Design and model preparation of ROV to define the principle of stability of a submerged body

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Design and model preparation of ROV to define the principle of stability of a submerged body

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Abstract

This paper is the first step in the world of Remotely Operated Vehicle (ROV) - an underwater robot. At a first glance, you might think that it is the most complicated robot made by the humans as it has to work in deep water. They are equipped with numerous tools like lights, cameras, sensors, manipulators, etc to perform various sub sea work. But they work on a very basic and simple principle of, "Stability of the submerged body" which enables it (I) to be stable in the water currents i.e. stiff in pitch and roll (II) to perform any specific work anywhere in the water column. In this paper we will describe how the stability for a submerged body is achieved by a large separation between centre of gravity of the body and centre of buoyancy with the help of model.

Key words *– ROV, Stability of a submerged body, Buoyancy*

1. Introduction

An ROV – remotely operated vehicle is, a crewless submersible vehicle that is tethered to a vessel on the surface by a cable, called 'umbilical cable'. It is a group of cables that carry electric power, video and data signal back and forth between the operator and the vehicle. Most ROVs are equipped with at least, a video camera and lights. Additional equipment is commonly added to enhance the vehicles capabilities. [3]

An ROV is used for many underwater applications like underwater exploration and documentation, recoveries, inspection, search and rescue, trenching, cable and pipe laying and much more.

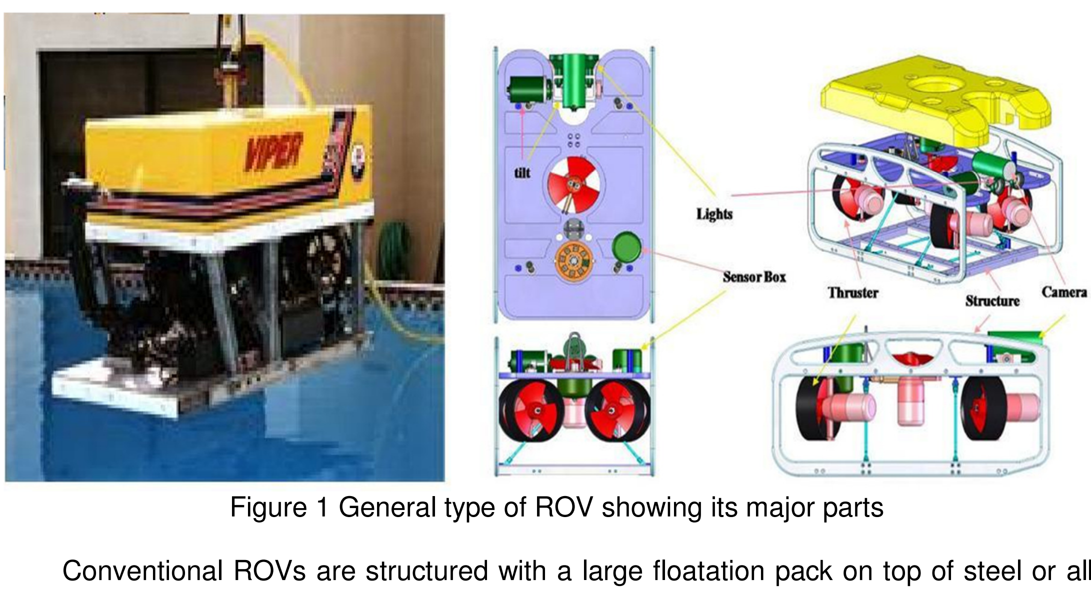

Figure 1 General type of ROV showing its major parts

Conventional ROVs are structured with a large floatation pack on top of steel or alloy chassis, to provide the necessary buoyancy. Syntactic form is often used for the floatation. A tool sled may be fitted at the bottom of the system and can accommodate a variety of sensor. By placing the light components on the top and the heavy component on the bottom, the overall system has a large separation between the centre of buoyancy and the centre of gravity; this provides stability and the stiffness to do work underwater. Electric cables may be run inside oil-filled tubing to protect them from corrosion in seawater. Thrusters are usually located in all three axes to overcome the drag force imparted by the water in order to achieve the motion in the desired direction i.e. Surge, Sway and Heave. Cameras, lights and manipulators are on the front of the ROV. [3]

2. Concept of Model Design

2.1 Centre of buoyancy

When a body immersed in a fluid, an upward force known as 'force of buoyancy' is exerted by the fluid on the body. This upward force is equal to the weight of the fluid displaced by the body and the point at which force of buoyancy acts is known as centre of buoyancy. [1]

2.2 Principal of stability of a submerged body

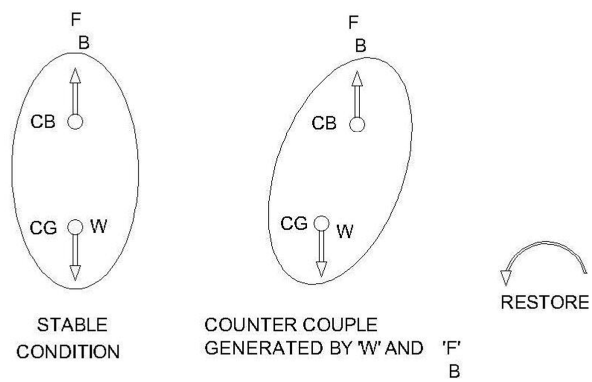

Figure 2.2 Principle of stability of a submerged body [1]

