Neutral Buoyancy

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Abstract- *Water is one of the important modes of transportation. The goods and the commodities are mainly transported through the water since the cost of transportation is much cheaper than other modes of operation. And in the case of weight, ships can hold much greater weight than through aviation. This is facilitated by the means of buoyancy. Since 71% of our earth is water it becomes a major way in all aspects. Not only through water but also we can move through under the water by utilizing property of buoyancy. The submarines, SCUBA driver and even our brain utilize a type of buoyancy called neutral buoyancy. Even the fish also utilizes this buoyancy in order to swim in water. The fishes have bladders, when bladders are filled with air it rises and releases air so that it can sink. For developing a ROUV the development of neutral buoyancy is necessary. This can be achieved artificially by adding external weight so as to make the weight of the fluid displaced equal to the weight of the body. The main aim of this paper is to study the development of this neutral buoyancy artificially and to find how the neutral buoyancy acts on the body.*

Keywords- Neutral buoyancy, ROUV, bladder, external load

I. INTRODUCTION

Developing neutral buoyancy of a body is a very difficult task. The submarines are achieving neutral buoyancy by filling certain chamber with water. Also the fishes utilize the bladders for rising and sinking, but the submarines are big structures, this technology cannot be used in small robotic fishes, surveillance bots etc. So other technologies should be developed for achieving the neutral buoyancy. The main condition for achieving the neutral buoyancy is to make the weight of the displaced water is equal to the weight of the body. And also the center of gravity should coincide with the center of buoyancy.

The main problem was to:

- Find the weight of the fluid displaced
- How the find weight equal to vacuum
- How the weight is to be added
- The position weight needed to be added

Objectives of this work:

The objective of the work is to study about neutral buoyancy. How neutral buoyancy is achieved and to study how the neutral buoyancy acts on the body. Since it is an important thing needed in under water vehicle. The underwater movement of each vehicle depends on the neutral buoyancy and negative buoyancy. For smooth development of a underwater vehicle the neutral buoyancy should be considered.

II. METHODOLGY

The buoyancy can be divided into three

1. POSITIVE BOUYANCY

In positive buoyant condition the weight of the fluid displaced will be more than the weight of the body. Without any external mass the hollow body will float over water i.e., positive buoyant condition.
e.g.: Foam, empty bottle

Figure 1: Body in positive buoyant condition.

2. NEGATIVE BOUYANCY

In negative buoyant condition the body weight will be more than the weight of the fluid displace. Since the body weight is more the body will sink.
e.g.: stone

Figure 2: Body in negative buoyant condition.

3. NEUTRAL BOUYANCY

When the weight of body is equal to the weight of the fluid displaced the body is said to be in neutral buoyant condition. When a body is neutrally buoyant it will float under water.

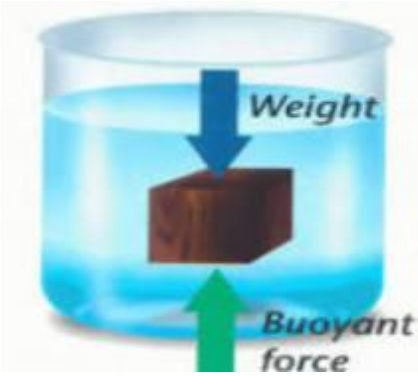

Figure 3: Body in neutral buoyant condition.

On the basis of shape of the body the center of buoyancy and the center of gravity changes. As the shapes become complicated, the calculations for finding the center of buoyancy and the center of gravity will be very difficult. Hence in that case the body is divided and considered into standard shapes and should consider whole Centre of gravity and Centre of buoyancy of the body. By making small changes in its center of buoyancy and center of gravity will do the rest. And based on the size, weight needed to be added to make it in neutral buoyant condition will vary. The experiment can be done using two general shapes such as cylindrical body and circular body and can analyze how the neutral buoyancy can be achieved and how the neutral buoyancy acts on the desired body.

III. EXPERIMENT

The experiment is to achieve the condition of neutral buoyancy in a hollow body and also to find the type of reaction acting on the body. This can be made using trial and error method and also by using mathematical method (STEM design).

