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Experimental Investigation Of Flow Past A Rough Surfaced Cylinder

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ABSTRACT
The present work is the result of extensive experimentation on cylindrical bodies with varying cylinder diameters, surface roughness and air velocity. The experimental variables include cylinders of diameters as 12.5mm, 15 mm, 20 mm, and 25 mm, air velocity as 24.10, 24.45 and26.14 m/s andsurface roughness as 325 micron, 260 micron, 200 micron and 160 micron. The drag coefficient of flow in each case was calculated from data obtained by performing tests on an air flow bench (AF12). A comparison for the drag co-efficient and pressure distribution between the smooth and rough surfaces of the cylinders are extensively presented. In case of smooth surface cylinder, the separation angles for different diameter of cylinder calculation are found to be around 80^0~90° on either side of the cylinder from the upstream stagnation point. The drag coefficients for smooth surface of different diameter cylinders are calculated by experimentation and subsequent changes in drag due to introducing surface roughness are demonstrated. The surface roughness is found by experimentation of different drag coefficient.

Keywords-Cylinder, Drag coefficient, Drag force, Pressure distribution, Surface roughness.

I. Introduction

The resistance of a body as it moves through a fluid is of great technical importance in hydrodynamics and aerodynamics. The study of the performance of bodies in moving airstreams is called aerodynamics. Reduced drag force lowers fuel consumption, larger operational range and higher achievable speeds. Different flow phenomena such as flow separation, pressure distribution over the surface, drag, etc. are also studied at different diameter of cylinder.

Simplicity of geometric and widespread applications in real life, the flow past a circular cylinder has been a subject for studies. Drag coefficient is a function of speed, flow direction, object position, object shape and size, fluid density and fluid viscosity. Theoretical flow over a cylinder is considered to be in viscous, incompressible and irrotational; known as ‘Potential Flow’ in which the reattachment of streamlines is considered to be complete and symmetrical to detachment at the upstream resulting in zero drag force. In real life, more or less, drag is present in case of flow over the body. There is presence of viscosity and the flow is neither incompressible nor irrotational. This paper is subjected to experimental investigation of air flow over a circular cylinder of different diameter. Experimental procedure is carried out in an airflow bench with a circular cylinder of different diameter having a pressure distribution and drag force on the surface. separation angle on both the top and bottom surfaces at zero relative roughness by predicting the instability of coefficient of pressure C_P at the surface of the cylinder as C_P tends to fluctuate frequently within the separated zone. Coefficient of drag C_D is another important dimensionless parameter whose relative fluctuation is observed under different surface roughness which can be used to predict the critical relative roughness for flow over the cylinder. Experimental procedure is to measure C_P at different angular position on the surface of the cylinder to predict the overall drag coefficient and separation angle of the cylinder. Many researches had been carried out to predict the variation of Co-efficient of drag vs. Reynolds number for circular cylinder.

Effect of relative roughness on drag for the flow over circular cylinder was observed [1], in the range of Reynolds number 6×10^3 to 5×10^6. Authors investigated vortex shedding phenomena in this range. In [2], authors described the effect of three dimensionality on the lift and drag of nominally two-dimensional cylinders which is useful to describe the variation of numerical results between two dimensional and three dimensional analysis. Authors also described the effect of surface roughness for flow over a body at high Reynolds number using wind tunnel. In [3], authors presented comprehensive description of flow phenomena at different Reynolds number and in [4], authors studied that drag reduction of a circular cylinder in an air-stream is studied the flow characteristics of a bluff body cut from a circular cylinder. Two types of test models were employed in their study. In [5], authors discussed flow past a circular cylinder for Re= 10^0 to 10^7numerically by solving the unsteady incompressible two dimensional Navier-Stokes equations. In [6], authors used I-type small cylinder with a cutting angle of $\theta s = 65^o$ as passive control at a stagger angle of $\alpha=0$ and it is most effective in reducing the drag of the large circular cylinder, among the passive control cylinders used in this investigation. In [7], authors described separation angle for flow over the cylinder at low Reynolds number. In [8], authors presented the result of an investigation on the effect of wind turbulence for the reduction of drag for a speed skater. A speed skater competing in an indoor oval is subjected to turbulent flow condition. The goal of the research is to calculate drag coefficients for different Reynolds numbers. The goal of the report is to identify the characteristics of different drag coefficient on bluff body aerodynamics and to show the need of slender bodies through the drag values. In [9], authors presented that a circular cylinder produces large drag due to pressure difference between upstream and downstream. The difference in pressure is caused by the periodic separation of flow over surface of the cylinder.

