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Engineering Fracking Fluids with Computer Simulation

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There are no comprehensive simulation-based tools for engineering the flows of viscoelastic fluid-particle suspensions in fully three-dimensional geometries. On the other hand, the need for such a tool in engineering applications is immense. Suspensions of rigid particles in viscoelastic fluids play key roles in many energy applications. For example, in oil drilling the "drilling mud" is a very viscous, viscoelastic fluid designed to shear-thin during drilling, but thicken at stoppage so that the "cuttings" can remain suspended. In a related application known as hydraulic fracturing suspensions of solids called "proppant" are used to prop open the fracture by pumping them into the well. It is well-known that particle flow and settling in a viscoelastic fluid can be quite different from that which is observed in Newtonian fluids. First, it is now well known that the "fluid particle split" at bifurcation cracks is controlled by fluid rheology in a manner that is not understood. Second, in Newtonian fluids, the presence of an imposed shear flow in the direction perpendicular to gravity (which we term *a cross or orthogonal shear flow*) has no effect on the settling of a spherical particle in Stokes flow (i.e. at vanishingly small Reynolds number). By contrast, in a non-Newtonian liquid, the complex rheological properties induce a nonlinear coupling between the sedimentation and shear flow. Recent experimental data have shown both the shear thinning and the elasticity of the suspending polymeric solutions significantly affects the fluid-particle split at bifurcations, as well as the settling rate of the solids. In the present work, we use the Immersed Boundary Method to develop computer simulations of viscoelastic flow in suspensions of spheres to study these problems. These simulations allow us to understand the detailed physical mechanisms for the remarkable physical behavior seen in practice, and actually suggest design rules for creating new fluid recipes.