In submarine the condition for changing the type of buoyancy is achieved by filling the body with water, since the body of the submarine is huge it is possible. But in the case of a small body it is not an efficient method. For a structure to achieve this mechanism we need motors, control valves and vacuum pumps, etc., which makes the structure bulky and complicated.

The other method to achieve the neutral buoyancy is by attaching load to the body. This method can be done by using trial and error method or by STEM design (mathematical modeling method).

1. For the process of trial and error method first the initial condition of a body should be found, so that the position and amount of weight to be added can be decided. Two different bodies are considered to understand the effect of neutral buoyancy on each and to understand the process easily.

Initially an empty the circular body (ball) and cylindrical body is floating over the water as shown in figure 4 (a) and (b).

(a) (b)

Figure 4: The bodies considered to the experiment.

In trial and error method the process is done by adding and eliminating the weight on the base of the body according to the need. The adding and eliminating of the weight should be done until the body weight is equal to the

weight of the fluid displaced/buoyant force i.e., the body floats under water. It is a lengthy process.

The circular body or the ball have uniform structure hence the centre of gravity and centre of buoyancy of the ball will coincide at the centre. As in case of cylindrical body due to the non-uniform structure the centre of gravity changes with respect to the standard cylindrical body. Hence the process of weight adding should be done by considering the position of the body in water each time. And the upper surface of the body should be parallel with the water surface to get the neutral buoyant condition accurately.

Figure 6: Circular body or ball in neutral buoyant condition by trial and error method.

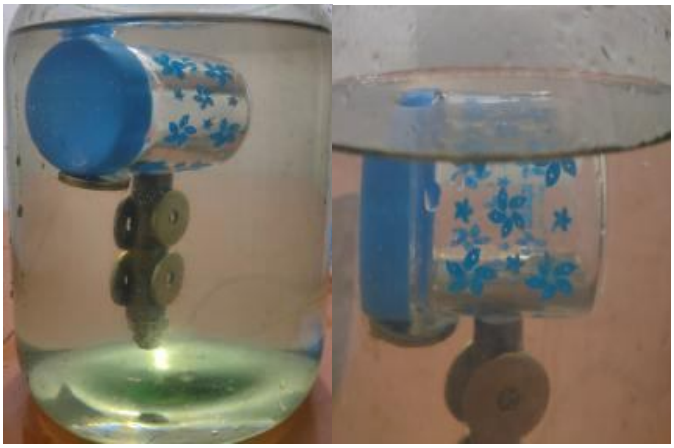

Figure 7: Cylindrical body in neutral buoyant condition by trial and error method.

2. In the STEM design method the mathematical calculations are made in order to calculate the load to make a body in neutral buoyant condition. Basically it has three steps for calculating the weight needed to control the buoyancy. The three steps are:

STEP 1: Finding the volume of the body by measuring the dimensions, since the volume of the body in cm^3 is equal to the weight of the fluid displaced in grams.

STEP 2: weigh the body in air to measure the body weight accurately.

STEP 3: Finding the buoyant force (F_b) by using the equation

F_b = object weight in air – weight of displaced fluid

Where, $\boldsymbol{F_b}$ is the buoyant force. This buoyant force is equal to the weight needed to control the buoyancy. If F_b is a positive number, the buoyancy will be negative and we need to add a positive buoyant material (foam) to make the body neutrally buoyant. If F_b is a negative number, the buoyancy will be positive and we need to add weight to make the body neutrally buoyant.

Hence by using this STEM design method neutral buoyant condition can be achieved easily. Let the same body that is used in trial and error method can be considered in the STEM method too. The calculations are as follows:

1. For circular body or ball

Radius of the ball= 2.86 cm
Volume= $(4/3)\ \pi r^3$
$= (4/3)\ \pi\ (2.86^3)$
$= 98 \approx 100\ cm^3$
Weight in air= 15 g
Buoyant force ($\boldsymbol{F_b}$) = 15-100= -85

The buoyant force is negative hence the weight added to make the body neutrally buoyant is 85 g. By adding 85 gram of weight the body can be brought into a situation as shown in figure easily:

Figure 8: Circular body or ball in neutral buoyant condition by STEM design method.

