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On the coalescence of two drops undergoing a head-on collision in a Bingham fluid

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In this work, we consider the canonical problem of the drainage of a thin film of Bingham fluid squeezed out between two spherical, Newtonian drops pushed against each other under the action of an external force. The only prior research to have studied this problem is the analytical work due to Jeelani and coworkers (Can. J. Chem. Eng., vol. 65, pp. 384-390, 1987, and J. Phys. Chem., vol. 90, pp. 6054-6059, 1986.). Unfortunately, these results have been obtained from a simplistic lubrication analysis for nearly planar films, or for dimpled films with ad-hoc assumptions about the film shape. In this work, we have performed detailed numerical simulations of the evolution of the shape of a thin, Bingham film with an immobile interface based on the lubrication equations, and compare our trends with existing work on the drainage of Newtonian films.

The drainage of a film of Bingham fluid between two colliding Newtonian drops differs from that of a Newtonian film in two principal ways. First, drainage rates are slower for Bingham films as compared to Newtonian films of the same viscosity. The difference becomes strong for low capillary numbers in the spherical configuration of the film, and for large capillary numbers in the dimpled configuration. Second, once the Bingham film becomes dimpled, it can freeze completely once it reaches a critical thickness. Counterintuitively, this critical thickness is independent of the force pushing the drops against each other! Our results suggest that on a map of drop radius vs. shear rate, the parameter regime for coalescence for Bingham films will be shrunk relative to Newtonian films, and will be completely hindered below a critical shear rate and above a critical drop size.

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