Fuel Dispersion Effects on Reaction Structure in Confined Supersonic Flowpaths

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Supersonic combustors rely on low-loss fuel injection mechanisms to achieve rapid fuel-air mixing and high combustion efficiency. These combustors typically feature multijet configurations, where multiple transverse fuel jets are injected into a confined supersonic crossflow. This configuration results in the formation of strong bow shocks that interact with each other and subsequently reflect from combustor walls, creating a series of curved shock waves. These shock waves interact with the boundary layer near the walls, leading to flow separation and the formation of recirculation zones that provide favorable conditions for flameholding [1]. The curved shocks further enhance vorticity generation in the wake, promoting improved mixing. However, these configurations suffer from increased pressure losses and suppression of jet penetration due to interactions between opposing jets. The goal of this work is to investigate and characterize flame ignition and stabilization mechanisms in such confined, shock-mediated configurations. Sonic ethylene jets injected into a Mach 3 crossflow are simulated using an in-house adaptive mesh refinement (AMR)-based compressible flow solver with detailed finite-rate chemistry [2]. Two distinct regions are identified for flame ignition and stabilization: (i) windward-stabilized flames in the shear layers due to upstream fuel penetration, and (ii) jet-wake-stabilized flames anchored downstream in recirculation zones near reflected shocks, exhibiting intermittent ignition that transitions into quasi-steady flames. AMR is employed to resolve fine-scale features such as shocks, vortical structures, and flame fronts, enabling detailed analysis of ignition behavior, flame dynamics and combustion stability in confined supersonic flowpaths.

References

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