On Using Detailed Simulations to Study Primary Atomization

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Abstract

Commonly, atomization is thought to occur in two consecutive steps: the initial primary atomization of liquid streams into large and small scale structures, followed by secondary atomization of these structures into ever smaller drops. While a number of established models exist for the latter process, the details of the former process are as of this day not fully understood. This is in part due to the fact that experimental access to the primary atomization region is at best extremely difficult under most conditions of relevance to technical applications. Detailed numerical simulations may help study the fundamental mechanisms of the initial breakup in regions and under operating conditions, where experimental access and analysis is too challenging. However, simulating atomization accurately is a tremendous numerical challenge since time and length scales vary over several orders of magnitude, the phase interface is a material discontinuity, and surface tension forces are singular.

In this talk some recently developed numerical techniques to simulate atomization will be discussed briefly. These include the refined level set grid method to describe the motion of immiscible interfaces, the finite volume balanced force method for unstructured polyhedra meshes to account for surface tension forces in a stable and accurate manner in complex geometries, the multi-scale Eulerian interface tracking/Lagrangian point particle coupling procedure to couple near injector detailed primary atomization simulations to far field secondary atomization Lagrangian spray simulations, numerical techniques for level set based formulations to solve the governing equations in the presence of large density ratios and high shear in a stable manner, and consistent level set based filter functions to derive novel subgrid models for phase interface dynamics.

However, to achieve a simulation tool that is predictive, special focus must be placed on both code and solution verification. A novel method of applying the Method of Manufactured Solutions to one-fluid formulations will be presented, demonstrating that even in the presence of discontinuous immiscible interfaces, finite volume methods for scalar equations are at least first-order accurate in the infinity norm. Several remaining challenges to achieve a truly predictive simulation tool for atomization will then be discussed. Finally, simulation results for the atomization of turbulent liquid jets injected into gaseous crossflows, a turbulent liquid jet injected into compressed still air, and a single drop subjected to a turbulent crossflow will be presented.

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