Experimental Investigation of Flow Control within a Compact Inlet Duct

by

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ABSTRACT

This work was an experimental investigation of flow control applied to a compact inlet duct with a length-to-diameter ratio of 1.6, inlet to exit height offset of one diameter, and an exit to inlet area ratio of 1.27. The compactness of the duct comes at a price because the large curvature along the duct inevitably caused flow separation and strong secondary flows. These flow structures countered the aerodynamic purpose of the inlet; to decelerate the oncoming flow before reaching the exit plane while minimizing total pressure loss, unsteadiness, and distortion. Flow control was applied from a module immediately upstream of the inlet plane of the duct in order to improve performance by minimizing these three quantities.

All experiments conducted, unless noted otherwise, were conducted at an inlet Mach number of 0.44. Two flow control modules were tested: a two-dimensional control jet and hybrid "Fail-Safe" actuator that implemented both a passive element: vortex generators and an active element: skewed and pitched jets. The sensors and techniques used to measure the flow field include surface static pressure taps, total pressure sensors at the exit, and stereoscopic particle image velocity. A particular focus of the work was to highlight the improvement in pressure recovery at the aerodynamic interface plane (AIP).

The baseline flow field had the presence of both separation as well as strong secondary flows. Interestingly, the interaction of these two structures resulted in a non-symmetric flow field at the AIP. The simulation work showed similar results and explained the evolution of this flow field through flow topology.

When actuation was introduced, it proved to increase pressure recovery. The two-dimensional control jet achieved the highest pressure recovery improvement but was unable to improve the asymmetry in the flow field. The actuation of the skewed and pitched jets regained symmetry, decreasing significantly both the strength of the secondary structures and the flow unsteadiness and considerable pressure recovery improvement was reported. The presence of the vortex generators, at the correct height, in tandem with the jets of the Fail-Safe actuator improved pressure recovery modestly from the jets only case. In the end, the increase in performance brought about by the Fail-Safe actuator shows promising results for a modest input of mass flow rate.