2. For cylindrical body

Radius of cylindrical body = 2.5 cm
Height of cylindrical body = 6.5 cm
Volume= $\pi r^2 h$
$= \pi (2.5^2)(6.5)$
$= 128 \approx 130\ cm^3$
Weight in air= 20 g
Buoyant force (F_b) = 20-130= -110

From the above values it is clear that by adding a 110 gram of weight the neutral buoyancy can be developed in the cylindrical body. Since the body is not uniformly distributed hence some adjustments should be done. The cylindrical body in neutral buoyant condition will be in the condition as shown in figure:

Figure 9: Cylindrical body in neutral buoyant condition by STEM design method.

There will be slight difference in these values due to the water viscosity, turbidity etc., hence certain adjustments should be done to get a body into neutral buoyant condition.

IV. NEUTRAL BUOYANCY ANALYSIS

The neutral buoyant condition of a body implies the weight of the fluid displaced by the body equal to the weight of the body. It also define that the up thrust force (buoyant force) is equal to the weight of the body as shown in figure:

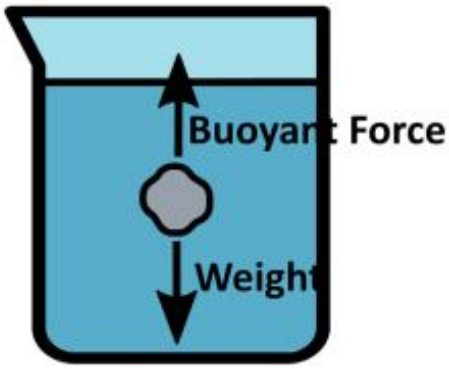

Figure 10: Schematic diagram of buoyant force acting on a body.

The neutral buoyancy helps the body to settle down in a particular location so that the weight of the body and up trust force is equal. It can change its buoyancy by changing the weight of the body. By achieving a body under neutral buoyant condition the body can sink and rise easily. When the body is in neutral buoyant condition the body can sink down by applying very small pressure in the downward direction. And this force is irrespective of the load of the overall body, since the weight of the body gets reduced inside the water. Hence we can use this principle irrespective of the size of the body. When the body needs to be lift or even when a problem is associated with the system, the body can rise to the surface without the aid of any additional force. The up thrust force will be higher if there is a power loss since the force that help the body to sink is removed, and that up thrust force will lift the body to the surface. So as to make the up thrust force (buoyant force) equal to the force due to the weight of the body.

The demonstration of neutral buoyancy analysis can be done using circular body or ball under consideration. Let the body be in neutral buoyant condition as shown in figure:

Figure 12: Circular body or ball in neutral buoyant condition

The stages in which the ball will move when an external force is applied are shown in figure 13. The figure involve certain stages in which the ball will move and finally reach the initial position to attain balanced condition.

