Research on the Influence of the Shape of an Object on Its Fluid Resistance

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ABSTRACT: In the chapter on Fluids in Edexcel Physics, it is mentioned that different shapes have different effects on fluid resistance. In this study, the effect of the shape of the object on the fluid resistance is studied. Experimental methods are mainly used. In the experiment, by studying the movement speeds of different shapes of iron blocks in water, the different fluid resistances of different shapes of iron blocks were inferred, and the influence of different shapes on fluid resistance was further speculated. In the course of the experiment, different shapes of iron blocks were used, and weights and measuring cylinders were also used. The amount of resistance received is determined by measuring the length of time it takes for different iron blocks to move at a constant distance in water under constant tensile force. The final conclusion is that the more square the object moves in the fluid, the greater the fluid resistance is. The more sleek streamlined an object is, the less fluid resistance it is subjected to as it moves through the fluid.

1. INTRODUCTION

The fluid resistance is related to the shape of the object and will be affected by the shape of the object[1].

The driving and running of the car is in the air, swimming is in the water, and the air and water are both a fluid. So this paper designed this experiment, using an object like an iron block and a fluid like water. Prepare iron blocks of cubes, spheres, and ellipsoids of the same mass, put iron blocks of the same mass but of different shapes in water, and analyze the fluid resistance by changing their shape.

This study gives us a clearer picture of the effect of shape on fluid resistance. This further analyzes the effects of objects of different shapes in the fluid. This allows us to better understand some phenomena in life. For example, the aircraft's shape can be made into a streamlined shape, so that the air resistance of the aircraft during high-speed flight will be greatly reduced. Based on this result, the shape of the vehicle can be analyzed and improved, and it can be determined that the less fluid resistance of the vehicle in what shape is subjected to, the more fuel can be saved. It can also allow us to improve the shape better when designing vehicles[2].

2. EXPERIMENT DESCRIPTION

Frictional resistance is in the opposite direction of the fluid's movement[3].

The fluid resistance increases with increasing velocity, and the resultant force is zero when the velocity of an object in the fluid increases to the terminal velocity[4].

2.1. Objective

Verify how different shapes affect fluid resistance.

Method: Objects of different shapes are placed in the liquid and subjected to constant tension to accelerate from rest until they reach the terminal speed state, and pass the same distance at the terminal speed. The size of the speed is analyzed by the length of the measurement time, and the size of the resistance is analyzed by the size of the speed of the object at the terminal speed state.

2.2. Equipment

Three ferrous objects of the same mass (100g) are selected, and the shapes are as follows. Spheres, cubes, ellipsoids. The reason for this choice is to gradually change the shape from angular to streamlined.

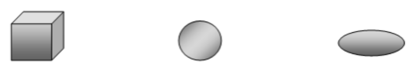

Figure 1. Objects of three shapes: cube, sphere, and ellipsoid

This study requires the following experimental equipment: 50cm high cylinder filled with water, lightweight rope that does not lengthen, two smooth pulleys and a stand to hold the pulleys in place, weights (100g each), and stopwatch.

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2.3. Build the experimental setup

Fill the graduating cylinder with water and place it on the horizontal ground. The first pulley is fixed with a bracket directly above the graduating cylinder, and the second pulley is located on the right side of the first pulley, and a certain distance flows out between the two pulleys to prevent mutual influence. A string is inserted in the pulley, one end connecting the iron block to the measuring cylinder, and the other end connecting the weight to hang in the air.

Construct the experimental apparatus as shown in the figure 2.

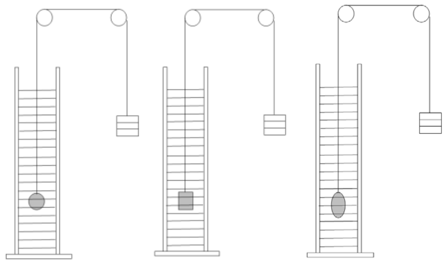

Figure 2. Objects of three shapes are placed in a cylinder

2.4. Analyze the force

For an object at rest in the water, there is no drag force. The tensile force of the object plus the buoyancy force is equal to the gravity[5].

$$T + U = W \quad (1)$$

As we apply a force to an object, it experiences an acceleration, its velocity grows, so does its drag, which is the opposite of speed.

This drag force counteracts the applied force and reduces the net force and the object's acceleration.

