LAB REPORT

AE351

Measurement of pressure distribution in the wind tunnel test section

and

flow visualization over a Delta wing

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EXP (a)

OBJECTIVE:

Observe the vortex pair on the leeward side of a delta wing at incidence, and study their breakdown.

THEORY:

The aim of this experiment is to visualize the vortex formation of the leeward side of the delta wing. When a slender delta wing with a sharp leading edge is at a moderate angle of attack, it creates a characteristic vortex pattern on the leeward side of the wing. This is because of the separation of flow along the leading edge of the wing forming a separated shear layer. The shear layer form counter-rotating vortex pairs that move up to the top of the wing. These vortex patterns enhance the lift at low speeds. Increasing the angle of attack or velocity can lead to vortex breakdown or shredding. The vortex lift comes at the cost of increased drag, so more powerful engines are needed to maintain low speed or high angle-of-attack flight. A normal wing built for high-speed use typically has undesirable characteristics at low speeds, but in this regime, the delta gradually changes over to a mode of lift based on the vortex it generates, a mode where it has smooth and stable flight characteristics.

EQUIPMENTS:

1. Low-speed wind tunnel:

   The specifications of the low-speed wind tunnel are:-

S.No.	Property	Measurement
1.	Type	Open – Return Suction Type
2.	No. Of Screenings in the settling chamber	6
3.	Contraction ratio	16:1
4.	Test section dimensions	0.6 m X 0.6 m X 3 m
5.	Max. Velocity	~25 m/s
6.	Motor	20 Hp AC

2. Delta wing model:

   When a slender delta wing with a sharp leading edge is
   at a moderate angle of attack, a vortex pair is generated on the lee side of the delta wing. This happens due to the separation of the flow along the leading edge of the delta wing forming a separated shear layer. This shear layer rolls up to form a counter-rotating vortex pair that move past the top surface of the wing. The formation of these vortices delays the stall which happens at a relatively high angle.

3. Laser: For flow illumination, a continuous low power green laser is used.

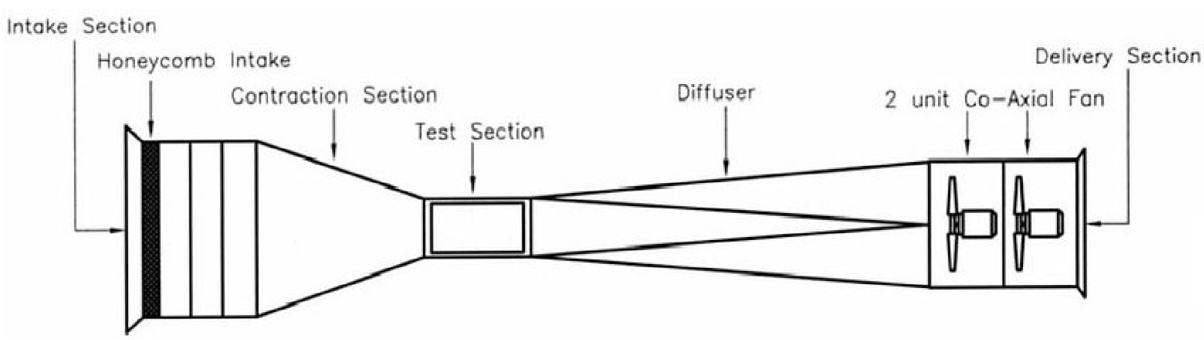
4. Smoke Generator: For flow seeding a smoke generator as shown in the figure below is used.

5. Pitot Static tube: The Pitot static tube is used to measure the fluid velocity.

PROCEDURE:

1. Mount the Pitot static tube in the test section to measure the flow velocity.
2. Connect the Pitot static tube to the digital manometer.
3. Connect the manometer to the DAQ system and acquire the velocity data.
4. Remove the Pitot static tube and mount the delta wing for flow visualization in the test section.
5. Start the tunnel, smoke generator and laser for illumination. Observe the vortices formed at a moderate angle of attack.

OBSERVATION:



When the delta wing is placed in the wind the wind tunnel vortices are formed on both sides mostly symmetric. As we go towards the trailing side of the wing vortex size increases. As we move towards trailing edge vortex size increases and thus strength decreases. At some point, usually at a high angle of attacks and high velocity, vortex breakdown occurs. This causes a sudden loss in the lift of the plane. The other side tries to move up and then vortex breakdown occurs on that side. As a result, the delta wing oscillates about its axis.

