Mechanics Seminar

Free surface flows with complex interfaces

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Abstract.

Fluid-fluid interfaces abound both in nature and industry. Typical examples range from lung surfactants and ocular tear films to food processing and enhanced oil recovery. In many cases, however, the interface between fluid phases is doped with solid or deformable particles, polymer chains, and surfactant molecules. These species lead to highly intricate interfacial rheological behaviors that cannot be captured by the well known Young-Laplace equation. More importantly, complex interfaces can have a substantial impact on the bulk dynamics and optimal operating conditions of processing flows with free surfaces, like those encountered in coating and printing applications. In this talk, I briefly discuss the interfacial traction boundary condition for complex interfacial rheological models. Then, I use finite element simulations to study planar extrudate swell flows with a viscous liquid-air interface. The formulation consists of the equations of motion for Newtonian liquids in the bulk flow coupled with an interfacial traction boundary condition based on the Boussinesq-Scriven model. The latter is a surface analog of the compressible Newtonian model for bulk fluids, such that the interface is characterized by the interfacial tension coefficient together with two additional viscosity parameters. The results reveal that the interfacial viscosity plays a key role in the resulting dynamics, slowing down the flow both in the bulk liquid and at the interface. As a result, the extrudate swells dramatically to conserve mass in the slow plug flow that develops under the free surface. This augmented die-swell effect as well as other accurate predictions of interface-induced flow changes are critical in top-notch applications that rely on free surface flows, especially those at small scales, where high precision is at a premium.