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The effect of surfactants on the instability of a rotating liquid jet

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Abstract

It has long been known that the presence of surfactants on the free surface of a liquid jet can create surface tension gradients along the interface. The resulting formation of tangential stresses along the surface lead to Marangoni type flows and greatly affect the resulting dynamics of rupture. In this way surfactants can be used to manipulate the breakup of a liquid jet and control the size of droplets produced. In this paper we investigate the effects of insoluble surfactants on the breakup of rotating liquid jets with applications to industrial prilling. Using a long wavelength approximation we reduce the governing equations into a set of one-dimensional equations. We use an asymptotic theory to find steady solutions and then carry out a linear instability analysis on these solutions. We show that steady state centreline solutions are independent of viscosity to leading order and that the most unstable wavenumber and growth rate of disturbances decrease as the effectiveness of surfactants is increased. We also numerically solve these equations using a finite difference scheme to investigate the effects of changing the initial surfactant concentration and other fluid parameters. Our results show that differences in breakup lengths between rotating surfactant-laden jets and surfactant-free jets increase with the rate of rotation. Moreover, we find that satellite droplet sizes decrease as the rate of rotation is decreased with the effect of surfactants amplifying the reduction in sizes. Furthermore, the presence of surfactants at fixed rotation rates is shown to produce larger main droplets at low disturbance wavenumbers whilst satellite droplets are smaller for moderate disturbance wavenumbers $\kappa \approx 0.7$.

Keywords: Surfactants; Prilling; Jets

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