Multiscale Simulation of Thin Films in Multiphase Flow

Ananthan M

Multiphase Flow Simulations Lab, Dept. of Mechanical Engineering
Indian Institute of Science, Bangalore

A common scenario in multi-phase flow simulation is the formation of thin fluid films in between colliding fluid masses or when a fluid drop interacts with a surface.These films can be very thin O(100nm) and cannot be fully resolved in DNS of multiphase flows even with Adaptive Mesh Refinement.This means final stages of film drainage happens in a sub-grid scale and results in numerical coalescence which is nonphysical.Here we develop a Multiscale approach to compute the flow of the film by coupling a Thin Film model to our conventional N-S solver using which we can capture the evolution of thin film and finally rupture and dewetting.

Continuity Equation: $\nabla \cdot \vec{V} = 0$

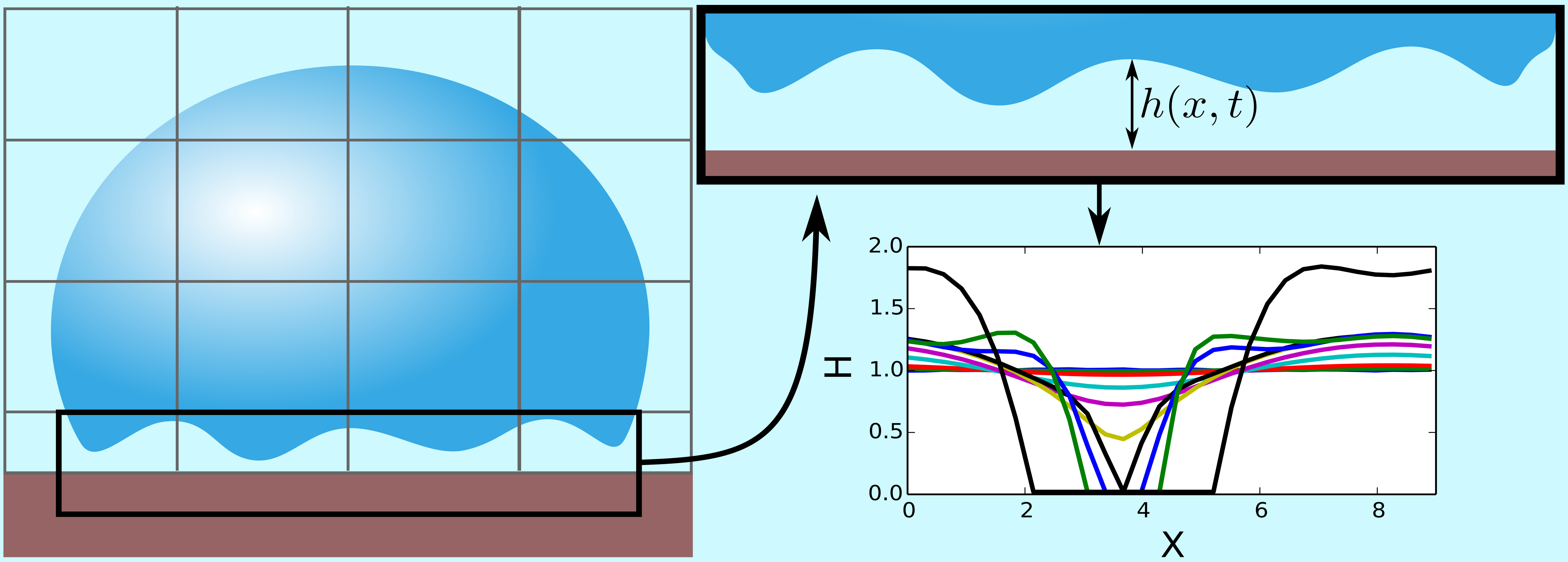
Navier-Stokes Equation with Surface Tension and van-der Waals forces

$$\rho \frac{D\vec{V}}{Dt} = \rho \left[\frac{\partial \vec{V}}{\partial t} + \left(\vec{V} \cdot \nabla \right) \vec{V} \right] = -\nabla P + \nabla \Pi + \mu \nabla^2 \vec{V}$$

where $\Pi = -\left(\frac{A}{6\pi h^3} \right) + \left(\frac{8B}{h^9} \right)$ $\qquad P = P_b - \sigma \frac{\partial^2 h}{\partial x^2}$

