configuration allows us to monitor both the deformation rate and the stress along the drop, from which we infer the evolution of the resistance to flow throughout the detachment process. Measurements reveal an exponential decrease in the effective viscosity near the neck of the drop as a function of the current neck diameter (see Figure 1). We will discuss how this catastrophic drop in the resistance to flow depends on the relevant parameters of the problem as well as its consequences on the abrupt acceleration and acute pinch of the drop.

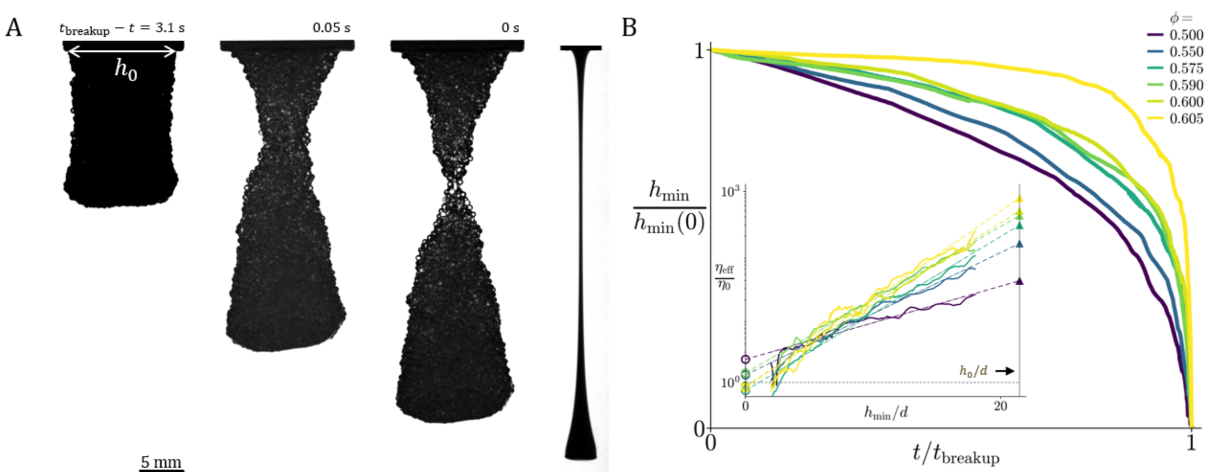

Figure 1. (A) Drop detachment. Left: Image sequence for a concentrated suspension drop ($\phi = 0.60$, the particle diameter is $d = 0.6$ mm, the suspending liquid viscosity is $\eta_0 = 2.4$ Pa·s). Right: Snapshot for a highly viscous liquid (same initial drop shape, the viscosity is 40 Pa·s). (B) Temporal evolution of the neck diameter for different particle volume fractions (time is rescaled by the total breakup time). Inset: bulk effective viscosity versus neck diameter, as inferred from the evolution of the stress and deformation rate at the neck.