World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:10, No:01, 2016

The Structure and Development of a Wing Tip Vortex under the Effect of Synthetic Jet Actuation

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Abstract : The effect of synthetic jet actuation on the roll-up and the development of a wing tip vortex downstream a square-tipped rectangular wing was investigated experimentally using hotwire anemometry. The wing is equipped with a hallow cavity designed to generate a high aspect ratio synthetic jets blowing at an angles with respect to the spanwise direction. The structure of the wing tip vortex under the effect of fluidic actuation was examined at a chord Reynolds number Re_c=8×10^4. An extensive qualitative study on the effect of actuation on the spanwise pressure distribution at c⁄4 was achieved using pressure scanner measurements in order to determine the optimal actuation parameters namely, the blowing momentum coefficient, Cμ, and the non-dimensionalized actuation frequency, F^+. A qualitative study on the effect of actuation parameters on the spanwise pressure distribution showed that optimal actuation frequencies of the synthetic jet were found within the range amplified by both long and short wave instabilities where spanwise pressure coefficients exhibited a considerable decrease by up to 60%. The vortex appeared larger and more diffuse than that of the natural vortex case. Operating the synthetic jet seemed to introduce unsteadiness and turbulence into the vortex core. Based on the 'a priori' optimal selected parameters, results of the hotwire wake survey indicated that the actuation achieved a reduction and broadening of the axial velocity deficit. A decrease in the peak tangential velocity associated with an increase in the vortex core radius was reported as a result of the accelerated radial transport of angular momentum. Peak vorticity level near the core was also found to be largely diffused as a direct result of the increased turbulent mixing within the vortex. The wing tip vortex a exhibited a reduced strength and a diffused core as a direct result of increased turbulent mixing due to the presence of turbulent small scale vortices within its core. It is believed that the increased turbulence within the vortex due to the synthetic jet control was the main mechanism associated with the decreased strength and increased size of the wing tip vortex as it evolves downstream. A comparison with a 'non-optimal' case was included to demonstrate the effectiveness of selecting the appropriate control parameters. The Synthetic Jet will be operated at various actuation configurations and an extensive parametric study is projected to determine the optimal actuation parameters.

Keywords : flow control, hotwire anemometry, synthetic jet, wing tip vortex
Conference Title : ICAFC 2016 : International Conference on Aircraft Flow Control
Conference Location : Zurich, Switzerland
Conference Dates : January 12-13, 2016