OBJECTIVES

To determine the drag coefficient of a circular cylinder using direct weighing and pressure distribution methods.

LEARNING OUTCOMES

At the end of this lab session, students should be able to:

1. Collect and record drag force, total pressure and static pressure data using both direct weighing and pressure distribution methods.
2. Established the drag force and pressure distribution around an oval cylinder.
3. Determine the pressure coefficient and drag coefficient experimentally and analytically.
4. Present the experimental data in form of graphs of drag force against dynamic pressure neatly
5. Established the drag coefficient out of pressure coefficient against measuring angles graph.
6. Write a clear and meaningful account of experimental results that describe the drag phenomena.

THEORY

The resistance of a body as it moves through a fluid is of great technical importance in hydrodynamics and aerodynamics. In this experiment we place a circular cylinder in an air stream and measure its resistance, or drag by two methods; direct weighing method and pressure distribution method.

The curve had shown in Figure 1represents a section of an oval cylinder. Motion of the cylinder through stationary fluid produces actions on its surface, which give rise to a resultant force.

At any chosen point A of the surface of the cylinder, the effect of the fluid may conveniently be resolved into two components, pressure, p, normal to the surface and shear stress along the surface.

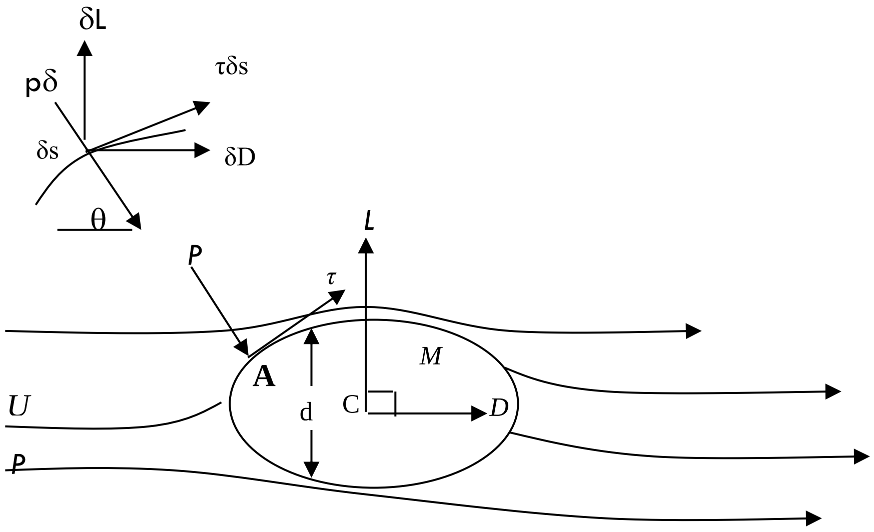

Figure 1 A section of an oval cylinder

Let U denote the uniform speed of the motion and ρ the density of the fluid, then the dynamic pressure in the undisturbed stream, $\frac{1}{2}\rho U^2$, is

$$\tfrac{1}{2}\rho U^2 = P_o - p_o \tag{1}$$

Where P_o is the total pressure and p_o is the static pressure in the oncoming stream.

This pressure is a useful quantity by which the gauge pressure p and shear stress τ may be dimensionalised, and the following dimensionless term are defined

$$\text{Pressure coefficient, } c_p = \frac{p - p_o}{\frac{1}{2}\rho U^2}; \tag{2}$$

$$\text{Skin friction coefficient} = c_f = \frac{\tau}{\frac{1}{2}\rho U^2} \tag{3}$$

The combined effect of pressure and shear stress gives rise to resultant force on the cylinder. This resultant may conveniently be resolved into the following components acting at any chosen origin C of the section as shown in Figure 1.

a. A component in the direction of U, called the drag force, of intensity D per unit length of cylinder.
b. A component normal to the direction of U, called the lift force, of intensity L per unit length of cylinder
c. A moment about the origin C, called the pitching moment, of intensity M per unit length of cylinder

These components may be expressed by definition of drag coefficients as follows:-

$$\text{Drag coefficient, } C_D = \frac{D}{\frac{1}{2}\rho U^2 d} \tag{4}$$

$$\text{Lift coefficient, } C_L = \frac{L}{\frac{1}{2}\rho U^2 d} \qquad (5)$$

$$\text{Pitching moment coefficient, } C_M = \frac{M}{\frac{1}{2}\rho U^2 d^2} \qquad (6)$$

In which *d* denotes a suitable dimension which characterizes the size of the cylinder. In Figure 1 this is shown as the width measured across the cylinder, normal to *U*.

