Paper ID: 72801

IAF SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations - IAF SPACE PROPULSION SYMPOSIUM (IP)

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NUMERICAL SIMULATION OF FLOW ATOMIZATION CAUSED BY TWO IMPINGING LIQUID JETS

Abstract

Impingement of liquid jets is an efficient method for rapid atomization and mixing of liquid propellants (fuel and oxidizer) in space propulsion systems. The impingement of liquid jets results in the formation of a liquid sheet which destabilizes, breaks and disintegrates into ligaments and droplets under the influence of aerodynamic and hydrodynamic instabilities. The performance of liquid propellant engines is highly dependent on the quality of atomization and mixing of propellants. To model and simulate the complex multi-scale two-phase flow generated by impinging jets, significant computational resources are required. Moreover, experimental techniques, even today, are not capable of measuring such complex flow dynamics with sufficient accuracy. Therefore, in this paper, we have utilized a numerical modeling approach which requires less computational resources and resolves our complex two-phase flow problem with great accuracy.

In this paper, we have performed CFD simulations to investigate the atomization process of two liquid impinging jets in a like-doublet injector configuration. A hybrid VOF-to-DPM (Volume of Fluid to Discrete Phase Model) multiphase model, recently incorporated in ANSYS Fluent, has been used. This model is based on the Eulerian-Lagrangian approach. Two cases concerning liquid jets impinging with a velocity of 12.5 m/s (Reynolds number = 12689) and 25.5 m/s (Reynolds number = 25389) are simulated. The impingement angles considered are 50° and 80°. The two jets are cylindrical having a diameter of 1 mm in both cases. The results obtained from simulations agree very well with experimental results for both atomization characteristics and Sauter mean diameter (D_{32}) computed at different locations downstream of the impingement point. Detailed flow physics associated with jet impingement, sheet formation and breakup is very efficiently captured. The effects of jet velocities and impingement angles on the breakup performance and droplet size distributions are also analyzed. The results show that the high-velocity jets and high impingement angle produce smaller droplet sizes and enhance the atomization characteristics. The results also show that the liquid sheet formed by the impingement of high-velocity jets undergoes violent flapping and oscillations due to rapid formation of instability waves on the sheet. This results in quick atomization of the flow. However, for low-velocity impinging jets, instabilities on the sheet are not noticeable, and the atomization process is relatively slow. This study leads to the conclusion that the current approach provides high-fidelity simulation results for atomization characteristics of like-doublet impinging sprays used in liquid space propulsion systems.