Experiment - 8
Drag estimation on symmetrical airfoil NACA0015 from wake profile measurent

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1. Aim :

- To estimate Drag from wake velocity profile measurement.
- To observe variation of Coefficients of Drag with Angle of Attack on increasing velocity.

2. Apparatus :

Required apparatus for performing this experiment are:

- Manometer
- C15-10 Armfield tunnel
- Pitot-static Probe
- Fan
- Symmetrical Airfoil model

3. Theory :

Drag : Drag is the force which opposes the motion of an object. Drag is calculated by :

$$D = \int_{-\infty}^{\infty} \rho v(V_\infty - v)\, dy$$

Coefficients of Drag : Drag coefficients caused due to skin friction and Drag. Drag coefficients is calculated by :

$$C_d = \frac{2D}{(\rho V_\infty^2 d)/2}$$

Stagnation and Static Pressure : Stagnation pressure is the pressure at the stagnation points in the fluid flow.Static pressure is the actual thermodynamic pressure of a flow.

$$P_{stag} = P_\infty + \frac{\rho v^2}{2}$$

Reynolds Number : The Reynolds number is the ratio of inertial forces to viscous forces within a fluid which is subjected to relative internal moment due to variation of velocities.

$$R_e = \frac{\rho V_{\infty d}}{\mu}$$

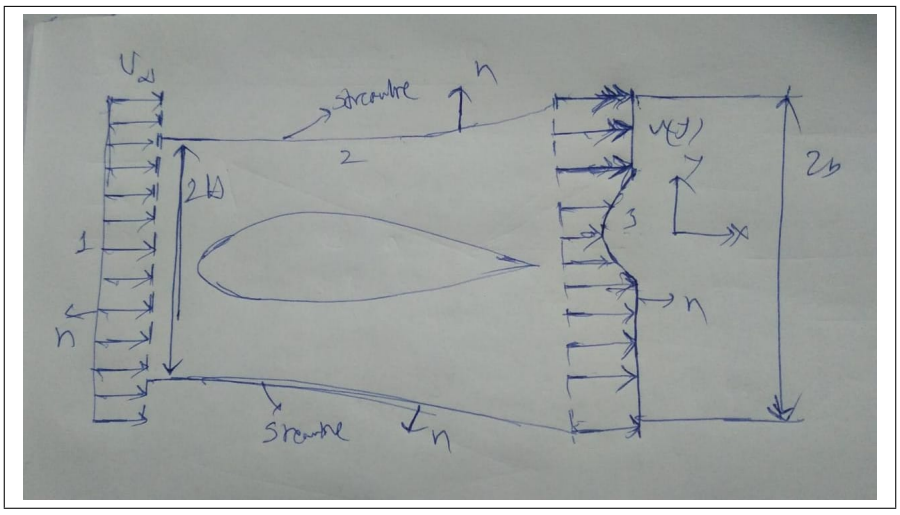

Figure 1: Wake and Velocity profile behind a symmetric airfoil

4. Procedure :

1. In wind tunnel test section is set.
2. Pitot-static probe is connected to manometer.
3. Fan speed is fixed.
4. Required readings are taken.

5. Observation :

5.1 Wake velocity profile with distance of Pitot probe

Table 1: **Wake profile velocity with distance of pitot probe**

Port No.	Distance from starting point(in mm)	Stagnation Pressure(in Pa)	Velocity(m/s)
P_1	0	-3	14.584
P_2	6	-4	14.528
P_3	12	-5	14.472
P_4	18	-5	14.472
P_5	24	-5	14.472
P_6	30	-7	14.359
P_7	36	-110	6.165
P_8	42	-5	14.472
P_9	48	-4	14.528
P_{10}	54	-3	14.584
Between P_4 & P_5	21	-5	14.472
Between P_5 & P_6	27	-5	14.472
Between P_6 & P_7	33	-20	13.600
Between P_7 & P_8	39	-22	13.479
Between P_8 & P_9	45	-3	14.584