The centre of buoyancy is 'CB' is the point at which the buoyancy forces 'F_B' will act. This occurs at the centroid of the displaced volume and remains in the same place as the body fully submerges. The body weight 'W' acts at the centre of gravity 'CG' which does not change its position, unless mass is shifted within the body. In any submerged body, hydrostatic stability exists when 'CG' is below the 'CB' as shown in figure. If we try to tilt the body, 'F_B' and 'W' produce a counter couple to restore the body. [1]

3. Methodology

The purpose of model preparation is to see that how the general ROVs are designed to be stable in heavy water current and positively buoyant by applying the simple but effective principle of stability of a submerged body.

3.1. Design of Model

3.1.1. Shape of body of the model

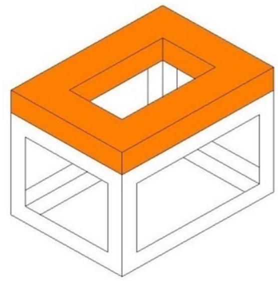

Figure 3.1.1 Shape of ROV model

There are numerous options for ROV body shape. Here the body or chassis of the model is made as rectangle frame of M.S angle. This simple option is chosen for the convenience in manual calculation of centre of gravity of the model.

3.1.2. Material of the body of the model

The best two materials for the model were aluminium and PVC as we should not forget the corrosion as model has to sink into the water. Aluminium does not rust and can be fabricated into any shape. However it is very expansive and difficult to weld. PVC does not rust, inexpensive and easy to work but the shape is more restricted than aluminium. Moreover the dimensions of the model are so small that it is difficult to get considerable separation between CG & centre of buoyancy in PVC material.

Finally M.S. angle of 25x25x5 is used to frame the chassis of the model. As M.S gets easily rusted, red oxide and paint is applied on the chassis.

3.1.3. Types of buoyancy control

While designing ROV it is usual to keep the vehicle weight within practical limit. Buoyancy helps to establish the desired specific gravity and make vehicle positively buoyant which ensure that they will return to the surface if power failure occurs.

There are two types of buoyancy control or ballast: Fixed and Variable ballast.

In fixed ballast, a large floatation pack made of syntactic foam as shown in figure 3.1.1 is placed on the top of the vehicle to gain positive buoyancy. The ‘syntactic foam’ has preformed hollow sphere as a main constitute made of glass, ceramic or polymer. The binder is generally polymer. [4] Where as variable ballast permits the ROV to be heavy when diving in high current situation. In variable ballast the water is pumped in and out of the tank situated on the sides or bottom of the vehicle.

In our model fixed ballast is used for buoyancy effect. The floatation pack is retrieved from an old life jacket used in ship. The shape of the floatation pack is kept hollow rectangle because the hollow space is the location of propeller to produce thrust for downward motion of ROV.

3.2. Calculation

3.2.1. Calculation of Centre of Gravity of the model

Calculation of centre of gravity is based on an assumption that the weight of the floatation pack is so less compare to the weight of the chassis and hence it is not taken in the calculation of the centre of gravity.

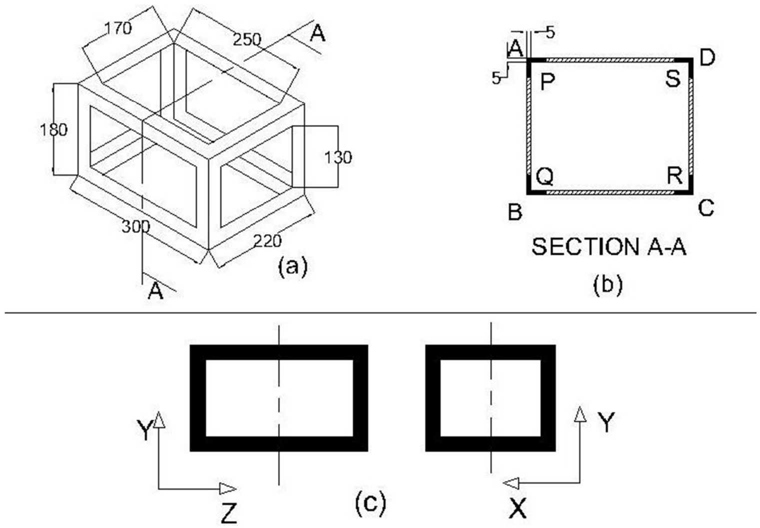

Figure 3.2.1 (a) Dimensions of ROV chassis; (b) Sectional View of chassis; (c) Chassis is symmetrical about Z axis and Y axis

As shown in figure 3.2.1 the body is symmetrical about Z axis and X axis i.e. in width & length, its CG will lie on the Y axis. The height of CG from the base is obtained by following equation:

