The Effect of Inlet Pulsations on Primary Atomization of Liquid Jets

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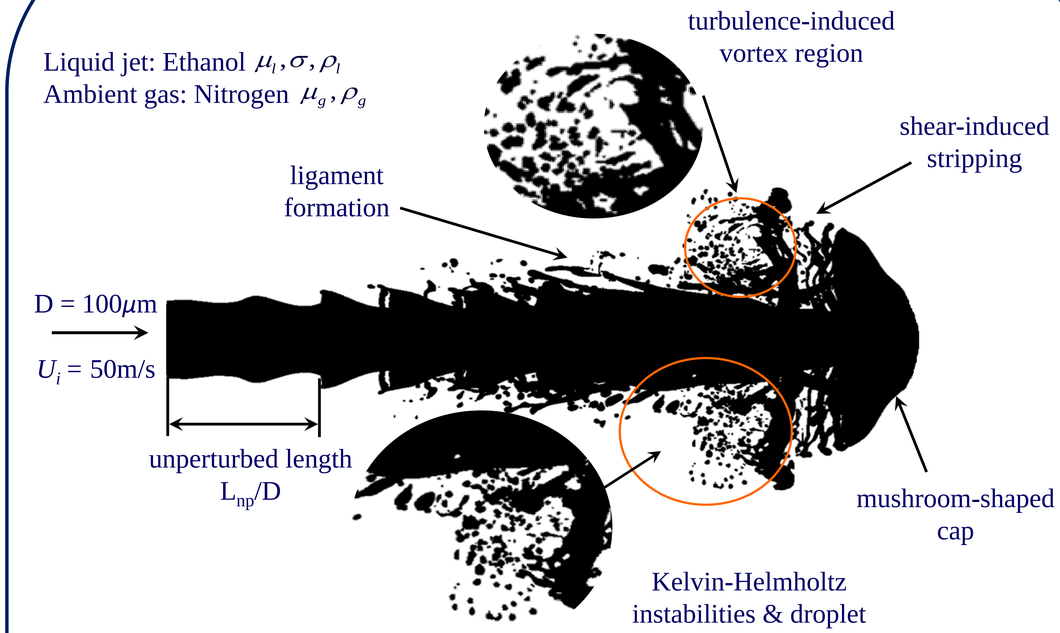
Primary Atomization: Liquid Jet Injection



Schematic of liquid ethanol jet injection in stagnant N_2 environment

Objectives

- Elucidate the physics underlying the primary atomization of liquid jets.
- Investigate the effect of inlet pulsations on the atomization process.
- Identify the reliability of numerical predictions using uncertainty quantification techniques (UQ) and sensitivity analyses.