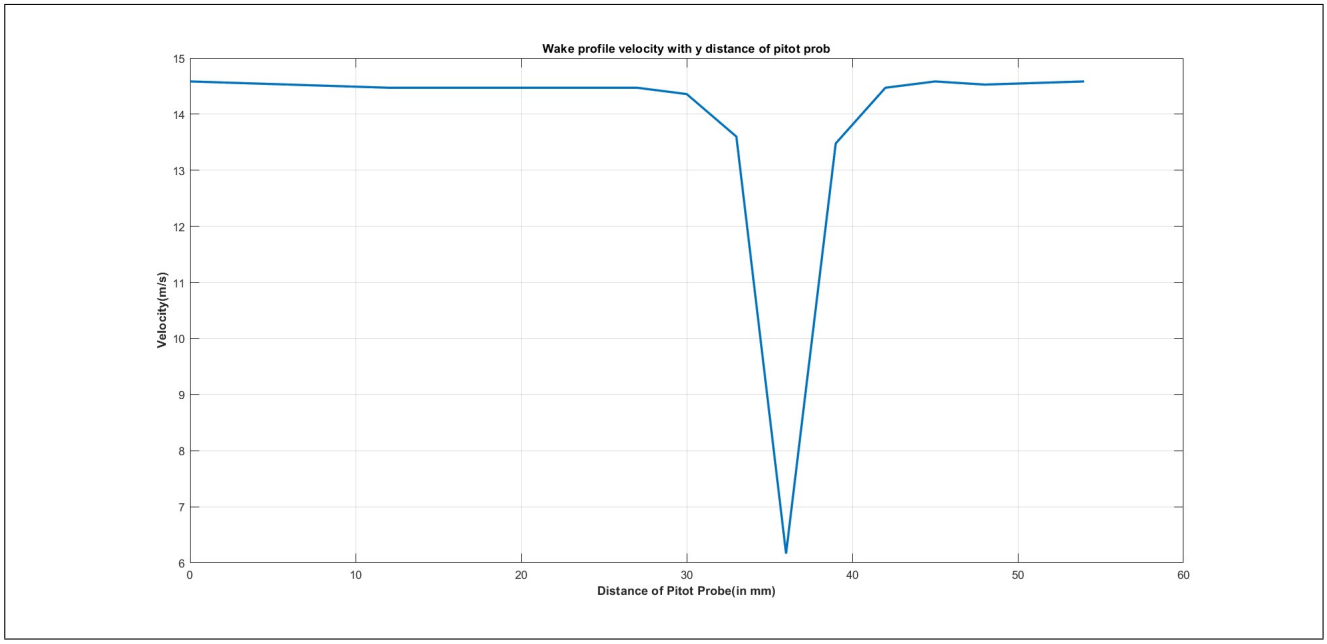

Figure 2: Variation of velocity with distance of pitot tube.

5.2 Coefficient of Drag vs Angle of Attack :

Table 2: **Variation of Drag Coefficients with Angle of Attack**

Sl. No.	Angle of Attack(α)	Coeff of Drag(C_d)(For V=15 m/s)	Coeff of Drag(C_d)(For V=20 m/s)
1	0	0.113	0.134
2	2	0.0469	0.027
3	4	0.0334	0.0602
4	6	0.0904	0.0652
5	8	0.0922	0.0762
6	10	0.1346	0.0538
7	12	0.28	0.0672