[2]

$$\boxed{\overline{y} = \frac{V1\,y1 - V2\,y2}{V1 - V2}}$$

V1 = Volume of ABCD = 180 x 300 x 220
= $11.88 \times 10^6\ mm^3$
y1 = Height of CG for volume ABCD from the base
= 90 mm
V2 = Volume of PQRS = 170 x 290 x 210
= $10.35 \times 10^6\ mm^3$
y2 = Height of CG for volume PQRS from the base
= 90 mm
By putting all these value in equation A, we get

$$\boxed{\overline{y}_{CG} = 90\ mm}$$

3.2.2. Calculation of Centre of Buoyancy of model

An assumption is made in this calculation is the volume displaced by chassis is very less compare to volume displaced by the floatation pack and hence only volume displaced by floatation pack is considered for calculation of centre of buoyancy.

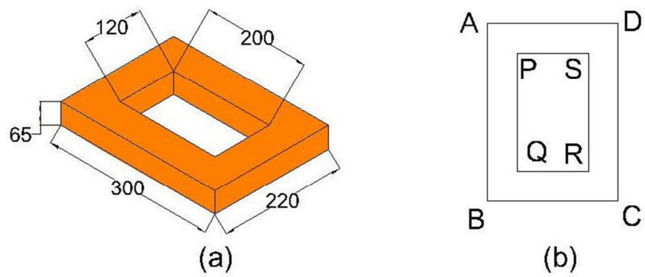

Figure 3.2.2 (a) Dimensions of Floatation Pack (b) Top of view of Floatation Pack

As the floatation pack is also symmetrical about Z and X axis. Its CB will lie on the Y axis. The height of CB from the base is also obtained by equation A as mentioned above.

$$\boxed{\bar{y} = \frac{V1\,y1 - V2\,y2}{V1 - V2}} \quad [2]$$

V1 = Volume of ABCD = 180 x 300 x 65
= 2.16 x 10^6 mm^3
y1 = Height of CB for volume ABCD from the base
= 200 mm
V2 = Volume of PQRS = 120 x 200 x 65
= 0.96 x 10^6 mm^3
y2 = Height of CB for volume PQRS from the base
= 212.5 mm
By putting all these value in equation A, we get

$$\boxed{\bar{y}_{CB} = 212.5 \text{ mm}}$$

3.2.3. Assessment of stability of the model

By calculation of CG and CB above, we can conclude that the difference between the height of CG and CB is 122.5 mm. Now let us assess the stability of the model by calculating the moment required to change the pitch angle by the following equation:

M = (W) BG sin θ
Where, W = weight of the model = 4.3 kg
BG = distance between CG & CB = 122.5 mm = 0.12 m
θ = pitch angle = 10°

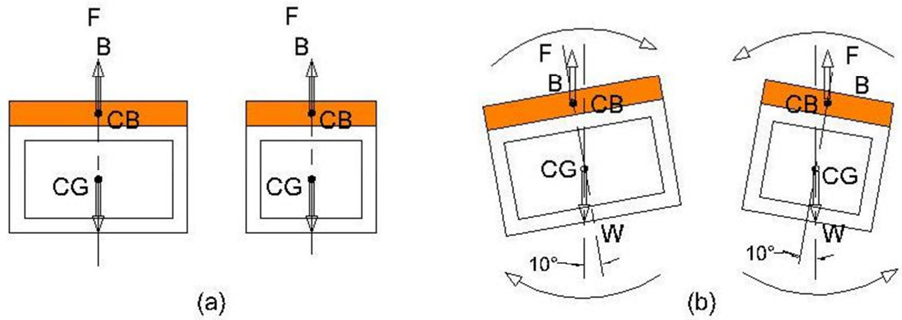

Figure 3.2.3 Assessment of the stability of the model in pitch and roll
(a) Equilibrium condition (b) model is pitching & rolling by 10°

$\therefore$ M = (W) BG sin θ

M = 4.3 x 9.81 x 0.12 x sin 10

$\boxed{\text{M = 1 N.m}}$

4. Result and Discussion

Observations are made in swimming pool water which confirms the results of calculation that the height of centre of buoyancy is above the centre of gravity of the model which results in (1) high stability when it sinks in the pool water i.e. stiff in pitch and roll because 1 N.m moment is required to change its pitch angle which is a considerable amount in steady pool water. (2) Despite of 4.3 kg weight it floats on the surface of pool water i.e. positive buoyancy.

And now, if more tools like thrusters, manipulators etc mounted on the chassis of the model CG will lowers more toward the bottom which result increased separation of CG and CB, and ultimately in stability of model.

5. Conclusion

Of course ROV is a complicated machine. Lots of intricacy is there in the design of prototype for offshore purpose. But by following the principle of stability of a submerged body we can get rid on most of the problem like vehicle weight, vehicle capacity, power consumption, location of instrument, maximum depth to dive etc. So it is a crucial parameter that must be satisfied in the design of ROV.

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