124g Dynamics of Thin Free Falling Viscous Films

Ramesh Raju Mudunuri and Vemuri Balakotaiah

Free falling films are being studied for more than half a century, yet our understanding of the dynamics is incomplete. These free surface flows have many engineering applications as in condensers, falling film evaporators, liquid coolers, gas-liquid reactors, etc. Waves evolve on the free surface exhibiting a rich array of phenomena. It is observed that even at low flow rates, the interface can exhibit a complex structure, making these flows ideal for studying spatiotemporal chaos. Further the wavy interface can enhance heat and mass transfer rates by 200-300%. Staring from the 2-D Navier-Stokes (NS) equations we develop a model to describe falling film dynamics using the integral method. These flows have two independent dimensionless parameters, the Reynolds and the Weber numbers. The resulting model, derived using a novel scaling, is a set of coupled evolution equations for the film thickness and flow rate. To validate the model we compare the model predictions with those predicted by the NS equations and experiments. The focus of this work is on the derivation and validation of the model followed by a discussion of the rich dynamics of thin falling films. Linear stability predictions of the model are in agreement with that of the NS equations. Non-linear analysis of the model in the traveling wave co-ordinate shows that the Weber number is the scaling parameter in the visco-capillary regime. Pulsing experiments show that the surface evolves into solitary, tear shaped pulses or periodic wave forms depending on the pulsing frequency (Liu & Gollub, Phys. Fluids **6** (5), 1994). We present simulation results which are in close agreement with these experiments. Further, we study numerically, interaction of solitary waves and generation of solitary waves by wave interaction. It is seen that large solitary waves travel faster than smaller waves swallowing them, resulting in wave suppression. As observed in the experiments, our simulations show that nonlinear wave interaction might lead to generation of solitary waves. The simulation results are in very close agreement with Liu & Gollub's experiments.