ME – PhD Thesis Defense

Contact Line Instabilities in Thin Film Flows on Curved Surfaces

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ABSTRACT

Thin fluid film flows are ubiquitous in nature and many industrial applications.Such flows are characterized by having the thickness in one direction being much smaller than the characteristic length scales in the other directions with the flow primarily occurring along the longer dimension. These flows exhibit a wide range of length and timescales and have garnered significant interest over the past forty years (see Craster and Matar [2009], Oron et al. [1997],Chatzigiannakis et al. [2021]). When the fluid is viscous or when the scale of the flow is small, viscous effects dominate inertial forces thus one can use lubrication approximation (Batchelor [1967]) to describe the dynamics of the flow. Surface tension forces play a significant role in the dynamics of such flows when the scale of the flow is comparable to the capillary length scale which is in order of millimeters for most liquids. A common occurrence in such flows is the emergence of finger-like structures from the moving contact line (the interface between gas, liquid and solid) as the liquid flows over a surface. Unlike the viscous fingering (Saffman-Taylor) instability observed in the Hele-Shaw flows (Saffman and Taylor [1958],Saffman [1986]) these instabilities occur at the moving contact line for a free surface flow. These flows are driven by body or surface-shear forces where we observe the formation of a capillary ridge in the vicinity of the contact line. The moving capillary ridge is unstable to perturbations in the transverse direction and results in the formation of finger-like structures (Hocking and Miksis [1993],Kondic [2003]). The main factors influencing the instability are the nature of the driving force and the wetting properties of the underlying surface (Diez and Kondic [2001]). This instability can potentially lead to formation of dry regions in the surface which is not desirable in many technological application (Kistler and Schweizer [1997]). In this study we examine the contact line driven fingering instability of a gravity driven thin liquid film flowing down a various convex surfaces: a flat surface, cylindrical surfaces, a conical surface and a spherical surface. Using a generalized lubrication approximation we derive an evolution equation for the height of the film so as to capture the flow and dynamics of the instability for surface tension dominant phenomena. Using numerical simulations we study the dynamics of instability on a constant flux configuration in which a constant height of fluid film is maintained as a boundary condition. We observe a complete coating of all the surface in constant flux configuration in contrast to constant volume of flow. This is of great relevance in industrial applications.

ABOUT THE SPEAKER

Ananthan is currently pursuing PhD in the department of Mechanical Engineering, Indian Institute of Science. He completed his BTech and Masters from thedepartment of Mechanical Engineering, NSS college of Engineering and from the department of Mechanical Engineering, Indian Institute of Science in 2014 and 2017, respectively. His areas of research interest are numerical simulations of multiphase flows and thin fluid films and experimental studies involving bubble surface interactions.