ANNOUNCEMENT OF FINAL Ph.D. THESIS DEFENSE

SINGULARITIES IN FREE SURFACE FLOWS

Sumeet Suresh Thete — Advisor: Prof. O. A. Basaran

School of Chemical Engineering, Purdue University

Free surface flows pertain to the class of problems in fluid mechanics where the shape of the interface separating two phases is not known *apriori*. Some examples of free surface flows include breakup and coalescence of liquid drops and rupture of thin films, which are central to many industrial applications such as sprays, inkjet printing, aerosol and mist formation, foams, coating flows, lamination, and polymer processing. Furthermore, breakup and coalescence of liquid bodies are prominent examples of finite-time singularities which occur due to the dramatic changes in topology − a contiguous mass of liquid disrupts to form two or more masses during breakup or rupture; and two initially disconnected masses merge and become one during coalescence. Thus, understanding the behavior close to singularity, associated with these topological transitions is important in studying and improving the above-mentioned technologies. In this talk, two problems involving rupture of free thin films or sheets of fluids having two free surfaces (as opposed to a film deposited on a solid substrate that has one free surface) giving rise to such a finite-time singularity, are discussed.

In the first problem, rupture of a sheet of a power law fluid under the competing influences of destabilizing van der Waals pressure and stabilizing capillary pressure is analyzed by solving transient partial differential evolution equations for film thickness and lateral velocity. In such a fluid, viscosity decreases with deformation rate raised to the $n - 1$ power where $0 < n \leq 1$ ($n = 1$ for a Newtonian fluid). When $6/7 < n \leq 1$, sheet rupture occurs under a balance between van der Waals pressure, inertial stress, and viscous stress. When $n < 6/7$, however, the dominant balance changes: Viscous stress becomes negligible and the sheet ruptures under the competition between van der Waals pressure, inertial stress, and capillary pressure.

In the second problem, the rupture of a sheet of a Newtonian fluid is analyzed under the competing influences of inertial stress, viscous stress, van der Waals pressure, and capillary pressure by solving a system of transient partial differential evolution equations for the film thickness and lateral velocity. Close to the finite-time singularity, the film rupture is asymptotically self-similar. Consequently, the problem is also analyzed by reducing the transient partial differential evolution equations to a corresponding set of ordinary

differential equations in similarity space. For sheets with negligible inertia, it is shown that the dominant balance of forces involves solely viscous and van der Waals forces, with capillary force remaining negligible throughout the thinning process in a viscous regime. On the other hand, for a sheet of an inviscid fluid for which the effect of viscosity is negligible, it is shown the the dominant balance of forces is between inertial, capillary, and van der Waals forces as the film evolves towards rupture in an inertial regime. Real fluids, however, have finite viscosity. Hence, for real fluids, it is further shown that the viscous and the inertial regimes are only transitory and can only describe the initial thinning dynamics of highly viscous and slightly viscous sheets, respectively. Moreover, regardless of the fluid's viscosity, it is demonstrated that for sheets that initially thin in either of these two regimes, their dynamics transition to a late stage or final inertial-viscous regime in which inertial, viscous, and van der Waals forces balance each other while capillary force remains negligible.