LARGE EDDY SIMULATION of a LEAN DIRECT INJECTION COMBUSTOR

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Designing commercially viable propulsion systems for supersonic aircraft is a major challenge. All modern combustors must balance the need for stability and performance with the goals of efficiency and cleanliness. These competing demands, however, are exacerbated in supersonic situations where the operating conditions are much more severe. Supersonic transport aircraft usually fly in the stratosphere, at cruising altitudes around 60,000 - 65,000 ft. Engine emissions produced at such high altitude contribute to depleting the ozone layer. Therefore, special combustor design considerations are needed to account for more stringent environmental and safety demands. The Lean Direct Injection (LDI) configuration is a good candidate for supersonic civil transport aircraft, where a combined geometry of a swirler and a venturi supposedly results in ultra low NOx and soot emissions. The combination of the swirl and the venturi has proven to maximize the liquid fuel atomization performance, and minimize pressure drop across the injector. In addition, it provides sufficient residence time for mixing of the fuel droplets with the swirling air to form a lean mixture. The swirler produces a central recirculation zone, which provides the required flame stability.

The current work studies the LDI configuration. Numerical simulations are done using the unstructured mesh, node-based CDP code with the flamelet/progress variable model for combustion closure. The main LDI flow features are shown and compared with experiments for the reactive and the nonreactive flow simulations. The effect of air preheating on the secondary droplet breakup is studied by investigating the spray histogram, the Sauter mean diameter, and the spray pattern. By comparison of the non-reactive and reactive test cases, the recirculation zone structure is found to change significantly by the effect of heat release. The effect of preheating is to change the thermal profile distribution, the rate of breakup, and finally the spray evaporation rate. All these factors control the flame structure and consequently the performance of the LDI combustor.