II. Experimentation

Hydraulic mechanics Lab facilities of National Institute of Technology (NIT) was used to study the flow over the cylinder experimentally. The set-up air flow bench as shown in Fig 1, consists of two types of attachments: (i) for drag force by direct weighing method as shown in Fig 2, and (ii) drag co-efficient by pressure distribution method as shown in Fig 3.The setup consists of adjusting lever to control flow, a multitube manometer for pressure measurement. A circular cylinder has been placed with its axis normal to the direction of airstream and resistance (drag) has been measured by two methods: (i) by direct weighing method, and (ii) by pressure distribution method.

In Direct weighing method, drag force due to air flow was balanced by applying suitable load on the lever of the set up. Similarly, the pressure data have been noted for the varying angular position (0^0-180^0 and 180^0 to 360^0) with respect to the direction of flow. The same procedure for the measurement of drag force and pressure distribution has been repeated for varying diameter of cylinders, velocity of air flow and surface roughness.

Fig 1: Experimental setup

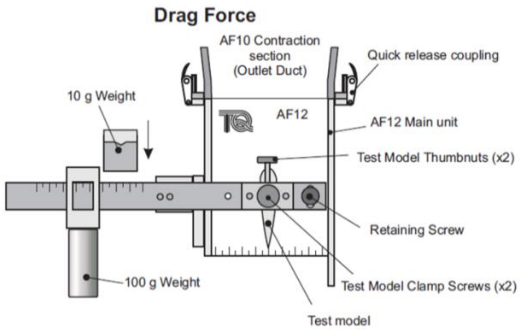

Fig 2: Drag Force by Direct weighing method

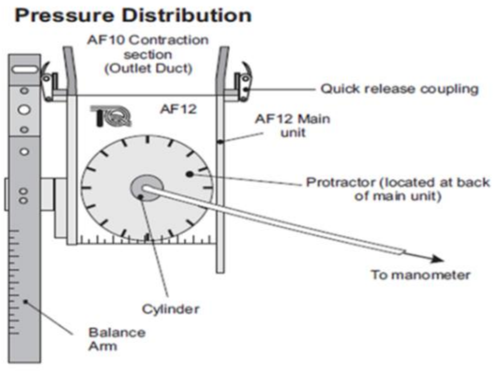

Fig 3: Drag Coefficient by Pressure Distribution method

III. Results and Discussion

Fig 4, Fig 5 and Fig 6 represent variation of drag coefficients as obtained from direct measurement method with cylinder diameters of varying surface roughness. The variation of drag co-efficient with air flow velocity for the cylinders of varying roughness have been shown in Fig 7, Fig 8, and Fig 9. Similary the variation of drag co-efficient with velocity for the same roughness of cylinders of different diameters have been presented in Figures 10 to 12. A typicalplot shown in Fig 13, Fig 14, Fig 15 and Fig 16, has been shown for pressure distribution at varying location for the cylinder of same roughness and varying diameters.

