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EXPERIMENTAL INVESTIGATION OF DRAG FOR IDENTICAL CROSS SECTIONAL SHAPES.

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Abstract- Aerodynamic study is the basis for any automobile industry as it gives the value for drag force which acts parallel and in the opposite direction of the motion of the automobile body. Drag force is a frictional force which affects the motion of a body. In this paper, frictional resistance effects have been studied to identify the effect of shape on friction and hence on drag force. Drag force affects the performance of any moving objects. So it is necessary to minimize the effect of drag. For that, change in shape of a body is done for a identical cross sectional area.

Performance is carried out using suction type subsonic wind tunnel and digital strain gauge to measure drag co-efficient of different shapes at different velocities. Pitot tube is used to measure velocity of the flow.

Keywords – Drag force, Drag co-efficient, Frictional resistance, Aerodynamics, Shape effect

1. INTRODUCTION

Drag force is the resisting force of air which acts in the opposite direction of motion of the moving object. It also provides friction effect on the surface of the body. Drag force which is parallel to the direction of motion of air can be divided in to two parts: friction drag and pressure drag.

Friction drag occurs because of the resistive effect between the motion of fluid and the surface in contact with the fluid. Due to result of this, the boundary layer development occurs and also changes in Reynolds number can be experienced.

Eddy motion occurred during the flow of fluid when it passes over surface of the body. This eddy flow generates pressure drag on surface of the body. This pressure drag also occurs due to wake formation and flow separation which can be experienced from the formation of wake behind a passing boat in river. This pressure drag affects less to the Reynolds number than frictional drag. Precisely pressure drag and friction drag both occur due to viscosity but it differentiate each other because of having different flow phenomena. In addition to this, friction drag is utilized for attached flows in which cross sectional area of the body and boundary layer flow matters.

The flow around the bodies having a variety of shapes follows the same behavior as flow around a cylinder and a sphere. Coefficient of drag depends on the shape of the body, velocity of flow, body's surface roughness and also on the angle of inclination of body with flow at which the body is oriented within the flow.

In actual practice, nearby bodies can influence the pattern of flow around the object being studied, and this can greatly affect the actual value of C_d.

When fluid flows over a curved surface, a pressure gradient is developed over the surface. This gradient accelerates the flow when the pressure becomes less or the gradient is decreasing and it decelerates the flow when the pressure becomes greater or the adverse gradient is increasing. Flow separation can lead to increase in pressure at trailing edge and hence decrease in lift occurs [4]. If the flow is slowed too much, it will separate from the surface and form a wake or region of turbulence behind the body. Experiments have shown that the pressure within the wake is essentially constant and is about the same as it is within the free stream flow.

The separation of boundary layer flow from a curved surface will give rise to an unequal pressure distribution over the surface of the body, and this produces the pressure drag.

For low velocity of flow, the viscous shear will create the maximum component of drag, and for high velocity the pressure drag component will dominate.

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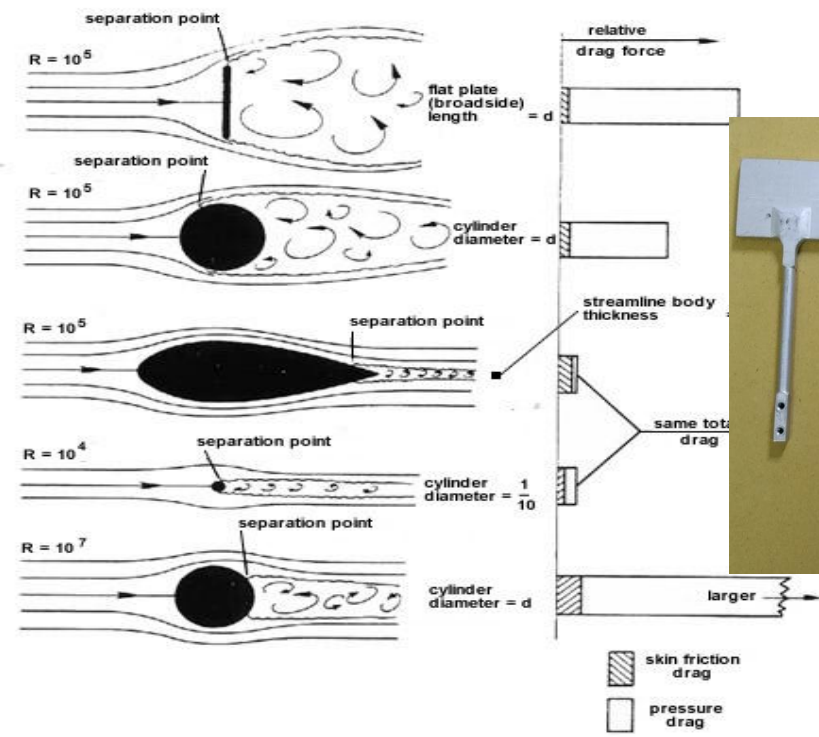

