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Surfactant spreading on a thin liquid layer: Modeling and Theory
ELLEN PETERSON, MICHAEL SHEARER, KAREN DANIELS, DAVID FALLEST, NCSU — To model the spreading of a droplet of insoluble surfactant on a thin liquid layer, we use the lubrication approximation of the Stokes equations. The resulting system of nonlinear PDE describes the height of the fluid surface and the distribution of surfactant on the surface. The flow is driven by the surface tension gradient induced by the surfactant. Ignoring the smoothing effects of capillarity and diffusion of surfactant, the system simplifies to a pair of transport equations. These equations admit a similarity solution characterized by Jensen and Grotberg (1992) that sets the spreading rate of the surfactant layer. We employ finite difference simulations to capture the shape of the free surface and the surfactant distribution. The leading edge of the surfactant layer is treated as a free boundary, with a boundary condition corresponding to a jump in the free surface height first discovered by Gaver and Grotberg (1990). We are able to examine a solution for both the outer region as well as the boundary layer that accounts for the behavior of the film near the center of the surfactant droplet. For the full system, with capillarity, gravity, and diffusion on the surface, the leading shock smooths to a ridge. We compare simulations of the full thin film system with experimental observations of film height profiles, and with the observed spreading rate of the surfactant layer.

Ellen Peterson
NCSU

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