Eventually, velocity increases to the point where the drag force is exactly matched to the applied force, bringing the net force to zero.

From this point on, the object is in equilibrium, there is no acceleration, and the velocity remains constant, equal to its steady-state value called the terminal velocity.

At this point we perform a force analysis of the object, which is subjected to an upward pulling force, downward gravity, upward buoyancy and downward fluid resistance.

Because the motion of the object reaches a uniform speed, so the combined force is zero. We can therefore list the following formula: buoyancy Gala force equals gravity plus fluid resistance.

$$T + U = W + F \quad (2)$$

2.5. Measurement data

The first step is to select the round ball to hang at the end of the line and put it into the water until it reaches bottom. In the upper position of the graduating cylinder, the 20 cm long interval is fixed with a rubber strip. A 20 cm long interval is fixed with a rubber strip in the upper position of the graduating cylinder in order to ensure that the terminal speed is reached when the ball reaches this position.

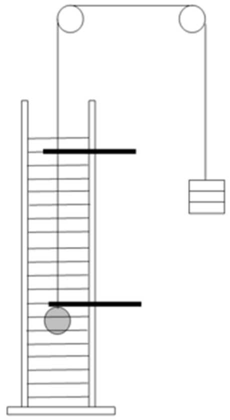

Figure 3. Two rubber bands are marked on the cylinder, and the sphere passes through two rubber bands to record the time

On the right side, straighten the line and hang the 100g weight and start releasing the weight. Measure the time interval at which the pellet passes through the two rubber strips. Repeat the measurement ten times to get an average.

On the right side, pull the cable straight up and hang the 200g weight and start releasing the weight. Measure the time interval at which the pellet passes through the two rubber strips. Repeat the measurement ten times to obtain an average.

On the right side, pull the cable straight up and hang the 300g weight and start releasing the weight. Measure the time interval at which the pellet passes through the two rubber strips. Repeat the measurement ten times to get an average.

The second step is to select the cube that hangs from the end of the line and put it into the water until it reaches the bottom. In the upper position of the graduating cylinder, the 20 cm long interval is fixed with a rubber strip.

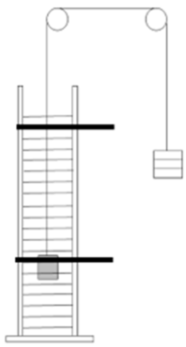

Figure 4. Two rubber bands are marked on the cylinder, and the cube passes through two rubber bands to record the time

On the right side, straighten the line and hang the 100g weight and start releasing the weight. Measure the time interval at which the cube passes through the two rubber strips. Repeat the measurement ten times to get an average.

On the right side, pull the cable straight up and hang the 200g weight and start releasing the weight. Measure the time interval at which the cube passes through the two rubber strips. Repeat the measurement ten times to obtain an average.

On the right side, pull the cable straight up and hang the 300g weight and start releasing the weight. Measure the time interval at which the cube passes through the two rubber strips. Repeat the measurement ten times to obtain an average.

The third step is to select the ellipsoid to hang at the end of the line and put it into the water until it reaches the bottom. In the upper position of the graduating cylinder, the 20 cm long interval is fixed with a rubber strip.

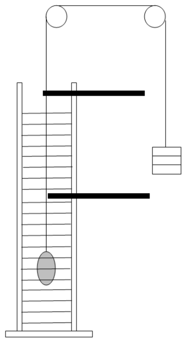

Figure 5. Two rubber bands are marked on the cylinder, and the ellipsoid passes through two rubber bands to record the time

On the right side, straighten the line and hang the 100g weight and start releasing the weight. Measure the time interval at which the ellipsoid passes through the two rubber strips. Repeat the measurement ten times to get an average.

On the right side, pull the cable straight up and hang the 200g weight and start releasing the weight. Measure the time interval at which the ellipsoid passes through the two rubber strips. Repeat the measurement ten times to get an average.

On the right side, pull the cable straight up and hang the 300g weight and start releasing the weight. Measure the time interval at which the ellipsoid passes through the two rubber strips. Repeat the measurement ten times to obtain an average.

3. RESULTS AND ANLYSIS

The measured data canbe filled into Table 1. The upper row of Table 1 represents three different objects, and the left column represents three different masses of weights. The corresponding measurement data are also filled in Table 1 in the middle.

