ABSTRACT

The supersonic or hypersonic flow through an aircraft intake must be decelerated before entering the combustion chamber to ensure efficient combustion. The flow retardation in the high-speed aircraft intake is generally achieved through the evolution of multiple shock waves. However, the occurrence of shock and boundary-layer interactions (SBLIs) in intakes often results in detrimental consequences such as poor total pressure recovery, abrupt thickening or separation of the boundary layer, unsteady shock oscillations, aerodynamic heating, etc. These effects can become more severe in hypersonic flows essentially due to viscous and vorticity interaction, and higher shock-layer temperature. Hence, the SBLIs must be controlled to eliminate or reduce the losses. In this study, an attempt is made to control the interactions using the passive methods owing to their obvious advantages. The present study experimentally evaluates the effectiveness of a thin porous surface deployed over a shallow cavity as the shock control, and the conventional micro-vortex generators as the boundary layer control in manipulating the SBLIs occurring in a double-ramp mixed-compression intake, mounted in a shock tunnel, at hypersonic Mach numbers. Both quantitative and qualitative investigations have been carried out by measuring the static pressure distributions over the ramp-surface and visualizing the interactions using the time-resolved Schlieren technique. Besides, the time-resolved flow visualization technique is utilized to investigate the unsteady nature of the shock structure, separation bubble, and the flow evolution.

The thin porous surface deployed over a shallow cavity is installed in the higher adverse pressure gradient regions at Mach 5.7 and Mach 7.9 mixed-compression intakes. With the variation of diameter and pitch of the pores, the porosity in the Mach 5.7 intake is varied as: 4.5%, 7.5%, 17%, 21.6%, and 25%, whereas 17% and 25% porosity limits are considered at Mach 7.9. At 25% surface perforation and Mach 5.7, a maximum of 20.53% drop in static pressure is observed at a near-reattachment location of the separation bubble. At Mach 7.9, the 25% surface perforation has maintained its superiority in decreasing the wall static pressure to a maximum of 20.20% at the near-reattachment location. However, the 17% porous surface-controlled configuration suppresses the separation bubble most effectively for both the Mach numbers.

A spanwise array of conventional micro-vortex generators (MVGs) are deployed upstream of and at the interaction regions in a Mach 5.7 mixed-compression intake. They are found to be useful in reducing the extent of the interactions. The height of MVGs in the present investigation is varied as 0.5 mm, 0.7 mm, and 1.0 mm. The MVGs of height 1.0 mm, deployed at the interaction region, are quite efficient in decreasing the wall static pressure, with a maximum of 13.57% reduction at the downstream proximal location. The Schlieren images show a decrease in the size of the separation bubble for all the MVG controlled intakes; however, the MVGs of height 0.7 mm, deployed upstream of the interaction zone, is found to be the most efficient in suppressing the bubble.

Keywords: Boundary layer, Cavity, Porous surface, Micro-vortex generator, Mixed-compression intake, Shock wave, Schlieren technique, Separation bubble, Wall static pressure