Abstract

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Department: **DEPARTMENT OF AEROSPACE ENGINEERING**

Thesis title: **Effects of Combustor Configurations on Combustion Modes and Flow Dynamics in Scramjet Engines**

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Numerical and experimental studies are conducted to investigate the effect of combustor configurations on modes and their dynamics in Scramjet combustors with the goal of better understanding the interplay between flow, heat-release and shock waves in high-speed combustion environments. 5 different configurations, consisting of a strut-based Mach 2 combustor and four different variants of a cavity based Mach 2 combustor are tested. For the strut-based combustor configuration, URANS simulations (SST-kω) show that as long as the oblique shocks are anchored at the leading edge of the strut, the flow-field remains relatively stable to changes in heat release rates due to changes in fuel-flow rates. The shock-train downstream of the strut, steepen or flatten in response to changes in fuel-flow rates, but the overall shock-cluster remains anchored in the near-field of the strut. For modes of combustion at higher fuel-flow rates with no oblique shock at the strut leading edge, any change in fuel flow rate, sudden or gradual, increase or decrease, is shown to cause the isolator shocks to immediately move upstream causing unstart like conditions. A plausible physical mechanism for this phenomenon is presented. For the cavity based combustor configuration, URANS simulations (SST-kω) show hysteresis in the top wall pressure profile and in the dynamic response of the pseudoshock for sudden changes in fuel flow rates. The suitability of a synthetic analogue, consisting of a constant area duct with an imposed back pressure in revealing pseudo-shock behavior in the cavity stabilized scramjet combustor is presented. The time taken by compression or rarefaction waves to reach the lead shock of the shocktrain during the increase or decrease in combustor pressure is shown to be responsible for the delay in the upstream or downstream motion of the pseudoshock. Experimental studies on four different variations of the Mach 2 cavity based combustor configuration show that the configuration with a 2^o expansion corner at the fuel injector along with an upstream pylon may provide the best performance in terms of fuel-penetration, area relief and combustion dynamics. Experimental studies on the cavity configuration with the 2^o expansion corner at the fuel injector burning GH2 in air show spontaneously excited, self-sustained, large-amplitude, injector-coupled, RAM-mode oscillations occurring at a frequency of 1297 $\pm$ 65 Hz resulting from the periodic blockage of the transversely oriented GH2 injector due to upstream-propagating, progressively-steepening compression waves. The rate at which compression pulses steepen into upstream propagating shockwaves, the speed at which shock waves move upstream into the isolator, the extent to which the fuel at the injector is pulled upstream by the upstream propagating shock, the speed at which vortex-dominated flame fronts convect downstream are all quantified using Schlieren data. Finally, based on all these studies, certain observations about the advantages and disadvantages of each configuration are presented in summary.