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STABILITY STUDY OF MIROV: FABRICATED REMOTELY OPERATED UNDERWATER VEHICLE

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ABSTRACT

Remotely Operated Underwater Vehicles (ROVs) is dominant to underwater robotics which has very high demand in marine exploration and discovery. This study discussed the up thrust force or buoyancy effects for the fabricated ROV which named as MIMET-ROVTek ROVorknown as MIROV. The study is conducted on the stability in terms of centre of mass, centre of gravity, buoyancy and centroid of the MIROV body. In addition, this study also describe the capability of ROV body works at the actual sites in Pulau Tuba, Langkawi up to depth of 15 meters and 2 knots current with a good buoyancy. The material used for ROV ballastis Polyvinyl Chloride (PVC). The centre of gravity, centre of mass, centroid and buoyancy is defined using theoretical mathematical calculation by taking all related physical parameters. Moreover, this MIROV body is modelled from scratch. The final model design were used the commercial computer aided software; SolidWork®. The proven calculated buoyancy were measured to shows the MIROV body achieved the neutral buoyancy once it fully or partially submerged into the water. This ROV also have capability to dive smoothly up to expected depths ~15 meters with associated flotation element and controlled by the vertical thruster assembled to the ROV body.

Keywords: remotely operated underwater vehicle, MIROV, buoyancy, centroid and centre of gravity, solidwork.

INTRODUCTION

A Remotely Operated Underwater Vehicle (ROV) is define as an underwater machine which is extensively practiced in lot of underwater exploration such as industrial, marine study or offshore purpose [1, 2, and 3]. ROVs are controlled and operated vehicles via a tether along with human supervision. Underwater vehicles need to consider more movement possibilities, especially vertical movement whereas this movement are label as the vehicle's buoyancy. Buoyancy is the up thrust force utilized by fluid on a form that is immersed. Underwater vehicles will submerge or float depends upon the net effect of the weight of the object and the buoyant force generated by the object. The stability characteristics of the ROV which influence the balancing level during manoeuvring with associated of some factors in underwater such as the current, wave and pressure [4].

Human explore to find out the ways to make their work easier especially in underwater sectors since many years ago. Hence, several inventions and methods are created to reduce the human's workload. Nowadays, underwater job is one of the demanding sectors which are expanding broadly in either marine or offshore industries [5, 6, and 7]. So, an underwater vehicle was invented to reduce the risks to human life because the vehicle can sink to greater depth and capable to stay there for longer time due to any kind of operations in underwater. The point needs to concerns is the buoyancy effects to avoid the sinking problem happen or misleading ROV manoeuvring.

The main purpose of ROV is to replace the peoples who are working in underwater industry and also the finest choice over human divers [8]. In fact, there are several obstacles in developing underwater vehicles which is the target of depth, buoyancy control and the stability in underwater [9, 10]. All objects in water, including underwater vehicles, will find their natural disposition in water due to gravity acting upon their mass and relative buoyancy. This position however may not be level, which in the case of an underwater vehicle makes positioning and imaging problematic. This issue is usually minimized by careful trimming like locating of ballast or buoyancy elements on the vehicle. If the load increased to the vehicle, it effects the ROV's buoyancy which causes unstable operation where the motion level increases. The associated load which is the crawler, grip stick, cable, subsea port, camera and other elements in ROV have different weightage yet the location shall be considered due to the stability purpose.

MIROV DESIGN AND FABRICATION

The MIROV model was designed using SolidWork® software and the details is shown in Figure-1. Each component are measured separately their centre of mass, centre of gravity and the centroid to set the geometry coincide. Using the mathematical formula as in Equation. (1) and Equation. (2), the data were used as basic data to start the fabrication process. In the Equation. (1), by considered the rigid body as infinite number of particles, the centre of gravity and centre of mass were calculated for each coordinate x, y and z. The formula is still using the same concept, which is for mass just simply replacing the *W* for gravity to *m* for mass. The centroid of

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the MIROV was measured by using the Equation. (2) to set the geometry centre or coordinate (x,y,z) for MIROV model. This centroid needs to measure carefully since MIROV consist of the components and parts which are not symmetrical. Some of the parts only assemble at one side of the body and some parts of the body are empty. To ensure the centroid measured is correct, each component is measured follow the flow chart in Figure-1.

$$\bar{x} = \frac{\int xdW}{\int dW};\ \bar{y} = \frac{\int ydW}{\int dW};\ \bar{z} = \frac{\int zdW}{\int zW} \tag{1}$$

$$\bar{x} = \frac{\int xdA}{A};\ \bar{y} = \frac{\int ydA}{A};\ \bar{z} = \frac{\int zdA}{A} \tag{2}$$

The components measured then assembled to the main frame chassis of the ROV as shown in Figure-2. The size of the fabricated chassis is 54 cm, height of 45 cm and width of 50 cm. One of the objective in this research is to build ROV in lower cost, therefore the material used for this chassis is iron steel rod and coated with marine grade paint.