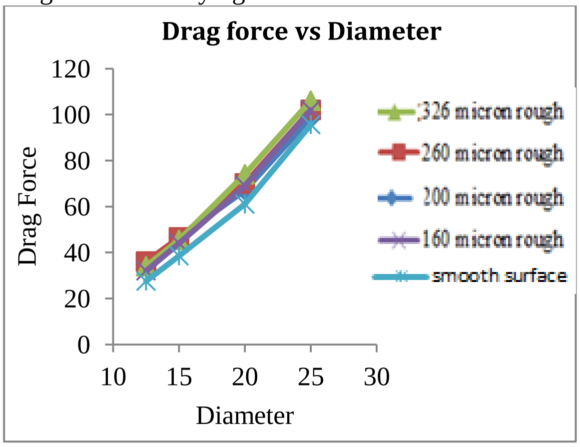

Fig.4 Drag force for Different diameter of cylinder at velocity=26.14 m/sec

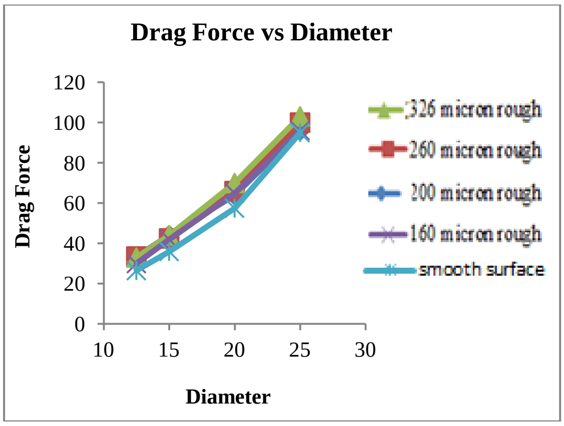

Fig.5 Drag force for Different diameter of cylinder at velocity=24.45 m/sec

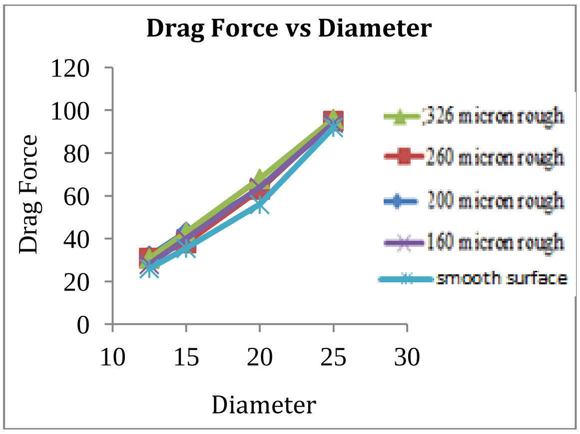

Fig.6 Drag force for Different diameter of cylinder at velocity=24.10 m/sec.

The experimental data of drag force obtained under varying conditions of flow velocity and constant diameter of the cylinder have been plotted in Fig 4 to Fig 6. In this case diameter is constant, velocity increase and drag force increase. In smooth surface drag force is less when roughness increases drag force will increases.

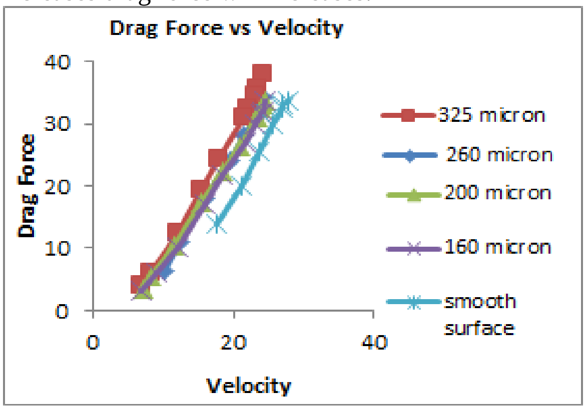

Fig.7 Drag force for 12.5mm diameter of cylinder at different roughness.

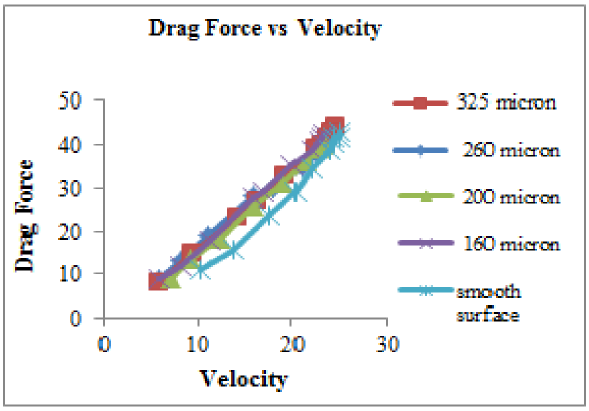

Fig.8 Drag force for 15mm diameter of cylinder at different roughness.

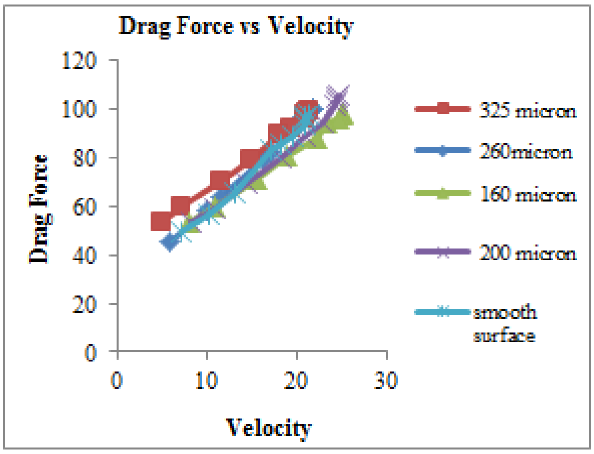

Fig.9 Drag force for 25mm diameter of cylinder at different roughness.

