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Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

Author: Mr. Tamal Jana
Indian Institute of Technology Kharagpur, India, tfortamal@gmail.com

Mr. THILLAIKUMAR T
Indian Institute of Technology Kharagpur, India, thillaikumart97@gmail.com
Prof.Dr. Mrinal Kaushik
Indian Institute of Technology Kharagpur, India, mkaushik@aero.iitkgp.ac.in

EXPERIMENTAL STUDIES ON THE EFFICACY OF CAVITY WITH POROUS UPPER SURFACE IN CONTROLLING THE SHOCK/BOUNDARY-LAYER INTERACTIONS IN A HYPERSONIC INTAKE

Abstract

With exception of scramjets, the engine intakes operating at supersonic and hypersonic Mach numbers must decelerate the flow to subsonic level, before entering the combustor for an efficient combustion. This is essentially obtained through a progression of oblique and/or normal shock waves in the intake-isolator. However, the advantages of shock enabled compression does not come standalone but with colossal losses due to the shock-wave/boundary-layer interactions (SBLIs). The repercussions in the flow due to the SBLIs include, but not restricted to: intake unstart, abrupt thickening and/or separation of the boundary layer and unsteady shock oscillations. Thus, the control of SBLIs is of utmost importance to alleviate such losses. In this study, the effects of a cavity with porous upper surface on the SBLIs occurring in a Mach 5.7 mixed-compression intake, have been experimentally investigated. Porosity of the surface covering the cavity are varied (by changing the diameter and pitch of the pores) as, 7.5%, 17% and 25%, to investigate the separation effects on interactions. The uncontrolled intake is also studied for comparison. Qualitative investigation of the Schlieren images supports the findings of wall pressure data. For the intake controlled with porous cavity, the injection of fluid upstream of the impinging cowl shock smears the shock into a series of nearly isothermal compression waves, in turn, reduces the shock strength. A maximum of about 20.50% reduction in the static pressure is achieved with 25% surface porosity. It can be seen from the Schlieren flow visualization that, the surface perforation in fact decreases the shock strength by smearing the impinging cowl shock to the lambda-shock. But, due to the injection of fluid (through the cavity) upstream of the cowl shock, the thickness of boundary layer increases which eventually promotes the SBLI. This fluid injection is indeed responsible for the growth of the separation bubble. Thus, the net effect on the separation bubble will be an optimization between the adverse effect of boundary layer thickening and the favorable effect of reduced shock strength. Up to 17% surface porosity, the overall effect results in the suppression of the bubble. Whereas, at higher surface porosity, the fluid injection at the upstream of the impinging cowl shock becomes sufficiently high, which thickens the boundary layer to such an extent that cannot be reduced by decreasing the shock strength. Hence, the bubble starts growing again. Qualitative analysis of the Schlieren images support the findings of wall static pressure distribution.