Mechanical Engineering Thesis Defense

Identifying Liquid Structures Based on Length Scales & Rebuilding Them Using a Sphere Model

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Abstract

Identifying and tracking the location of the fluid interface is a fundamental aspect of multiphase flows. The Volume of Fluid (VOF) and Level Set methods are widely used to track the interface accurately. Analyzing the liquid structures such as sheets, ligaments, and droplets helps understand the flow physics and fluid breakup mechanism, aids in predicting droplet formation, improves atomization modeling and spray combustion. The thesis focuses on developing a new method to identify these liquid structures and devise a sphere model for droplet size prediction by augmenting concepts of linear algebra, rigid body dynamics, computational fluid mechanics, scientific computing, and visualization. The first part of the thesis presents a new approach to classify the fluid structures based on their length scales along their principal axes. This approach provides a smooth tracking of the structures' generation history instead of relying on high-speed video imaging of the experiment or the computationally costly data from Direct Numerical Simulations (DNS). A droplet is observed to have three equal length scales, while a ligament has one and a sheet has two significantly larger length scales. The subsequent breakup of ligaments and droplets depends on the atomizer geometry, operating conditions, and fluid physical properties. While it's straightforward to apply DNS and estimate this breakup, it is proven to be computationally expensive. The second part of the thesis deals with developing a sphere model that would essentially reduce this computational cost. After identifying a liquid structure, the sphere model utilizes the level set data in the domain to rebuild the structure using spheres. Geometrically quantifying these fluid structures provides a straightforward way of predicting the droplet size and distribution.

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