IAF SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

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INVESTIGATION OF SHOCKS, BOUNDARY LAYER AND FUEL INJECTION INTERACTION IN THE HIFIRE-2 SCRAMJET

Abstract

There has been a growing interest in hypersonic vehicles due to the wide range of applications, including space launchers and commercial trans atmospheric vehicles.. In order to meet the new requirements of fast-flying, significant advancements in propulsion will be required. Ramjet or Scramjet engines, for example, can operate with ambient air as an oxidizer, eliminating the need for onboard oxidizers. When ramjets and scramjets operate at supersonic cruising speeds, they compress the air before allowing it to enter the combustion chamber. Due to the very short residence time of a few milliseconds, fuel and air can barely mix and burn at these high flow velocities, making solving this problem challenging. Increasing mixing efficiency by using cross-flow injection or modifying combustion geometry, such as cavities, can drastically improve the combustion performance in terms of total pressure losses. A perpendicular fuel injection blocks the mainstream and generates powerful shock waves, which interact with the boundary layer and are reflected up to the bottom wall, creating complex flow physics that coexist near the injector wall between supersonic and subsonic pressure zones. In addition to experimental data, numerical simulations can help better understand this hypersonic phenomenon. To develop useful numerical tools for the complete engine design, including engine geometry, injection placement, and operating conditions, it is essential to understand the physics of turbulence interaction, transfer from large to small scales in compressible flows.This study aims to investigate the effect of shock development and interaction with the mainstream using LES. The flowfield within the HIFiRE-2 combustor has been analyzed under different conditions: before the injection (cold flow simulations), after the injection (cold flow simulations), and after the ignition (hot flow conditions). We have implemented combustion models to account for kinetic times. An analysis of the LES simulation of the HIFiRE-2 scramjet revealed the direct and mutual effects of the shock waves’ interaction with vorticity, the addition of heat, friction, mixing, and boundary layer separation on the total pressure loss.