Figure 1: Drag effect on different shapes at various velocity.

The drag co efficient C_d is equal to the drag D divided by the quantity: density ρ times half the velocity squared times the reference area A. The drag coefficient then expresses the ratio of the drag force to the force produced by the dynamic pressure times the area.

$$C_d = \frac{Drag\ Force\ D}{1/_2\,\rho A v^2}$$

K.Gemba[2] performed number of experiments for different shapes and with different velocities to become familier with the idea of developing relation with an object model and its drag by testing with load cell and concluded that aerodynamic models create insignificant drag force on the object while lesser aerodynamic shape creates drag forces which are twice in its value than obtained by aerodynamic models. Even he found the relationship between the drag coefficient and Reynolds number.

Hoerner[3] studied drag force on rigid bluff bodies and found that drag coefficients for bluff bodies can be quite different depending on Reynolds number. During plotting of experimental drag coefficients against Reynolds number for a sphere (and other objects) shows that there are transitional points where the drag coefficient can change value rapidly. Therefore, if the Reynolds number ranges of two different experiments differ, it must be assumed that there could be a possible Re range between these two experimental sets where drag coefficient could drastically change.

Debashish Burman[10] and his students used just in time method for different flow visualization and drag effect on different shapes and understand the nature of drag by making informal predictions about the drag. The hands on learner driven approach helped them to build a strong intuitive sense of how flows interact with different shapes.

2. EXPERIMENTAL WORK

Experimental setup consists of subsonic type of open circuit wind tunnel with pitot tube inserted inside wind tunnel for measuring the velocity of flow as shown in figure 2(a). Different objects like as rectangular plate, cup and hemi sphere, sphere, circular plate and square plates are provided as shown in figure 2(b) with equal cross sectional area of 0.0079 m^2 for measuring the drag force through strain gauge for different velocities ranging from 25-35 m/sec. Variable frequency drive motor is provided for changes the speed of the motor and hence velocity of flow.

In this experiment, drag force for different shapes is obtained by using digital strain gauge which indicates the value of drag force for different speed of motor. From this value of drag force, drag coefficient is found and results of drag coefficient with velocities are plotted on graph for all the different shapes.

Figure 2: (a) Experimental Setup of wind tunnel (b) Identical shapes of test models.

3. RESULTS AND DISCUSSION

Six different objects with constant cross sectional areas and with different shapes were tested for different velocities in suction type of wind tunnel. By performing experiments on different objects, drag force was measured using digital strain gauge. From the value obtained, drag coefficient was calculated for different geometries and velocity of flow was calculated by measuring the pressure difference in pitot tube for different speeds. Results obtained from the experiments are as below:

3.1 Rectangular/ Square/ Circular plates:

As indicated in figure 3, for particular range of velocities from 18-24 m/sec, increase in velocity decreases the drag coefficient for rectangular and square plate. It shows that effect of inertia force on object is higher than viscous force for low velocity flow. While for circular plate, deviation can be seen in drag co-efficient which suggest that flow behind the circular plate gives viscous force on the plate for circular section. From velocity range of 24- 30 m/sec, viscous effect is prominent for square and circular plate, which increases the drag forces on the plate and that increment, is linear. For rectangular plate, still viscous effect doesn't affect the inertia force and slope seems linearly decrease in drag coefficient. Lowest drag co-efficient obtained for rectangle as 1.55, square plate as 1.4 and 1.31 for circular shape. Afterwards increase in velocity increases the drag coefficient and rise in drag is linear for all three cases. Finally for velocity range from 30-35 m/sec, viscous effect is more with increase in velocity. And in all three cases, increase in drag coefficient occurs.

