Experiment - 6

Drag estimation on cylinder from wake profile measurement

Arka Pramanick, AE21B007
Department of Aerospace Engineering
IIT Madras

Instructor:
Professor Dr. R. Sriram

21 March, 2023

---

1. Aim :

- To estimate Drag from wake velocity profile measurement.
- To check relation between Coefficients of Drag and Reynolds no.

2. Apparatus :

Required apparatus for performing this experiment are:

- Manometer
- C15-10 Armfield tunnel
- Pitot-static Probe
- Fan
- Cylinder 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 :

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

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.

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

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 Y distance of Pitot probe

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

Port No.	Distance from starting point(in mm)	Stagnation Pressure(in mm of water)	Velocity(m/s)
P_1	0	-1.1	8.854
P_2	6	-1.4	8.579
P_3	12	-2.1	7.899
P_4	18	-1.8	7.155
P_5	24	-3.1	6.812
P_6	30	-3.4	6.450
P_7	36	-2.6	7.376
P_8	42	-2.5	7.483
P_9	48	-1.7	8.295
P_{10}	54	-1.1	8.854

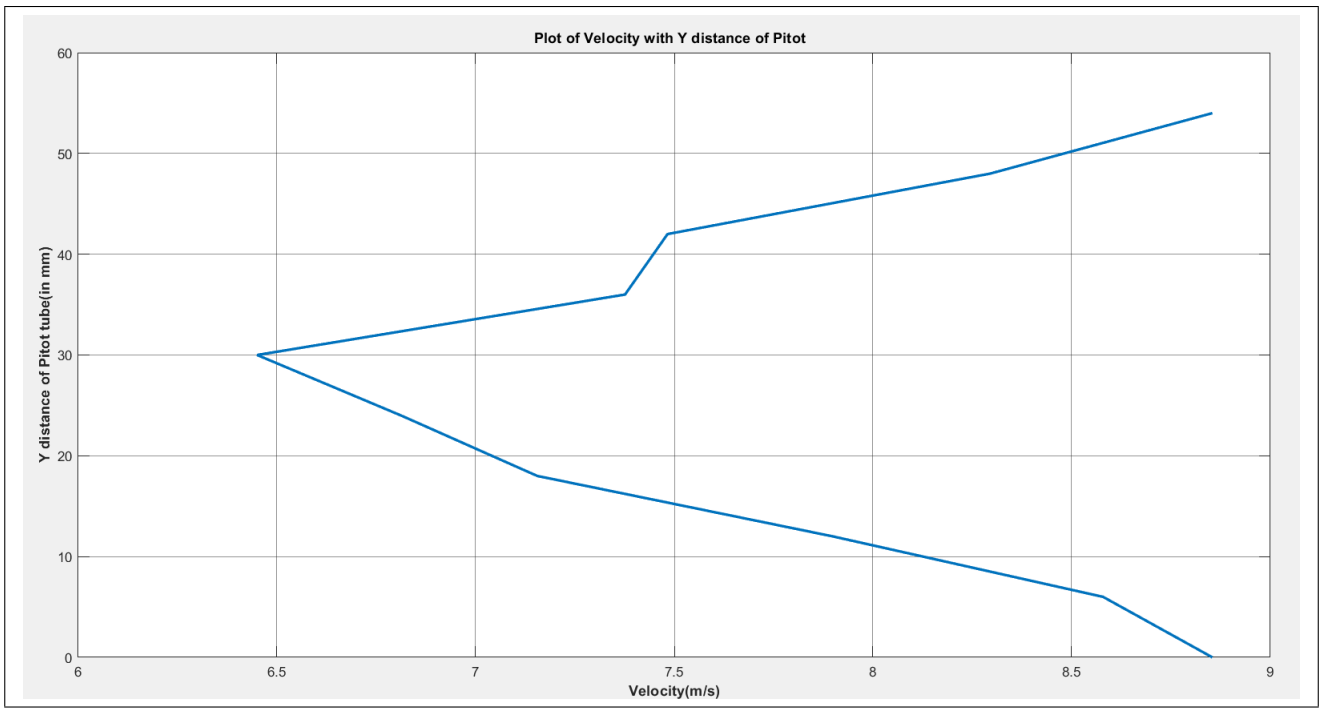

Figure 1: Variation of velocity with y distance of pitot tube.

