TMMV01 Aerodynamics: Computer Lab

Rohith Prem Maben (rohma417) , Yuvarajendra Anjaneya Reddy (yuvan983)

TMMV01, Linköping University, 2018

1 Lab Results

This is a report of the first Aerodynamics lab and the results include those of numerical simulations of flow in a boundary layer in laminar and turbulent zones. The other results are those of a flat plate delta wing estimation of normal and lift coefficients.

2 Measurement of Forces on Delta Wings

2.1 Estimation of force coefficients

The data set provided is post processed to extract the normal coefficients and lift coefficients.

N, CN, CL and the terms for potential lift and vortex lift in a clear and illustrative way. The method used to estimate the normal force coefficient(CN) and lift force coefficient(CL) using Polhamus leading edge suction analogy shows good correlation with the experimental results. The vortex lift coefficient shows a peak value at higher angles of attack than that of the potential lift coefficient making it evident, that the vortices are responsible for the non-linear aerodynamic characteristics. A drop is observed at the later stage.

[1]

Parameter	Value
Aspect ratio	1.8566
Plate area	0.0326 m^2
Density (water tunnel)	997 (kg/m^3)
velocity	0.18 m/s
K_p	2.05
K_v	3.10

Fig. 1 . Delta wing Parameters

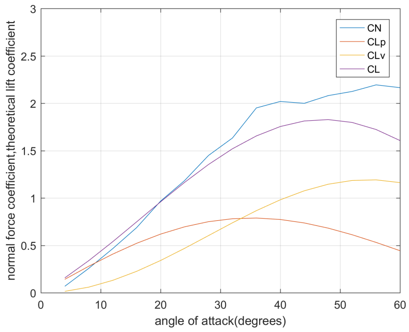

Fig. 2 . Normal and Lift coefficients estimated for delta plate vs Angle of attack

2.2 Assumptions and limitations of the force measurements

The Polhamus LE suction analogy can be used to estimate the lift coefficient only when the separated flows at the leading edge of a sharp delta wing reattaches at the top surface.

(1) To satisfy the Kutta condition at the TE, due to vortex reattachment the total lift coefficient is the sum of the potential and the vortex lift term.

(2) The correlation between theory and experimental test breaks down when the flow fails to reattach on the upper surface inboard of the vortex.

(3) Between aspect ratios 1 and 1.5 the equation shows good agreement for angles of attack excess of twenty degrees. [2].

2.3 Comparison of delta wing with the performance of a trapezoidal wing

A Trapezoidal wing sports a swept back LE and a swept forward TE. Due to the absence of the LE vortex induced axial flow component, the trapezoidal wing can stall earlier at lower angles of attack. As evident from the graph, the delta wing has a lower lift curve slope than that of a trapezoidal wing owing to the aspect ratio effects and higher wing loading in the later wing. [2].

3 Numerical simulation of flow in the boundary layer

3.1 Velocity profiles for laminar and turbulent boundary layer

The mean velocities are calculated for each probe location from the flat plate surface at increasing distance from the LE of the plate. From the laminar velocity profile, it is observed that, a relatively low velocity gradient occurs from the surface of the plate to the outer edge of the boundary layer.

Due to large fluctuations in the velocity in the turbulent boundary layer and higher shear between the layers the velocity gradient is high.

