Free Surface Flows of Suspensions: Continuum Modeling and Experiments

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Free surface flows of noncolloidal particle suspensions are studied numerically with continuum-level modeling and experimentally with nuclear magnetic resonance (NMR) flow visualization and x-ray radiography. The model includes the effects of shear-induced particle migration [1] using the diffusive-flux equation based on the Phillips model [2]. This model determines the particle volume fraction as a function of time, which is then coupled to the equations of motion through a generalized Newtonian viscosity dependent on the particle concentration. Normal forces can be considered using the approach of Fang et al. [3] based on the suspension balance model [4].The free surface location is determined using either an arbitrary Lagrangian Eulerian formulation that moves the mesh to adhere to the free surface or a level-set method that capture the interface location using an advected scalar field.

The model and experiments are demonstrated in three distinct geometries: 1) Bubble rise through a suspension, 2) Rod climbing where normal forces are significant, and 3) Mold filling in a geometry with an expansion and obstacle. Data are collected for model validation for the first geometry using x-ray radiography while the latter two geometries are investigated using NMR imaging. The NMR imaging gives particle volume fraction as a function of time and position, whereas the x-ray radiography gives only the location of the bubble with time. The finite element simulations are compared to experiments and found to capture qualitative behavior such as particle accumulation at the free-surface and rod anti-climbing, but do not yet match quantitatively.

References

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