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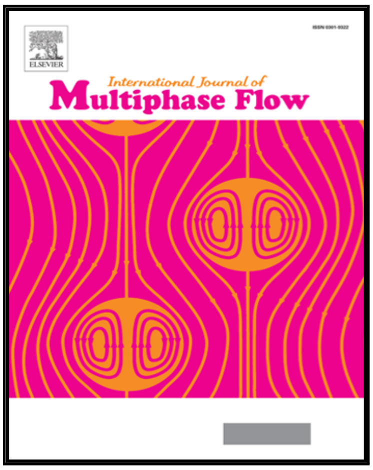

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Xiaoyi Li , Marios C. Soteriou

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Detailed Numerical Simulation of Liquid Jet Atomization in Crossflow of Increasing Density

Xiaoyi Li* and Marios C. Soteriou
United Technologies Research Center
East Hartford, Connecticut, 06108, USA

Abstract

Atomization of liquid fuel jets by cross-flowing airstream is critical to the performance of many aerospace combustors. Recent advances in numerical methods and increases in computational power have enabled the first principle, high fidelity simulation of this phenomenon. In the recent past we presented a detailed validation and analysis of such simulations against experimental data at ambient conditions. At combustor operating conditions, however, both temperature and pressure are significantly elevated. In this work we extend the same computational approach to the study of the impact of reduced liquid-gas density ratio due to increased air density associated with operating pressure elevation on the atomization physics. The previously validated ambient condition case is used as the baseline for comparison with three cases with decreasing density ratios. The density ratio is independently varied by adjusting the gas density and velocity together so that the momentum flux ratio and Weber number are maintained constant. The global-scale jet penetration and trajectory are slightly modified as the density ratio varies. The most significant changes are observed for the local processes of liquid breakup and atomization. As the density ratio is independently reduced, a transition of dominance from the Rayleigh-Taylor to the Kelvin-Helmholtz instability mechanisms on the liquid column surface is detected by analyzing the vorticity fields. Such a transition is verified using linear stability analyses and is also shown to be consistent with the simulation results of a non-monotonic variation of surface wavelength with density ratio. Downstream, a counter-rotating vortex pair (CVP) arises as the density ratio is reduced, the physical origins of which are similar to those documented for gaseous jet in cross-flow studies. Atomization effectiveness is reduced downstream with reduced density ratio and this is in agreement with experimental observation. This result is explained in terms of the density-ratio-related velocity-ratio changes that allow for a switch in behavior from a faster to a slower crossflow speed with respect to the liquid. As a result, at low density ratio recoiling of stretched structures and possibility of increased collision result in increasing Sauter Mean Diameter (SMD).

Key Words: Jet atomization; Crossflow; Density ratio; Instability transition; Rayleigh-Taylor; Kelvin-Helmholtz

* Corresponding author: lixy2@utrc.utc.com