Finite Volume Simulations of the Collision of Viscoelastic Droplets using Adaptive Re-meshing and Explicit Interface Tracking

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Abstract

The effectiveness of gelled fuel jet impingement, food production, and polymer–based spray coatings can depend on the atomization and droplet collision behavior of fluids with complex rheology. Non-Newtonian effects such as shear-thinning, shear thickening, and viscoelastic extensional hardening (usually a consequence of macromolecular interactions) could alter collision outcomes as well as drop-to-drop mixing rates. Extensional hardening specifically has been shown to promote the stability of liquid ligaments, a structure often formed during the transients of a droplet collision. In this study, direct numerical simulations of single phase viscoelastic droplet collisions are performed within a finite volume framework. The free surface is modeled with an explicit moving mesh interface tracking method, allowing highly accurate calculation of surface curvature, which is increasingly important with decreasing Weber number. In this method, the boundary of the computational domain acts as the free surface with pressure and velocity field boundary conditions applied directly. Control volume distortion due to large boundary deformation is minimized using quality–driven node smoothing and a localized edge reconnection algorithm specific to tetrahedral meshes. Mesh-to-mesh vector and scalar field mapping error is reduced using a recently developed second-order accurate conservative interpolation scheme. The free surface and viscoelastic implementations are validated against analytical solutions and experimental data. Simulation results capture rapid growth in viscoelastic stress during ligament drainage in areas surrounding pinch-off points. In addition, fluid ligaments have shown to be increasingly stable with higher Deborah numbers.

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