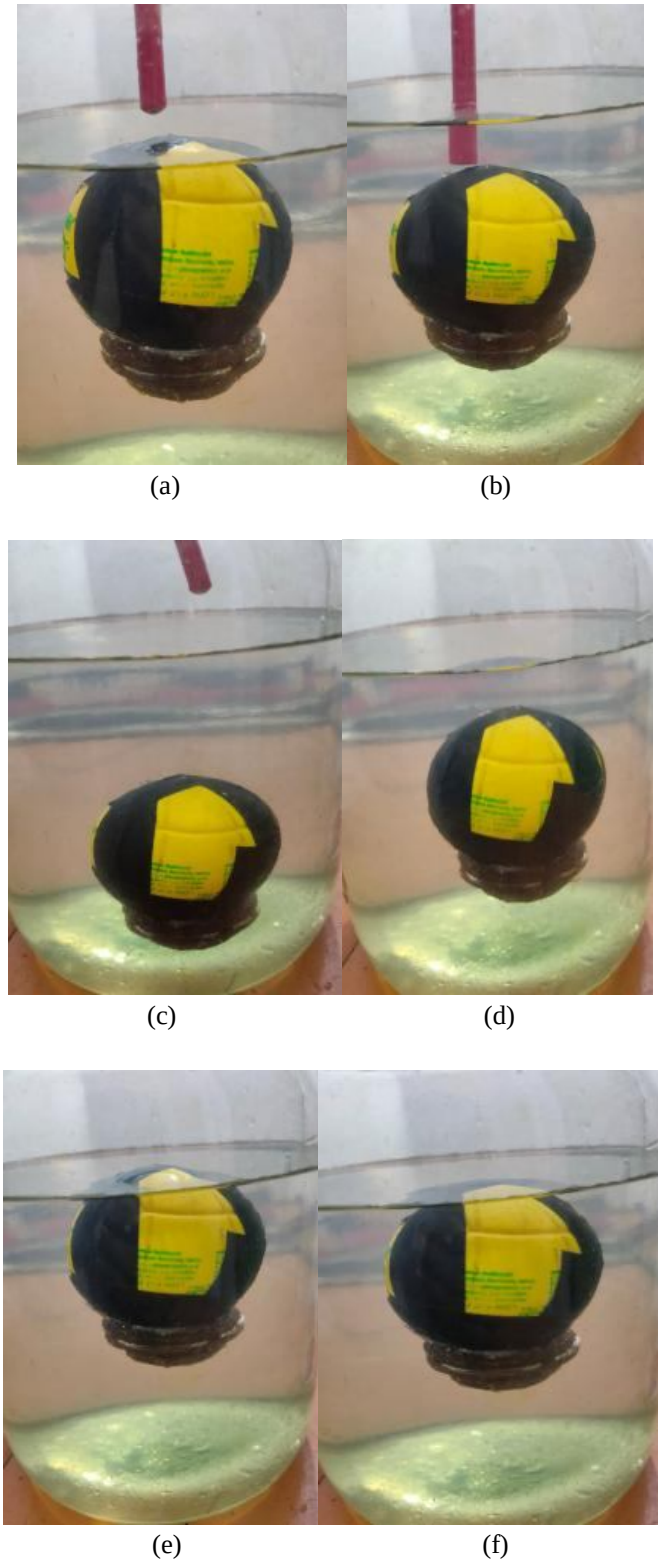

Figure 13: The path of ball in neutral buoyant condition under the application of a force.

Initially at the steady state the weight of the body and the buoyant force was in balanced condition. When a force is applied as shown in figure 13 (b), the force gets added with the weight of the body. Hence the body will sink as shown in figure 13 (c), as the body moves down due to the water resistance the force get reduced and the effect of the force gets vanished. Then the up thrust force (buoyant force) will lift the body to the position where this force will get balanced with the weight of the body as shown in figure 13 (f). It will take time for settling the body to the equilibrium position. There will be small oscillations before reaching the steady state. The complete path of the ball from the point of force application till the point of settling to the equilibrium position is shown in figure 13.

V. FUTURE WORK

The neutral buoyancy plays a major role in underwater vehicles. The neutral buoyancy can be changed to negative buoyant condition by adding an additional force. The underwater vehicles have to play with the neutral buoyancy as well as the negative buoyancy to move through the water. Hence the neutral buoyancy can be utilized in remotely operated underwater vehicle (ROUV/ROV), autonomous underwater vehicle (AUV) etc. These vehicles can be utilized for underwater surveillance, dead body detection, under water pollution monitoring, survey of underwater life, underwater pipeline monitoring, etc. The underwater tourism is also a good future scope of underwater vehicle. Hence the neutral buoyancy can play a major role in all these spaces.

VI. CONCLUSION

This paper describes the use of neutral buoyancy while designing an underwater vehicle. The underwater vehicle can move through the water conveniently by utilizing the neutral buoyancy and negative buoyancy. The calculations needed for finding the load to adjust a body to be in neutral buoyant conditions is explained here. It describes the position of the body in water and also the relation between the weight of the body, volume of fluid displaced and also the buoyant force (up thrust force) acting on the body. The neutral buoyancy analysis explains the mechanism and path in which a body in neutral buoyant condition regains its position of stability after the application of force for sinking the body under water.

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