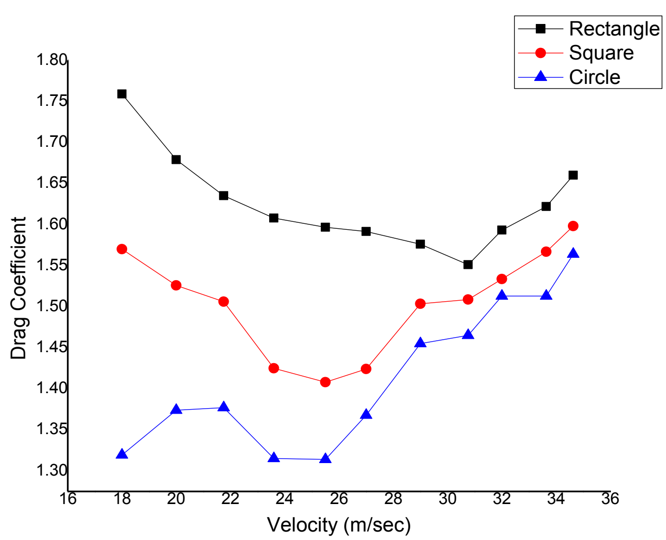

Figure 3: Drag coefficient versus flow velocity for rectangle, square and circle shape

3.2 Sphere/ Hemisphere/ Cup:

As shown in figure 4, for range from 18-24 m/sec, in all three cases decrease in drag force occurs with increase in velocity. In between from 24-30 m/sec, limiting value of drag co-efficient is obtained for sphere as 0.67, hemisphere as 0.66 and 1.45 for cup shape. Afterwards increase in velocity increases the drag coefficient and rise in drag is linear for all three cases. Throughout different velocity ranges, slightly higher drag is obtained for hemispherical shape than sphere.

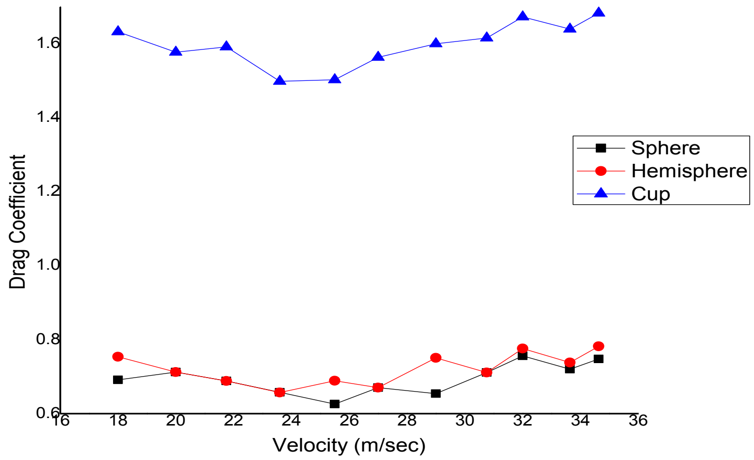

Figure 4: Drag coefficient versus flow velocity for sphere, hemisphere and cup shapes

4. CONCLUSION

Highest drag coefficient is obtained for rectangular plate at low velocity and is of 1.77 while lowest drag is of 1.55 at velocity of 31 m/sec.

For the same cross sectional area, it is observed that increase in amount of frictional resistance is highest for rectangular and cup shape. While for spherical and hemisphere shape it is in least amount. Stagnant area is obtained for rectangular, square and circular shapes which lead to high amount of increase in skin friction. For the case of cup shape, stagnant point is obtained and reverse flow occurs which leads to highest amount of skin friction and as a result highest drag is obtained. So it can be concluded that spherical or hemispherical shapes are the best suited for reducing skin frictional drag for any given cross sectional area for any ranges of velocities of flow.

Average of all coefficient of drag obtained for rectangular, square and circular plates are 1.62, 1.50, 1.41 while for sphere, hemisphere and for cup shape are 0.69, 0.72 and 1.59. So we can conclude that most efficient aerodynamic shape for given cross section is sphere and less efficient aerodynamic shape is rectangular plate.

5. ACKNOWLEDGEMENT

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