## Motivation and Objectives

- Substitution of jet and Diesel fuels by renewable alternatives, which have different fuel properties from the conventional fuels.
- Physical properties such as spatial and temporal droplet size distribution, spray cone angle and spray tip penetration affect spray behavior and overall combustion performance. These macroscopic effects introduce mechanism of breakup.
- Difficulties in experimental visualization.
- High fidelity simulation of full atomization. Computationally expensive and also overwhelmingly large amount of data is generated, which can easily obscure the observation of fuel property effects.
- Detailed understanding can be obtained by simulating a simpler, idealized configuration, typical of breakup and droplet formation.
- Ligament dynamics: Typical and universal feature of droplet creation. Instability growth on the surface of an atomizing jet due to aerodynamic stretching forms ligament, and ligament breakup under the influence of surface tension.
- Rayleigh-Plateau mechanism retains the essence of capillary destabilization and breakup.

## Numerical Setup

**Evolution of Liquid Fraction**

\[
\frac{d}{dt}(\rho \phi) = \nabla \cdot \left( \nu \nabla \phi \right) - \nabla \cdot \left( \phi \mathbf{u} \right) - \nabla \cdot \left( \rho \mathbf{u} \cdot \nabla \phi \right)
\]

**Momentum Equation**

\[
\frac{d}{dt}(\rho \mathbf{u}) = \nabla \cdot \left( \rho \mathbf{u} \mathbf{u} \right) - \nabla p + \nabla \cdot \left( \tau_{ij} \right)
\]

\(\tau_{ij} = \mu \left( \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3} \delta_{ij} \nabla \cdot \mathbf{u} \right)
\]

**Solver Validation**

- Advection tests: Comparable to other algebraic VoF methods.
- Dynamics of inertial flows: Excellent agreement with modest grid resolution. No issues with large density ratio.
- Dynamics of capillary flows: Good agreement with literature over several validation tests.
- Current work: Improvement of curvature estimation.

## Main Results

- Studied physical property effects on capillary breakup of seven fuels corresponding to conventional fuels and their renewable alternatives in the Diesel and aviation fuel categories.
- Satellite and main droplet sizes were observed. Satellite droplet sizes are sensitive to Reynolds number while main droplets are relatively insensitive to Reynolds number.
- Bridge evolution.
- Importance of the first and second harmonics is shown. Higher harmonics play role in later time step (right before it breaks up).

## Discussion

- Studied fuel property effects on evolution of Rayleigh Plateau instability of a ligament.
- After validation, the solver was used to simulate 7 fuels including conventional fuels in Diesel and aviation category and their renewable alternatives varying Reynolds number between 4 to 60.
- Reynolds number of 10 marks a strong change in fuel property dependence. Diesel fuels (4 < Re < 8) therefore show strong sensitivity to physical properties while aviation fuels are less sensitive.
- Breakup time decreases from the most viscous HRD76 fuel to least viscous hexene.
- Described bridge dynamics:
  - Transition to the pinch-off regime occurs around \(t = 0.94t_{break}\) for all the fuels.
  - The bridge length at breakup is insensitive to fuel properties and is given by \(L_{break} = 5L\).
  - Difference emerge in the radial evolution of the bridge.
- Described the nonlinear evolution in terms of growth of harmonics of the fundamental mode of disturbance: Up to pinch-off regime (\(t < 0.95t_{break}\), the evolution is described adequately by the first and second harmonics.
  - In the pinch-off regime, higher modes also contribute towards ligament evolution.