Interaction between a falling sphere and the structure of a non-Newtonian yield-stress fluid

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Abstract:

We present here an experimental study using mixtures of aqueous superabsorbent polymers where we systematically investigate the influence of the grain size on the effective rheology and its domain of validity. In water, these polymer powder grains swell up to 200 times and form gel grains whose size can be controlled by controlling the size of the initial powder. The rheology of this mixture (water and touching grains) combines viscous, elastic and plastic aspects and can be characterized using the free-fall of spheres of different diameters (between 3 and 30 mm-diameter) and densities (from 2200 to 15000 kg/m^3). As the typical size of the gel grains was varied between 1 and 8 mm, there is a range where it becomes comparable to the size of the falling spheres.

We observe four different regimes. (1) A steady-state motion with a constant terminal velocity, as in Newtonian fluids, is reached only for high density contrast between sphere and fluid and for spheres that are large enough compared with the gel grain size. (2) A no-motion regime that appears when spheres are not buoyant enough to overcome the yield stress of the mixture, or are too small compared to the grain size. (3) A slow fall regime where the velocity of the sphere progressively decreases. And (4), a "stick-slip" regime, where on an almost constant speed is superimposed an irregular vertical motion coming from the interaction between the sphere and the gel scales.

Besides these four regimes, we found that the yield stress and consistency of the mixtures always increase with the grain size. Moreover, the critical Yield parameter below which no motion is observed, increases as the sphere to grain diameters ratio becomes smaller than 3. This shows the control of the fluid microstructure on the validity of the viscoplastic rheological model.