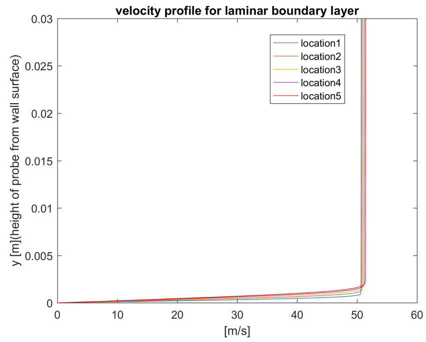

Fig. 3 . Velocity profile in laminar boundary layer

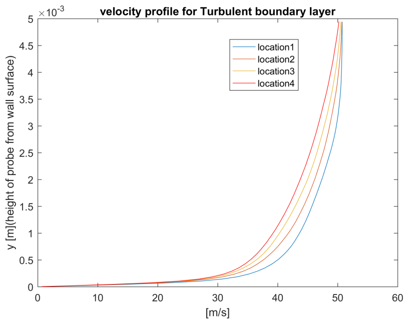

Fig. 4 . Velocity profile in turbulent boundary layer

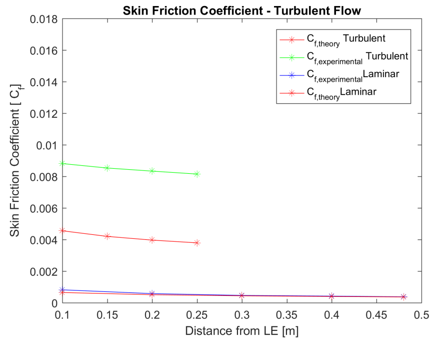

Fig. 5 . Skin friction coefficient in laminar and turbulent boundary layer(experimental and theoretical data

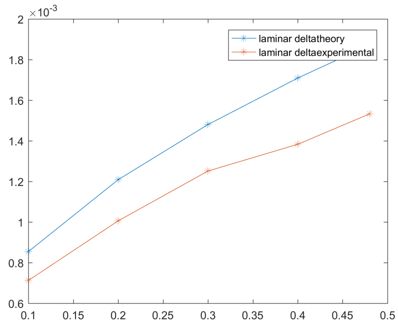

Fig. 6 . Thickness of laminar boundary layer

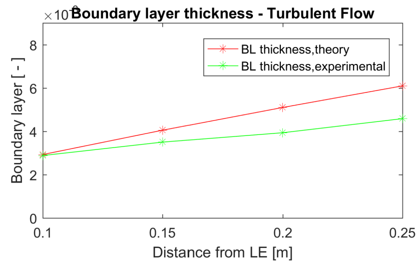

Fig. 7 . Thickness of turbulent boundary layer

3.2 Development of Boundary layer

Air flowing past a solid surface would stick to that surface. This results in a no slip condition,i.e the velocity of the fluid at the solid surface equals the velocity of that surface. The velocity of the fluid particles at the surface increase from a value of zero to a value that corresponds to the external flow outside the boundary layer. Due to the velocity gradient in the vertical direction of the plate the shear forces are relatively large. Outside the BL the shear stresses acting on the fluid element are negligible. Adverse pressure gradient and viscous forces causes the BL to separate from the surface. Pressure gradient, surface roughness and other effects leads to onset of turbulent BL from a laminar BL and it occurs over a considerable distance and not at a single point The turbulent BL can negotiate adverse pressure gradient or a longer period and can delay the onset of separation. .[2].

The boundary layer thickness is compared with the theoritical values. There is good co-relation observed for laminar BL between experimental and theoritical, while for the turbulent BL, the analytical formula underestimates skin friction coefficient.

3.3 Skin friction coefficient

For a laminar BL momentum transfer is in the direction perpendicular to the principal flow direction takes place on a molecular scale (micro), this molecular interchange of momentum results in the shear stress at the surface given by the eq. It is relatively thin with limited mass transfer. Relatively low velocity gradient near the wall and low skin friction.

For the turbulent BL in addition to the laminar shear stress there is an additional turbulent boundary layer shear stress due to the transverse transport of momentum that is very large (macro) and leading to higher thickness. Thick layer due to considerable mass transport, higher velocities near the surface and higher skin friction, due to velocity fluctuations leads to viscosity increase by a factor of 10 or more leading to higher skin friction component of drag.

Authenticity and Plagiarism

By submitting this report, the author(s) listed above declare that this document is exclusively product of their own genuine work, and that they have not plagiarized or taken advantage from any other student's work. If any irregularity is detected, the case will be forwarded to the University Disciplinary Board.

REFERENCES

[1] POLHAMUS C. *Predictions of vortex-lift characteristics by a leading-edge suction analogy*.

[2] Bertin J and Cummings R. *Aerodynamics for Engineers*. Always learning.