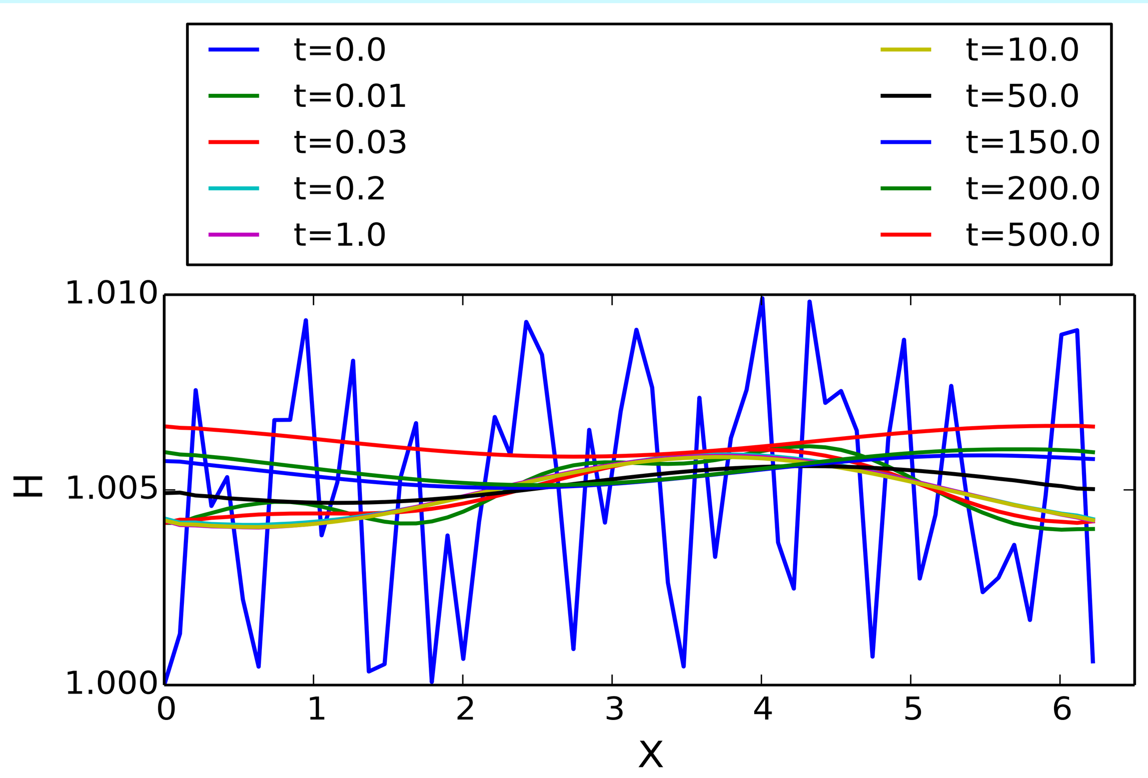
Thin Film Equation

$$\boxed{\frac{\partial h}{\partial t} + \frac{1}{3\mu} \frac{\partial}{\partial x} \left[\left(\sigma \frac{\partial^3 h}{\partial x^3} + \frac{\partial \Pi}{\partial h} \frac{\partial h}{\partial x} \right) h^3 \right] = 0}$$