Drag vs Velocity :

Table 2: **Variation of Drag Coefficients with Reynolds No**

Sl. No.	Velocity	Drag	Coeff of Drag(C_d)	Reynolds No.(R_e)
1	8	1.225	1.046	16109.98
2	10.2	1.3817	0.723	20709.94
3	12	1.458	0.553	12413.13
4	14.2	1.76	0.480	28595.21
5	16	2.23	0.476	32219.95
6	18	3.18	0.536	36247.44

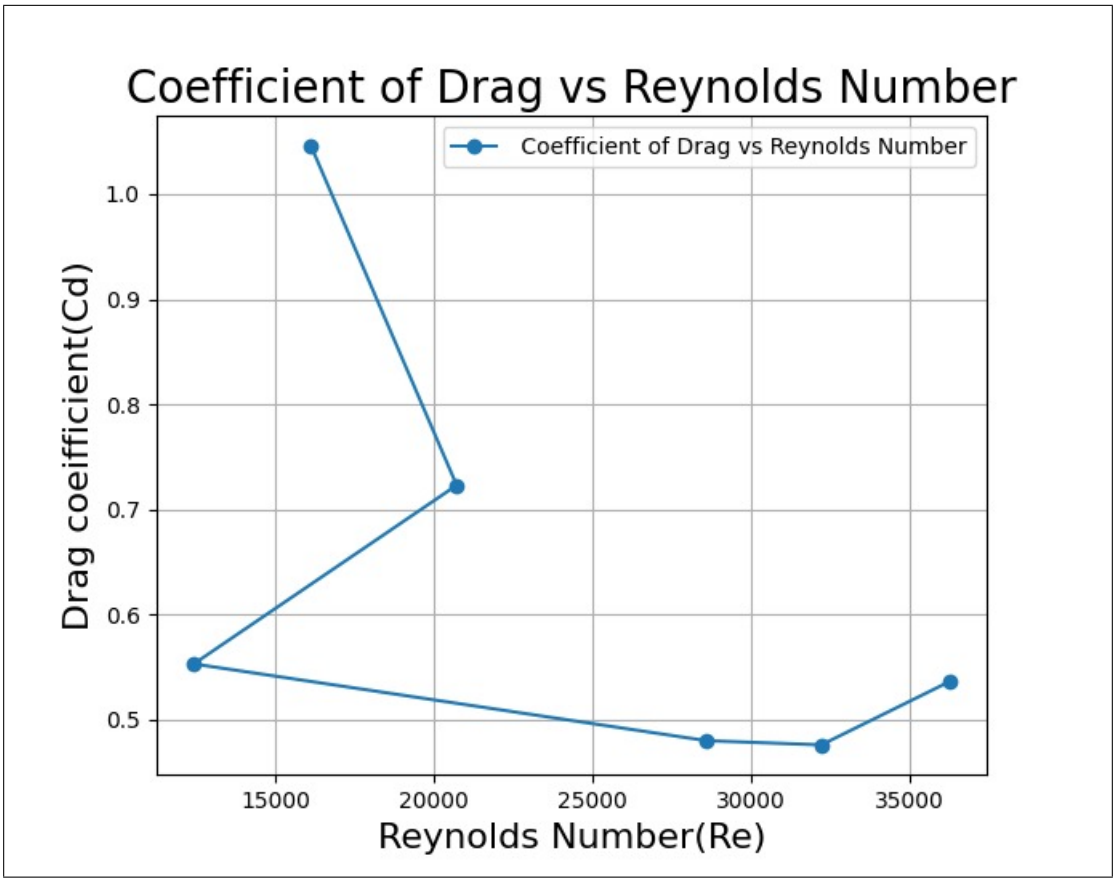

Figure 2: Variation of Coefficients of Drag with Reynolds No.

6. Calculations :

Density of air = 1.225 m^3
Zero error = -0.4 mm of Water
Static Pressure(P_∞ = -(6-0.4) mm of Water = -5.6 mm of water
Density of Water(ρ_w) = 1000 Kg/m^3

6.1 Calculation of wake profile velocity :

For port 1 :
Stagnation Pressure(P_{stag}) = -(1.5-0.4) mm of Water = -1.1 mm of Water

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

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

$$\Rightarrow \rho_w g h = \frac{\rho v^2}{2}$$

$$\Rightarrow v = \sqrt{\frac{1000 \times 9.8 \times (5.6 - 1.1) \times 10^{-3} \times 2}{1.225}}$$

$$\Rightarrow v = 8.854 m/s$$

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, $v_{avg} = \frac{v_i + v_{i+1}}{2}$
$\Delta y = 6mm = 0.006m$
$V_\infty = 10.2$ m/s

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

$$\Rightarrow D = 1.225 \times 0.006 (8.7165 \times 1.4835) + (8.239 \times 1.961) + (7.527 \times 2.673) + (6.9835 \times 3.2165) + (6.631 \times 3.569)$$

$$+ (6.913 \times 3.287) + (7.4295 \times 2.7705) + (7.889 \times 2.311) + (8.5745 \times 1.6255)$$

$$\therefore D = 1.3817N$$

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

Diameter(d) = 30 mm
For velocity(V_∞ 10.2 m/s,

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

$$\therefore C_d = 0.723$$

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

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

$$\therefore R_e = \frac{1.225 \times 10.2 \times 0.03}{1.81 \times 10^{-5}} = 20709.94$$

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.
- Drag increases on increasing velocity.
- Drag coefficient increases on increasing Reynolds number.