124i Effect of Surfactants on the Breakup of a Shear-Thinning Jet

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The fluid dynamics of jet breakup is a free surface problem involving complex interaction between inertia, viscous and capillary forces that has been extensively studied both theoretically and experimentally. The majority of these studies are concerned with the dynamics of Newtonian liquid jets in the absence of surface-active species. The surface tension driven instability of non-Newtonian, surfactant-laden jets has received much less attention in the literature, if at all. Since non-Newtonian fluids are commonly used in various processes in industry involving jet breakup such as spraying, atomization, jet printing, and since surfactants are frequently present as contaminants or artificially added to control drop size and coalescence, it is important to increase our understanding of the role played by surfactant in the breakup of non-Newtonian liquid jets. This study's objective was to develop a fully two-dimensional model describing the effect of surfactants on the deformation and breakup of a liquid jet whose rheology obeys the purely viscous non-Newtonian Carreau model.

A two-dimensional Galerkin–finite element method was used to solve the set of equations describing the dynamics of the surfactant-laden jet. The set includes the complete continuity and momentum equations describing the non-Newtonian fluid flow, and the convection-diffusion equation governing the surfactant mass transport.

Results indicate that in highly viscous shear thinning liquid jets, addition of surfactant may lead to satellite drop formation due to reverse of capillary flow induced by interfacial Marangoni stresses. Decreasing the power-law index causes satellite formation at lower values of surfactant strength (measured by the elasticity number) than its Newtonian counterpart. In contrast, at high Reynolds numbers addition of surfactant initially reduces the satellite drop size; however, after a critical value of surfactant strength, a subsequent increase in surfactant strength increases the satellite drop size. In addition we found that reducing the power-law index at Reynolds number near unity leads to elongation of the formed drops, but this effect diminishes as the Reynolds number increases.