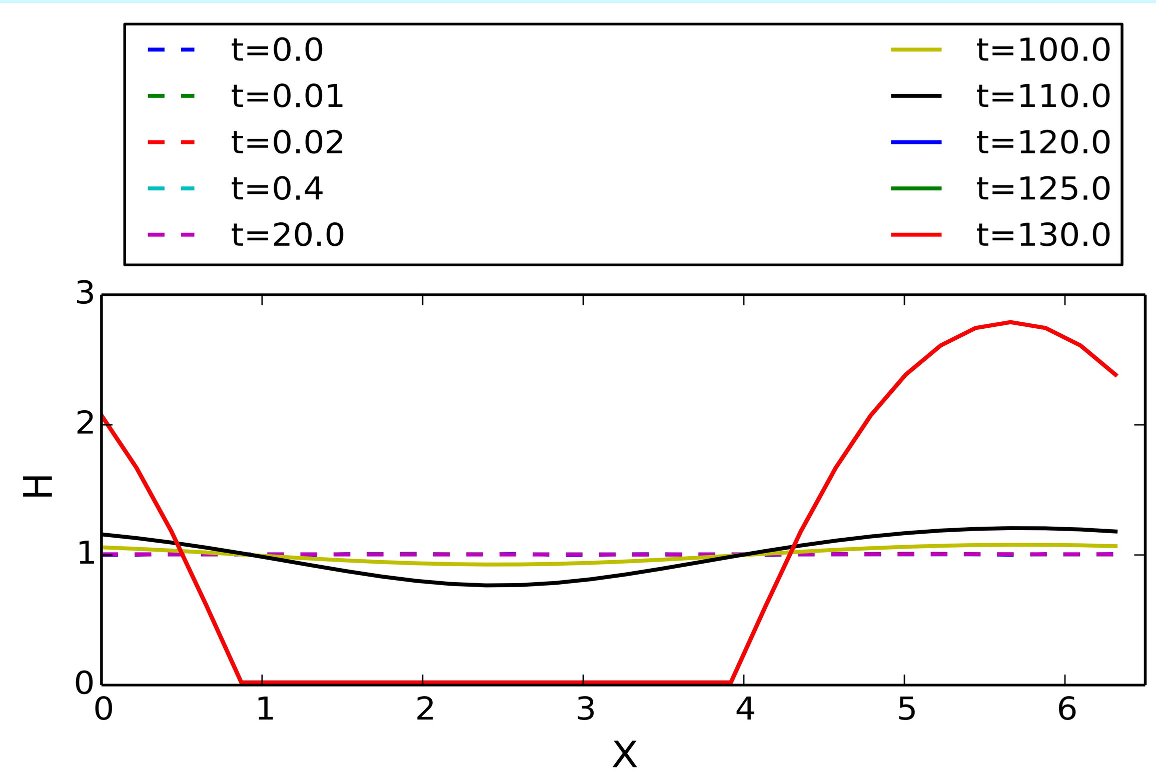


Wide range of length scales visible as the evolution of the thin film progresses culminating in the formation of a film in the sub-grid scale, where we couple the conventional N-S solver to our Thin Film model and evolution of the film , rupture and dewetting can be seen.

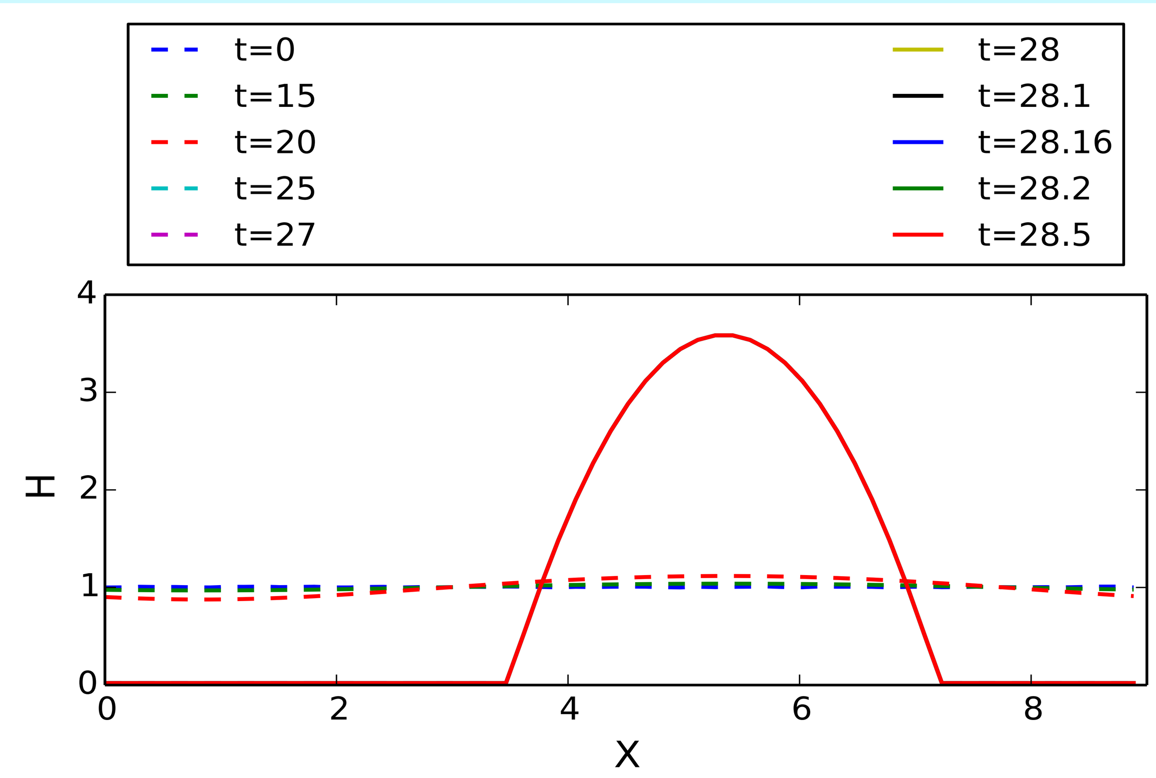
Evolution of Thin Film Instability in Non-denationalized form of Thin Film equation with H = 1 and a small amplitude perturbation of 0.01 in various domains



Subcritical domain,L = 1.98π.
A uniform stable film eventually forms.



Slightly supercritical domain, L = 2.01π. Eventually hole formation happens and rapidly it grows.



Fastest growing linear mode wavelength i.e. L $=2\sqrt{2}\pi$. Rupture and hole formation is fastest in this length scale.