EXP (b)

OBJECTIVE:

Measurement of pressure distribution in the wind tunnel test section.

THEORY:

Coefficient of pressure: The pressure coefficient C_p is a dimensionless number that describes the relative pressures throughout a flow field in fluid dynamics. Here,

$$C_p = (P - P_\infty)/(0.5\ \rho_\infty V_\infty^2)$$

P = pressure at the point where CP is to be measured.
P_∞ = pressure at the free stream or reference pressure.
ρ_∞ = reference density.
V_∞ = reference velocity.

If we consider the flow to be incompressible, then by Bernoulli's equation

$$(½)\rho V^2 + \rho gz + p = \text{constant}$$

We arrive at the relation for Cp to be,

$$Cp = 1 - (V/V_\infty)^2$$

PROCEDURE:

Measure the pressure distribution in the test section by measuring pressure difference at each port.

OBSERVATION:

Coefficient of pressure in the test section.
Since the flow is viscous, due to the formation of the boundary layer in the test section the cross-section area decreases for the flow and thus velocity increases and pressure drops.

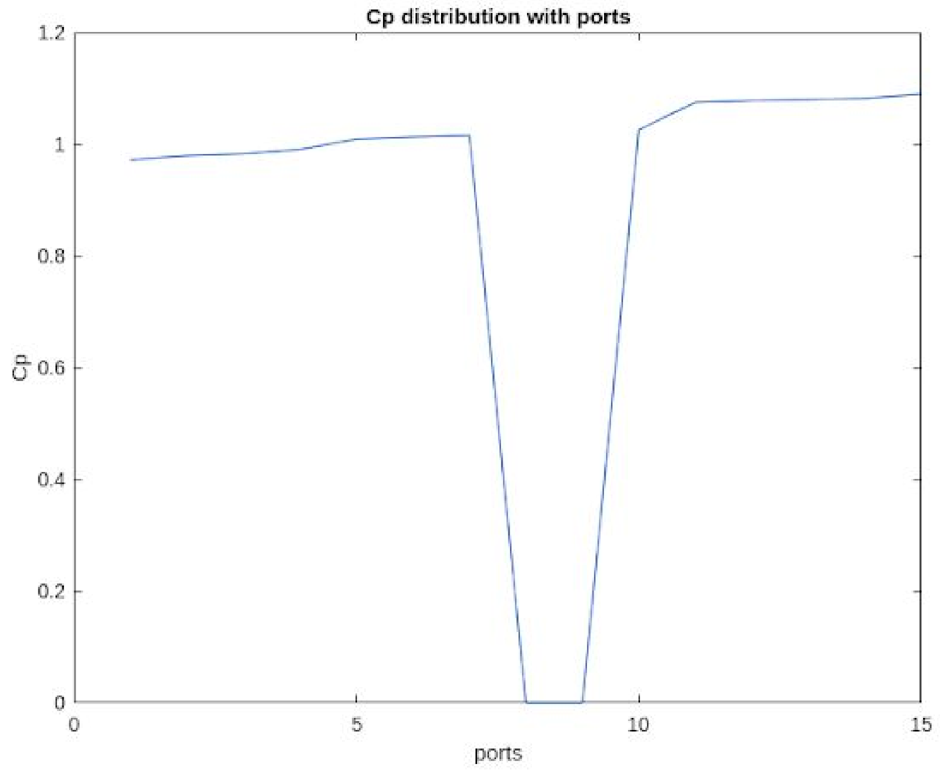
Flow velocity: 8 m/s

$$C_p = (P - P_\infty)/(0.5\, \rho_\infty V_\infty^{\,2})$$
$$C_p = 4.10x10\text{^}-3/(0.5x1.225x64x10\text{^}-2) = 0.9721$$

Cp distribution in the test section

Port No.	Change in pressure (mm of H_2O)	Cp
1	4.10	0.9721
2	4.13	0.9795
3	4.15	0.983
4	4.18	0.9907
5	4.26	1.009
6	4.28	1.013
7	4.29	1.016
8	0	0
9	0	0
10	4.33	1.026
11	4.43	1.049
12	4.44	1.052
13	4.46	1.056
14	4.47	1.059
15	4.49	1.064

Error Analysis: Due to errors in the instrument we get Cp >1. Port 8&9 are not included due to error.



<u>Conclusion</u>: Cp is the same throughout the test section of the wind tunnel.