Pressure Measurements on Delta wing with different leading edge radii
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ABSTRACT

The present study deals with experimental investigation of Delta wing with three different leading edge profiles. Experiments were conducted in a low speed wind tunnel to measure the pressure fields acting on the wing for different angles of attack from -15° to 15° in steps of 5° for a velocity of 38 m/s. Obtained surface pressure coefficients are plotted across various spans located at different root chord locations. Change in angle of attack for the delta wing has shown a nominal change in the wing upper surface pressure loading. Results obtained from experiments shows a decrease in mean $C_p$ for increase in angle of attack. Sharp leading edge wing had an earlier flow separation well before 71% chord location where as there was a delay in separation for small and large radius wings. This was visible from the low pressure zone occurrence on the upper surface of the wing. Also an anomalous behavior of attached flow was observed at 87% chord for small radius wing with an angle of attack10° has showed a reattachment of the separated flow.

1 INTRODUCTION

The design of delta wing planforms dates back to the 1930’s with the work of Alexander Lippisch and the pursuit of supersonic flight. Leading-edge vortex on slender wings has been a subject of study at aeronautical laboratories for many years. The wing upper surface pressure loading induced by leading-edge vortex has shown to provide a significant vortex –lift increment at moderate to high angles for slender wings.

At low angles of attack $\alpha$, the location of vortex breakdown (VBD) usually occurs within the wake region downstream of the wing. With increasing $\alpha$ the breakdown begins to migrate forward, crossing the wing trailing edge and settling over the top of wing surface. Once the VBD location is occurred over the wing, the higher pressures due to the VBD reduce the suction levels created by the leading-edge vortices (LEV). A loss in vortex lift is then experienced, and the longitudinal stability of the planform may also be affected as discussed by Lance W. Traub. Aerodynamic studies have shown that the VBD is to cause changes in the slopes of lift, drag, and pitching moments for slender plan forms with highly swept leading edges. Also, the magnitude of these VBD effects is dependent upon the wing sweep angle $\Lambda$ and leading edge flow separation. Overall, VBD significantly modifies the global flow field over swept wings and is therefore viewed by many researchers as an undesirable characteristic, performance-wise.
The approach was to investigate the basic nature of the surface pressure on a slender wing with different leading edge radius. The change in leading edge radius can be considered as the active macroscale flow control technique since it involves change in the geometry of the wing.

2 NOMENCLATURE

- $b$: wingspan
- $C_p$: coefficient of pressure
- $t$: wing thickness (14 mm)
- $c$: wing root chord (278 mm)
- $s$: wing planform area
- $x$: distance from apex along chordwise direction
- $y$: distance from root chord along spanwise direction
- $\alpha$: angle of attack
- $\eta$: non-dimensional distance parameter in the spanwise direction
- $\Lambda$: wing sweep back angle ($60^\circ$)

3 EXPERIMENTAL SETUP

Wind tunnel is of 20m long tunnel and has a rectangular test section dimensions of 0.9m*1.22m*1.82m with a maximum speed of 60 m/s. Delta wing wooden model is fitted to the tunnel by means of a mounting unit. Mounting unit has facility to vary the angle of attack ranging from $-15^\circ$ to $+15^\circ$ in steps of $5^\circ$. Wooden model has thirty two pressure tapings on the upper surface of the Delta wing. Pitot static tube is used for the free stream velocity estimations. The wind tunnel is equipped with DSA 3217 electronic pressure scanner interfaced with a personal computer to acquire the required data. Wing has a leading edge sweep of $60^\circ$, no twist and no camber. Model root chord is 278mm and the wing span is 320mm and the wing’s maximum thickness is 14mm.

4 RESULTS AND DISCUSSION

4.1 Mean $C_p$ distributions for sharp leading edge wing

Mean $C_p$ distribution for sharp leading edge wing at different with $\alpha = -15^\circ$ to $15^\circ$ for the four chordwise locations of 0.71c to 0.87c are plotted in figs 1– 4. It is observed from figure 1 that at 71% chord location mean $C_p$ decreases for increasing angle of attack. Variation of mean $C_p$ are in the range of 0.139 ($\alpha = -15^\circ$) to $-0.33$ ($\alpha = 15^\circ$) and 58% decrease in mean $C_p$ was observed for increasing the $\alpha$ from $-15^\circ$ to $15^\circ$. Flow passes over the delta wing and a low pressure zone is created due to the vortex formation and a potential flow region is formed near the root chord of the wing. The created low pressure zone is located inboard of the vortex sheet. This low pressure zone increases for angle of attack increases for the delta wing and this in turn decreases the mean pressure coefficient. $\partial C_p/\partial \eta$ is defined as the difference in $C_p$ value for change in the distance parameter along the spanwise direction that is moving from root chord to the leading edge in the ‘y’ direction. For $\alpha=15^\circ$, the maximum slope was observed at the 71%
chord of this configuration, and for this angle of attack there is a dominant vortex formed over the upper surface of the wing near the leading edge at this chord location.

4.2 Effect of leading edge radius

Comparative mean $C_p$ distributions at four different chord locations for $\alpha = 15^\circ$ are shown in Figures 5 to 8. It is observed from figure 5 at 71% chord location for sharp wing and small radius wing the vortex is fully dominant this is clearly visible from the sudden decrease in mean $C_p$ near the leading edge. But for large radius wing the pressure distribution is nearly constant over the spanwise direction. Large radius wing does not show a significant leading edge separation. At 77% chord there is decrease in mean $C_p$ compared to 71% chord for all the three configurations is observed in figure 6. Also trend in vortex formation resembles that at 71% chord indicating that there is increase in vortex strength and the flow structure is retained, that is vortex diameter has increased. Large radius wing still does not show a reduction in pressure near the leading edge compared to root chord region indicating the flow is still attached to the surface near the leading edge.
5 CONCLUSION

The major conclusions derived from the experimental pressure distribution are
(i) For sharp leading edge wing leading edge flow separation start at $\alpha = 5^0$ even at 71% chord location itself and for increase in angle of attack there is increase in separation from the surface. (ii) For small radius leading edge wing leading edge flow separation start at $\alpha = 5^0$ itself but the intensity of separation is lesser compared to sharp leading edge wing. (iii) For large radius leading edge wing a delayed flow separation is observed, at $\alpha = 15^0$ dominant flow separation is observed but vortex formation is not observed.

6. REFERENCES