Each row in this table represents a time comparison between different objects of the same mass. Each column represents a different time comparison of the same object under the action of weights of different masses.

Table 1. Temporal statistics table for three shapes

	Cube	Sphere	Ellipsoid
100g	2.12s	1.24s	0.98s
200g	1.02s	0.58s	0.45s
300g	0.35s	0.26s	0.22s

First of all, a weight of 100 grams is used to pull the object up, and when the object reaches the terminal speed, the gravity of the right weight is equal to the pulling force.

The gravity of the left block object and the tensile force of the weight are equal. The object is subject only to buoyancy and fluid resistance, and the buoyancy is equal to the fluid resistance.

$$U = F \tag{3}$$

After reaching the terminal speed, the buoyancy is equal to the fluid resistance. Since the buoyancy of the three ferrous objects is the same, all three are subjected to the same fluid resistance.

When the fluid resistance is the same, the cube takes the longest time to cross the two lines of leather bands, indicating the least speed. The sphere travels through two rubber bands, taking medium time to indicate medium speed. The ellipsoid travels the distance between two rubber bands, and the shortest time it takes indicates the fastest speed.

The final conclusion is that when the same resistance is generated, the speed of the ellipsoid is greater than the speed of the sphere, which is greater than the speed of the cube.

This study uses a weight of 200 grams to pull the object up when it rises. Objects are subjected to upward buoyancy and tension, downward gravity and fluid resistance. When the final uniform speed is reached, the resistance of the fluid is equal to the buoyancy plus the force of 1 N, which is a fixed value.

$$F = U + (T - W) = U + 1 \tag{4}$$

Based on the analysis of time, it is concluded that when the same resistance is generated, the speed of the ellipsoid is greater than the speed of the sphere is greater than the speed of the cube.

Use a weight of 300 grams to pull the object up when it rises. Objects are subjected to upward buoyancy and tension, downward gravity and fluid resistance. When the final uniform velocity is reached, the resistance of the fluid is equal to the buoyancy plus the force of 2 N, which is a fixed value.

$$F = U + (T - W) = U + 2 \tag{5}$$

Based on the analysis of time, it is concluded that when the same resistance is generated, the speed of the ellipsoid is greater than the speed of the sphere, which is greater than the speed of the cube.

The magnitude of the fluid resistance is affected by the speed in addition to the shape. When the shape is the same, the greater the velocity, the greater the resistance of the fluid [6].

Maintaining fluid resistance constant in the experiment is used as a control variable, and the relationship between shape and velocity is obtained, and the speed gradually increases from the cube to the sphere to the ellipsoid.

So based on the conclusions obtained, we can analyze it. When the cube, sphere, and ellipsoid are at the same speed, the fluid resistance of the cube is greater than the fluid resistance of the sphere, which is greater than the fluid resistance of the ellipsoid.

From cubes to spheres to ellipsoids, The shape changes of these three objects are very obvious from the corners to having no edges or corners, and then to the streamlined type, where the surface shape is getting smoother and smoother.

That is to say, when objects with edges and corners and objects without edges and streamlines are in the same environment and the same fluid, moving at the same speed, objects with edges and corners are more resistant than objects without edges and corners are more resistant than those that are streamlined objects.

4. CONCLUSION

This study explores the effect of an object's shape on its fluid resistance. After experimental verification, when objects with edges and corners and objects without edges and streamlined objects are in the same environment and the same fluid, moving at the same speed, objects with edges and corners are subject to greater resistance than objects without edges and corners.

The smoother the surface shape is, the less fluid resistance is received by the streamlined object when moving in the fluid, and the more angular the surface shape, the more non-streamlined the object is subjected to the fluid resistance when moving in the fluid.

So this explains why under normal circumstances, the fuel consumption of SUV cars is always greater than that of ordinary family cars. Because the shape of the SUV car will be closer to the square than the shape of the ordinary family car, the resistance will be greater. When the car starts, overcoming resistance to do more work, more fuel consumption. By the same token, running in tight clothes is always faster than running with bloated clothes, and swimming with your arms closed is faster than when your arms are open[7].

There are still some shortcomings in this experiment. Just choosing the three states of a cube sphere and an ellipsoid is not enough to represent all shapes. It is hoped that future research will investigate more and more complex shapes.

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