SPACE PROPULSION SYMPOSIUM (C4)
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RESEARCH ON SHOCK TRAIN LEADING EDGE DETECTION IN SCRAMJET

Abstract

A shock train is formed in the isolator of dual mode scramjet engine to adjust the supersonic flow to a high back pressure in the combustor. The shock train is liable to be disgorged from the isolator due to upstream and downstream disturbances, resulting in the catastrophic inlet unstart. To avoid inlet unstart, accurate and robust real-time detection methods should be developed to locating the shock train leading edge (STLE) in an operational scramjet.

So far most of the STLE detection methods were investigated in cold flow tests. In these tests the back pressure is produced by area blockage at the exit of the isolator to simulate the combustion-based thermal choking. Hence the complicated isolator-combustor interaction was not taken into account in these studies. Besides, most of the methods were developed with uniform inflow, neglecting the flow distortion at the entrance of the isolator caused by hypersonic inlet.

In this study hot flow scramjet tests were conducted on the direct connect facility at Ma 2.5, 2.7, 3.0 and 3.3 to address the two issues mentioned above. An asymmetric intake was installed between nozzle and isolator to imitate the effect of hypersonic inlet. Pressures along the isolator and combustor were measured by 22 pressure sensors at 5 kHz sampling rate.

Multiple STLE detection methods were evaluated and compared based on the test data. These methods generally fall into two categories. One category detects the STLE according to the pressure rise along the shock train, the other takes advantage of the pressure oscillation near the STLE. Analysis revealed that the former category degraded with asymmetric incoming flow. Because it is difficult to distinguish the pressure rise of the shock train from the background pressure fluctuation at the entrance of the isolator as result of inlet induced shocks and boundary layer separation. The latter category failed in the hot flow tests due to the strong high frequency noises generated in the combustion process. In literatures multi-sensor fusion approaches like fitting and filtering were recommended for their robustness. Therefore

a novel multi-sensor fusion method was introduced in this study to fit the pressure measurements to the well-known Waltrup-Billig Equation, which empirically depicts the pressure profile of a shock train. This method requires less priori knowledge about flow characteristics than the previous methods. It was proved to be robust to upstream and downstream disturbances and sensor faults.