Physical Mathematics Seminar

Ligament and Droplet Formation in Fast Liquid Jets and Sheets

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Abstract

This talk is about the breakup of liquids in the large Reynolds and Weber number regime known as atomization. Here, one sees the simultaneous onset of multiple small scale patterns and the formation of periodically spaced liquid ligaments pointing along the direction of flow. Droplets form out of these ligaments by the surface tension driven pinch-off characteristic of slow jets. This process is immensely important in industry, where fuels are atomized for combustion, and in nature, where strong winds form sea spray -- but it remains poorly understood.

I will present a simple model based on two laminar boundary layers shearing an interface. Perturbing both fluids and the interface with three-dimensional disturbances leads to a linear stability problem. Some properties of the resulting operator can be found analytically, but full solutions are obtained using a Chebyshev method. Because this operator is non-normal, transient growth properties must also be calculated; this is done using an SVD approach. The fastest growing solutions include a modal disturbance of shear layer roll-up type and a non-modal disturbance closely resembling the optimal streamwise vortex disturbance of a boundary layer. A superposition of these two solutions has properties that match those seen experimentally.

Aspects of this theory have been guided by numerical simulations, done in collaboration with Stephane Zaleski, which I will discuss briefly. Complications include the need to define a norm that accounts for interface deformations, leading to a measure of energy with good convergence properties but strange, still unexplained, physical consequences.

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