Flow Control in a Compact Inlet

by

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ABSTRACT

An experimental investigation of flow control, via various control jets actuators, was undertaken to eliminate separation and secondary flows in a compact inlet. The compact inlet studied was highly aggressive with a length-to-diameter ratio of 1.5. A brand new facility was designed and built to enable various actuation methodologies as well as multiple measurement techniques. Techniques included static surface pressure, total pressure, and stereoscopic particle image velocimetry. Experimental data were supplemented with numerical simulations courtesy of Prof. Kenneth Jansen, Dr. Onkar Sahni, and Yi Chen.

The baseline flow field was found to be dominated by two massive separations and secondary flow structures. These secondary structures were present at the aerodynamic interface plane in the form of two counter-rotating vortices inducing upwash along centerline. A dominant shedding frequency of 350 Hz was measured both at the aerodynamic interface plane and along the lower surface of the inlet.

Flow control experiments started utilizing a pair of control jets placed in streamwise locations where flow was found to separate. Tests were performed for a range of inlet Mach numbers from 0.2 to 0.44. Steady and unsteady static pressure measurements along the upper and lower walls of the duct were performed for various combinations of actuation. The parameters that were tested include the control jets momentum coefficient, their blowing ratio, the actuation frequency, as well as different combinations of jets. It was shown that using mass flux ratio as a criterion to define flow control is not sufficient, and one needs to provide both the momentum coefficient and the blowing ratio to quantify the flow control performance.

A detailed study was undertaken on controlling the upstream separation point for an inlet Mach number of 0.44. Similar to the baseline flow field, the flow field associated with the activation of a two-dimensional control jet actuator was dominated by secondary flow structures. Unlike the baseline, these secondary flow structures produced downwash along the centerline. The formation of such structures was caused by the core flow stagnating on the lower surface near the aerodynamic interface plane. Using the two-dimensional steady jet resulted in an increase in the spanwise flow within the inlet and a reduction in the energy content of the 350 Hz shedding frequency. Unsteady

forcing did not show much improvement over steady forcing for this configuration. A spanwise varying control jet and a hybrid Coanda jet / vortex generator jets were tested to reduce the three-dimensionality of the flow field. It was found that anytime the flow control method suppressed separation along the centerline, counter-rotating vortices existed in the lower corners of the aerodynamic interface plane.