In this above graph to show the effect of diameter and velocity together, drag force versus velocity plot is presented for different diameters of the cylinder in Fig 7 to 9.

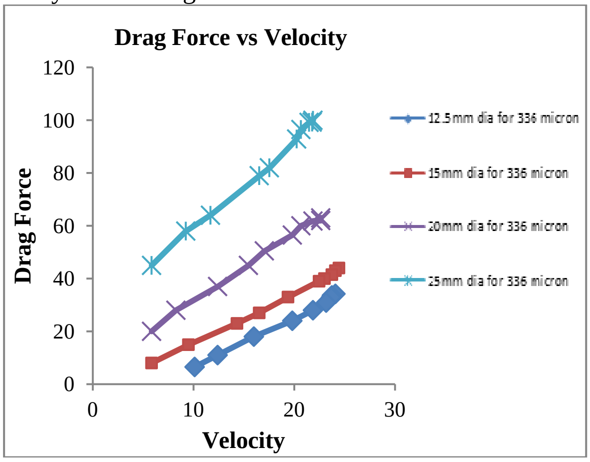

Fig.10 Drag force for different diameter of cylinder having roughness 336 micron.

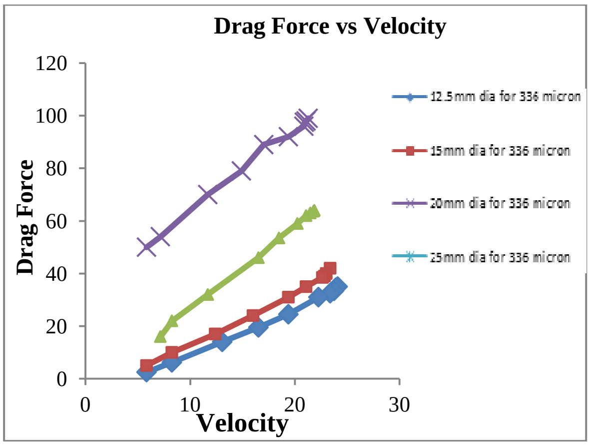

Fig.11 Drag force for different diameter of cylinder having roughness 260 micron.

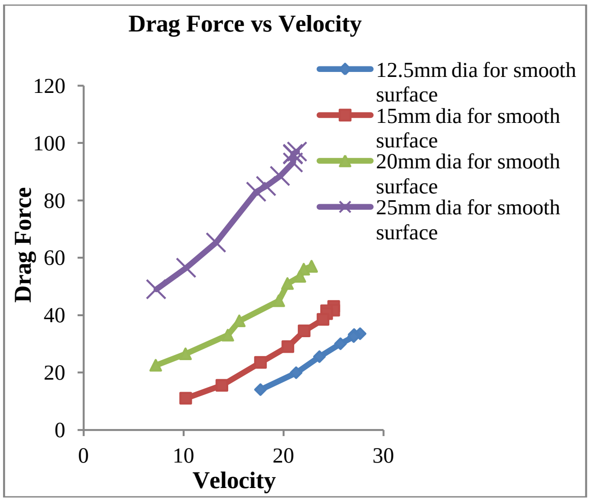

Fig.12 Drag force for different diameter of cylinder for smooth surface.

The above experimental data of pressure coefficient obtained under varying angles of incidence for the different conditions with velocity constant and diameter of the cylinder have been plotted in Fig 13 & Fig 14. Pressure distribution between smooth and rough surface of the cylinder calculation are found to be around 80^0-90^0 on either side of the cylinder from the upstream stagnation point.

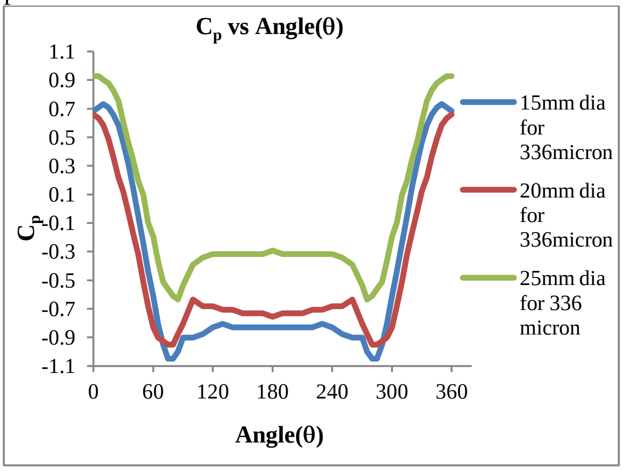

Fig.13At constant velocity 26.50 m/s distribution of $C_p$for different diameter of rough cylinder.