We may see how pressure and skin friction coefficients are related to lift and drag coefficients. Theoretical calculation shows that the drag of a cylinder may be found by measuring *p* and τ over the surface. For the case of circular cylinder, the effect of skin friction is very small compared to pressure drag and therefore may be neglected. This assumption allows us to calculate C_D from the measured pressure distribution over the cylinder surface. In this "Pressure distribution method", C_D can be calculated as

$$C_D = \int_0^{2\pi} c_p \mathrm{Cos}\,\theta\, d\theta \qquad (7)$$

Alternatively, by plotting $c_p \cos\theta$ against θ, C_D may be obtained from the area beneath the curve. The area A beneath the mean curve is :-

$$A = \int_0^{\pi} c_p \mathrm{Cos}\,\theta\, d\theta \qquad (8)$$

which from equation (7), we recognize as the drag coefficient. This integration can be evaluated in various ways such as by using Simpson's or the trapezium rule etc. (Hint: Refer to your Numerical Method notes on how to calculate area under a curve)

In "direct weighing method", the drag force is written as Dl, that is the product of the drag per unit length and the length l of the cylinder. Dl is measured in units of gram-force (gmf). By substituting Dl in equation 4, the experimental C_D by direct weighing method can now be calculated as

$$\text{Drag coefficient, } C_D = \frac{Dl}{\frac{1}{2}\rho U^2 dl} \qquad (9)$$

Where Dl is the experimental measured drag force in gmf, d is the diameter of cylinder and l is the length of cylinder

Assuming that the fluid is incompressible and non-viscous, the following theoretical formula can be applied:

$$p = p_a - p_0 = \frac{1}{2}\rho U^2 - \frac{1}{2}\rho u^2 \qquad (10)$$

$$p = \frac{1}{2}\rho U^2\left(1 - 4\sin^2\theta\right) \qquad (11)$$

$$c_p = \frac{p}{\frac{1}{2}\rho U^2} = 1 - 4\sin^2\theta \qquad (12)$$

Equation 10 to equation 12 is the theoretical result for an incompressible, inviscid fluid, and forms the basis of comparison with experimental results.

APPARATUS

The AF10 Airflow Bench and AF12 Drag Measurement Apparatus is shown in Figure 2.

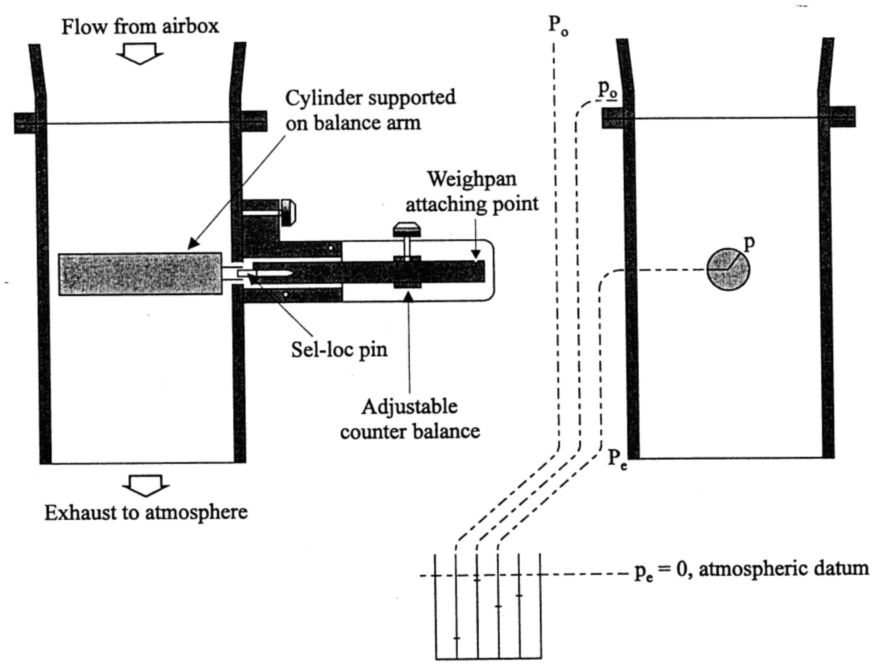

Figure 2 Diagram of apparatus

Given data:

Diameter of cylinder, *d*	= 12.5 mm
Length of cylinder, *l*	= 48 mm
1 mmH_2O	= 0.0981 mbar
1 gmf	= 981×10^{-3} N

NOTE:

Please refer to lab report guidelines for the details. The total mark for the report is 100 marks. During your lab session, direct observation assessment will be conducted with the total mark is 10.