Pinch-off of a viscous particulate suspension

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We study the viscous break-up of a capillary bridge of a particulate suspension: a dispersion of non-Brownian spherical beads suspended in a Newtonian liquid at solid volume fractions ranging from dilute to close to jamming. For all volume fractions, albeit the most concentrated ($\phi \gtrsim 48\%$), the minimal diameter of the bridge thins with a constant velocity $\dot{h}_{\rm min}$, like a pure viscous liquid, down to a diameter $h_{\rm acc}$ below which the thinning rate accelerates.

Keywords: Capillary break-up, particulate suspensions, extensional flow.

Motivated by the question of fragmentation of dispersed media, i.e. the formation of drops, we consider the pinch-off of a capillary bridge of a particulate suspension. For a pure viscous liquid, owing to the absence of intrinsic length and time scales, the minimal diameter of a thread undergoing a viscous capillary break-up is known to thin linearly in time until the last instants of pinch-off [1]. However, the break-up of a particulate suspension differs because of the discrete nature of the particles as well as the rheology. Such deviations from the purely viscous dynamics have been reported [2, 3, 4], but their dependence on the particle volume fraction and the effect of particle jamming at high concentration remain open questions.

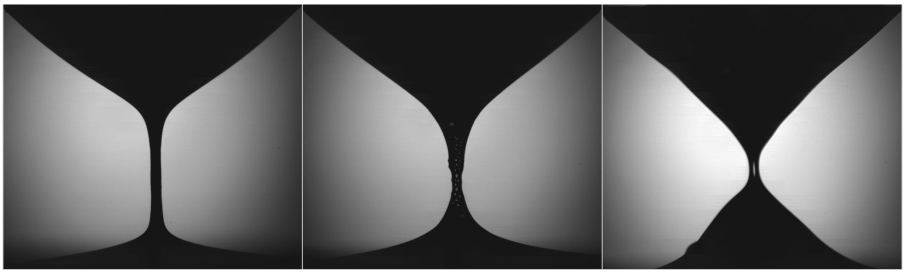

Figure 1: Pinch-off of an unstable capillary bridge of a particulate suspension for a volume fraction $\phi = 35\%$ and increasing particle sizes ($d = 10\,\mu\mathrm{m}, 80\,\mu\mathrm{m}, 500\,\mu\mathrm{m}$).

To address these questions, we use an unstable capillary bridge of a density matched suspension consisting of monodisperse spherical beads with diameter $10\,\mu\mathrm{m} \leq d \leq 500\,\mu\mathrm{m}$ suspended at different volume fractions $0 \leq \phi \leq 52\%$. A pendant drop is extruded quasi-statically from a millimeter-sized nozzle until it coalesces with a bath of the same suspension and forms an elongated capillary bridge which eventually pinches off. High-resolution imaging yields the profile and the minimal diameter of the bridge until the pinch-off.

In the early stage of the pinch-off, and up to large volume fractions ($\phi \lesssim 48\%$), the suspension bridge thins like an effective fluid. In the late stages, when the bridge diameter becomes of the order of a few d, the profile deviates from that of the effective fluid. The neck localizes and thins faster. The diameter at which this acceleration occurs is primarily set by the particle size d, and increases significantly with increasing volume fractions.

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