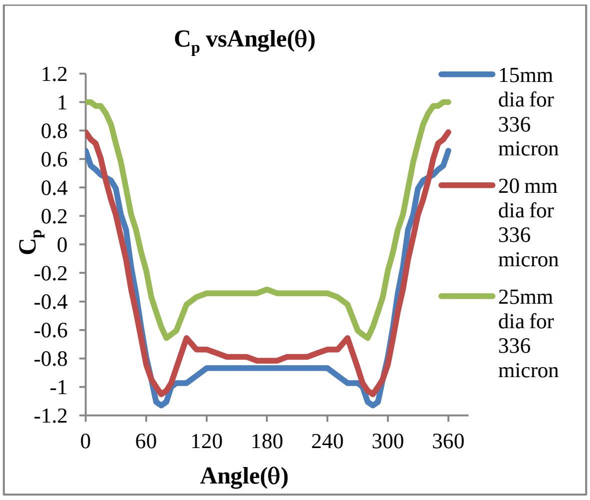

Fig.14At constant velocity 25.51 m/s distribution of C_p for different diameter of rough cylinder.

To show the effect of pressure coefficient and angle of incidence together, $C_p\cos\theta$ versus degree (θ) plot is presented for different diameters of the cylinder Fig 15 & Fig 16. Now C_D for experimental results derived from the area under the curve C_P Vs. cosθ Fig 15 is 1.04 and Fig 16 is 1.02.

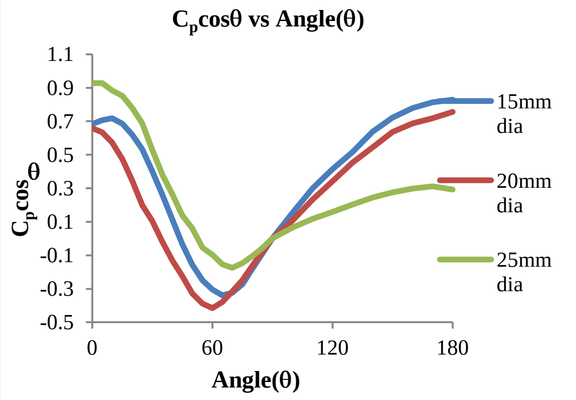

Fig.15 Pressure Distribution for different diameter of cylinder for roughness 336 micron and $C_p\cos\theta$.

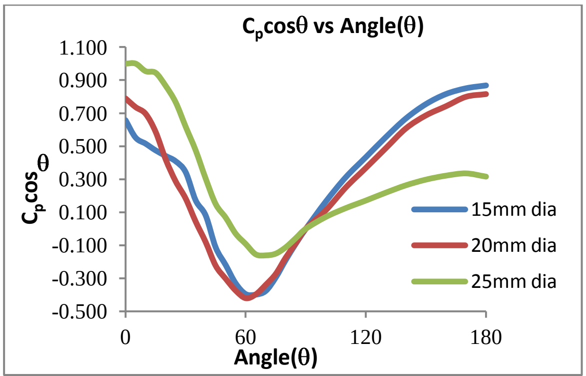

Fig.16 Pressure Distribution for different diameter of cylinder for roughness 336 micron and $C_p\cos\theta$.

IV. Conclusion

From the experimental findings and different plots shown above, the following conclusions can be derived:

- The drag force increases with increase in diameter of the cylinder.
- For a cylinder of particular diameter and roughness, drag force has been found to increase with increase in air velocity.
- Also, for a cylinder of given diameter and velocity, the drag force increases with surface roughness.
- As compare to both methods of drag force, the direct measurement method gives more reliable than the pressure distribution method. The drag co-efficient in earlier case has been found close to unity.
- The results of pressure distribution profiles clearly showthat the flow separates at around 80^0-90^0 on either side of the cylinder from the upstream stagnation point.
- The present study under taken can be further extended to studythe effect ofsurface roughness on flow parametersfor different shape and configuration of objects.
- The effect of surface roughness on the separation angle can be another centre of interest for future researchers.

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