3-D Interactions between a Finite-Span Synthetic Jet and a Cross-Flow

by

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A Thesis Submitted to the Graduate
Faculty of Rensselaer Polytechnic Institute
in Partial Fulfillment of the
Requirements for the degree of
MASTER OF SCIENCE
Major Subject: AERONAUTICAL ENGINEERING

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Troy, New York

August, 2011

ABSTRACT

An experimental investigation was performed to study the formation of secondary flow structures and interactions of a finite-span synthetic jet in a cross-flow at chord-based Reynolds numbers between 50,000 and 400,000 and angles of attack from 0^0 to 20^0. Six blowing ratios, in the range of 0.2 to 1.2 with an increment of 0.2 (where, the blowing ratio is defined based on the averaged outstroke jet velocity to the free-stream velocity) were tested. Experiments were conducted on a finite wing (aspect ratio of 5.33) with a cross-sectional profile of NACA 4421, where both 2-D and stereoscopic PIV data were collected at the center jet in the mid-span. The effect of the blowing ratio was analyzed based on 3-D time-averaged, phase-averaged and instantaneous flow fields at an angle of attack of 0^o and a chord Reynolds number of 100,000. For the low blowing ratio cases, spatial non-uniformities developed, due to the finite-span of the slit, which led to the formation of small and organized secondary structures or a streak-like pattern in the mean flow. On the other hand, for the high blowing ratio range turbulent vortical structures were dominant leading to larger spanwise structures, with a larger spanwise wavelength, in the mean flow. Moreover, the phase-locked flow fields exhibited a train of counter-rotating coherent vortices that lifted-off the surface as they advected downstream. In the mid-blowing ratio range, combined features of the low-range (near the slit) and high-range (in downstream locations) were found; where a pair of counter-rotating vortices issued in the same jet cycle collided with each other. To explore whether the flow is dominated by random or coherent motions, a large number of phase averages (36) flow fields were acquired, along with a time average of the same case, and a triple decomposition was performed. The coherent motions were shown to exist only near the orifice and the path of the vortex train, while the random motions were farther downstream (where the vortex train diminishes). In all cases the spanwise extent of the secondary coherent structures reduced with downstream distance with a larger decrease at higher blowing ratios. Similar observations were made in earlier studies on finite-span synthetic jets in quiescent conditions.