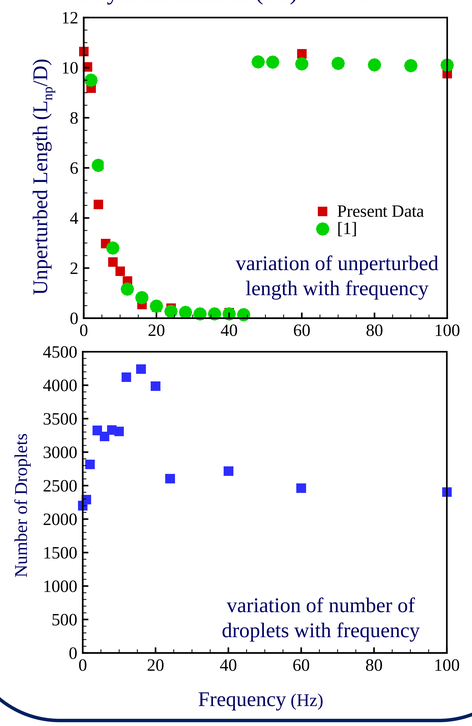
Validation

Physical Properties

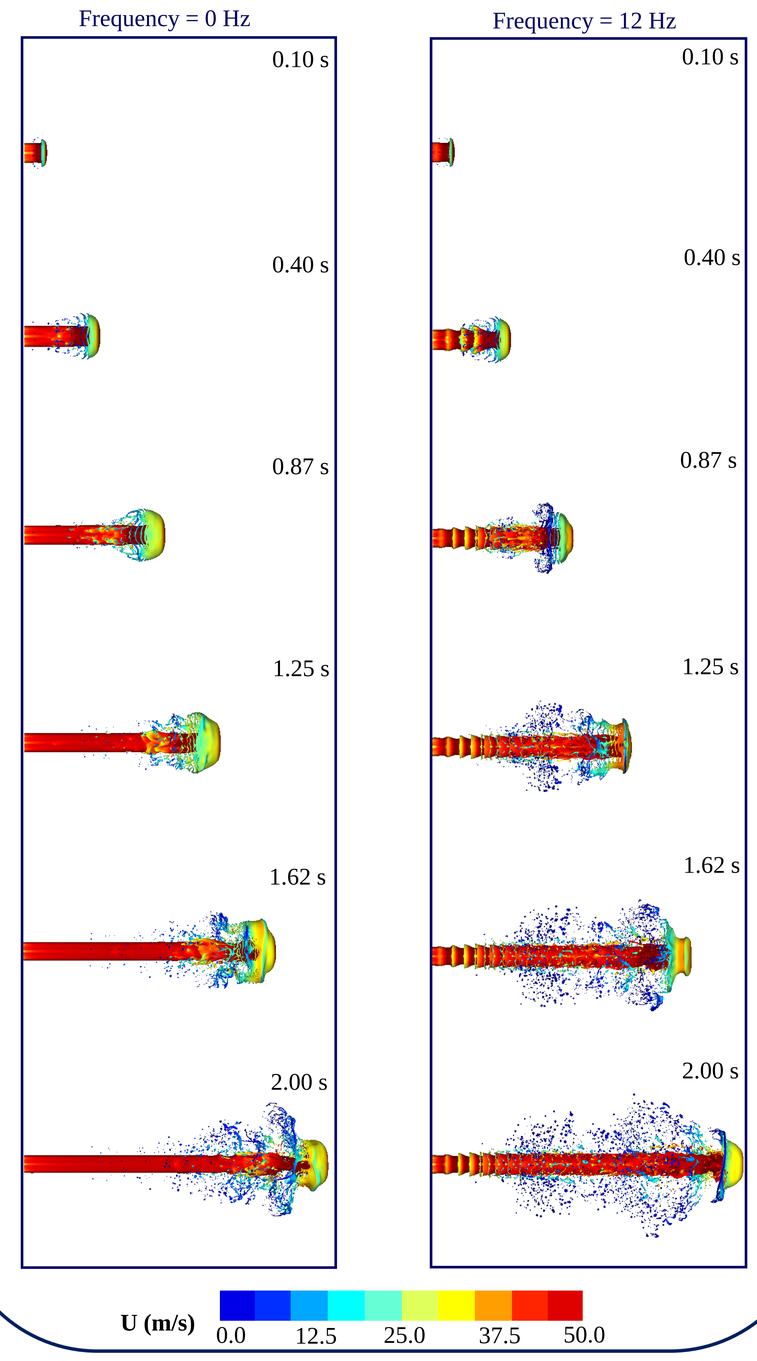
	Ethanol	Nitrogen
Density, ρ (kg/m^3)	848	34.5
Viscosity, μ (Pa·s)	2.87 x 10^{-3}	1.97 x 10^{-5}
Surface Tension, σ (N/m)	0.03	N/A

Relevant Non-Dimensional Parameters

Weber number (We)	287.5
Reynolds number (Re)	1477



Detailed Flow Physics



Methodology

Incompressible, variable-density, Navier-Stokes equations

$$\rho(\partial_t \mathbf{u} + \mathbf{u}\cdot\nabla\mathbf{u}) = -\nabla p + \nabla\cdot(2\mu \mathrm{D}) + \sigma\kappa\delta_s \mathrm{n}$$

$$\partial_t \rho + \nabla\cdot(\rho\mathbf{u}) = 0$$

$$\nabla\cdot\mathbf{u} = 0$$

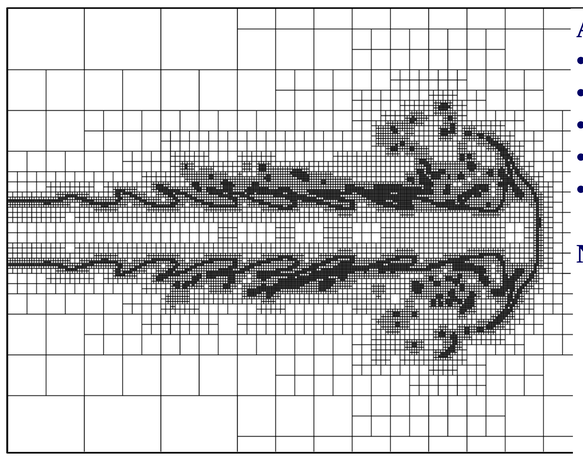
Volume of Fraction (VOF) used for interface capturing

$$\rho(c) \equiv c\rho_1 + (1-c)\rho_2$$

$$\mu(c) \equiv c\mu_1 + (1-c)\mu_2$$

Advection of volume fraction:

$$\partial_t c + \nabla\cdot(c\mathbf{u}) = 0$$



Adaptive Mesh Refinement (AMR)

- Gradient and value based refinement
- Cells without AMR = 671million
- Cells with AMR = 1.61 million
- Total reduction = 99.76%
- Min. cell size = 2 μm

Non-Dimensional Parameters

$$We = \frac{\rho_g (u_l - u_g)^2 D}{\sigma}$$

$$Re = \frac{\rho_l u_l D}{\mu_l}$$

References:

[1] Yang, X. and Turan, A., "Simulation of liquid jet atomization coupled with forced perturbation," *Physics of Fluids*, Vol. 29, 2017.