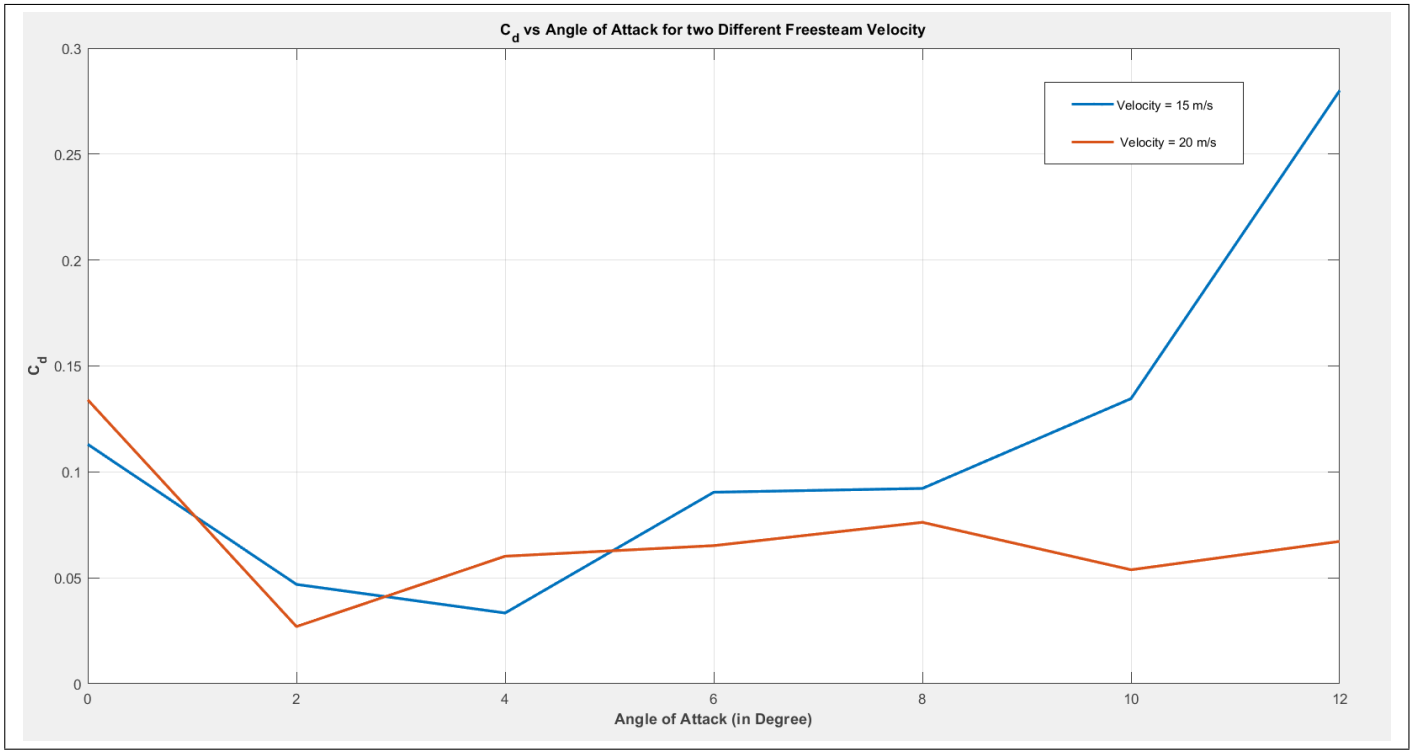

Figure 3: Variation of Coefficients of Drag with Angle of Attack for Two different Velocities

6. Calculations :

Density of air = 1.225 m^3
Static Pressure(P_∞ =-13.6 mm of Water = -133.28 Pa
Density of Water(ρ_w) = 1000 Kg/m^3

6.1 Calculation of wake profile velocity :

For port 1 :
Stagnation Pressure(P_{stag}) = -3 Pa

$$P_{stag} = P_\infty + \frac{\rho v^2}{2}$$
$$\Rightarrow P_{stag} - P_\infty = \frac{\rho v^2}{2}$$
$$\Rightarrow (133.28 - 3) = \frac{\rho v^2}{2}$$
$$\Rightarrow v = \sqrt{\frac{130.28 \times 2}{1.225}}$$
$$\Rightarrow v = 14.584 m/s$$

6.2 Calculation of Drag :

Drag(D) is calculated by ,
For 10 ports,

$$D = \int_{-\infty}^{\infty} \rho v(V_\infty - v)\, dy \approx \sum_{i=1}^{9} \rho v_{avg}(V_\infty - v_{avg})\Delta y$$

Where, $v_{avg} = \frac{v_i + v_{i+1}}{2}$
$\Delta y = 6mm = 0.006m$
$V_\infty = 15$ m/s

$$D = \sum_{i=1}^{9} \rho v_{avg}(V_\infty - v_{avg})\Delta y$$

$$\Rightarrow D = 1.225[(14.556) \times (15 - 14.556) + (14.5) \times (15 - 14.5) + (14.472) \times (15 - 14.472)$$
$$+(14.472)\times(15-14.472)+(14.4155)\times(15-14.4155)+(10.262)\times(15-10.262)+(10.3185)\times(15-10.3185)$$
$$+(14.5) \times (15 - 14.5) + (14.556) \times (15 - 14.556)] \times 0.006$$
$$\therefore D = 0.150N$$

6.3 Calculation of Coefficients of Drag (C_d) and Reynolds number(R_e):

Chord length(c) = 65 mm
For velocity(V_∞) = 15 m/s,

$$C_d = \frac{2D}{(\rho V_\infty^2 c)/2}$$

$$\therefore C_d = 0.0334$$

$$R_e = \frac{\rho V_\infty c}{\mu}$$

Where $\mu = 1.81 \times 10^{-5}$

$$\therefore R_e = \frac{1.225 \times 15 \times 0.065}{1.81 \times 10^{-5}} = 65987.57$$

7. Sources of Error:

- Error due to instrumental defect.
- Error may occur in taking readings before flow becomes steady.
- Error due to environmental effect like temperature,pressure change.
- Error in measurement due to presence of zero error in parameters.
- Dimensional error may occurs

8. Conclusion :

- Wake velocity profile is symmetrical.It falls suddenly at centerline then it remains almost constant as earlier.
- Generally Drag increases on increasing Angle of attack.
- Induced Drag increases as Angle of Attack increases and it decreases when airspeed increases. But for Parasite Drag increases as airspeed increases and remains unaffected on changing Angle of Attack.
- Wake calculation system is a very common method for calculating Drag and Coefficient of Drag.