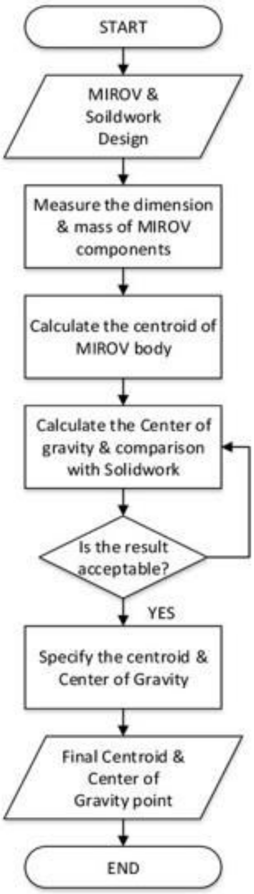

Figure-1. Design and fabrication flow chart.

Figure-2. MIROV frame chassis.

Since, the chassis is quite heavy and including thruster associated with special casing is heavy, this ROV needs special ballast on top of the main chassis, to ensure the stability in the water. The square shape ballast is made from PVC with special sealed are assembled on the top of the chassis as shown in Figure-3.

Figure-3. Square shape ballast assembled on the top of MIROV.

The top cover is assemble on the top of ROV to close the assemble parts. This top cover is design with many small hole to avoid the bubble trap during operation and it's made from fibre glass as shown in Figure-4. The size for this cover is 60 cm, height of 10 cm and width of 50 cm.

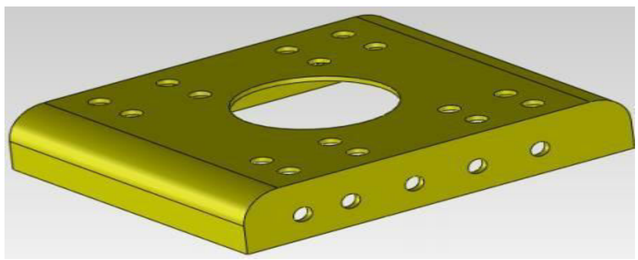

Figure-4. Top cover made from fibre glass for MIROV.

Associated with this MIROV are three thruster motors. One thruster for forward and reversed mode, one thruster for left and right mode and one thruster for upward and downwards mode. All thruster are assembled to suit with the motor of12VDC and 220VAC compatible. Figure-5 shows the thruster was associated to this model

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are capsulated in the aluminium casing. This thruster motor was designed with the cylindrical shaped of length 16 cm and the diameter of 10 cm. The thruster blade is designed with the length of each side of 7 cm and 35 degrees of angle flex attached with 7cm length of shaft. The length of the casing is 26 cm with 20 cm diameter.

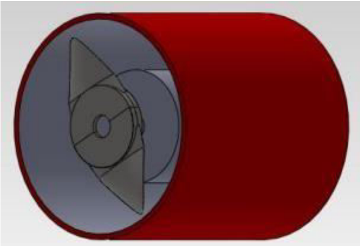

Figure-5. Thruster with associated motor together with casing.

FINAL DESIGN OF MIROV AFTER ASSEMBLY PROCESS

Figure-6 shows the complete design of MIROV in isometric view. In the design it's clearly can see the top cover, frame chassis associates with the capsulated thruster motors, ballast tanks, lamp and video camera. Figure-7 shows the real prototype of MIROV, which already assembled together with the umbilical cable and ready for site test.

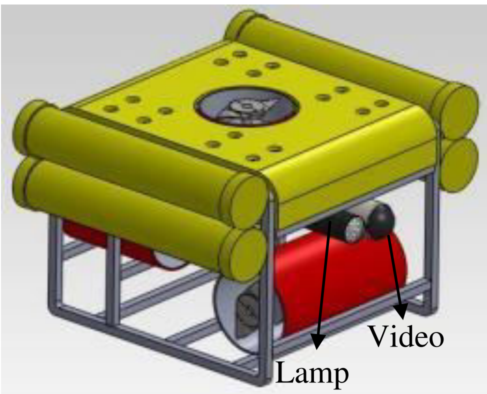

Figure-6. MIROV SolidWork® design.

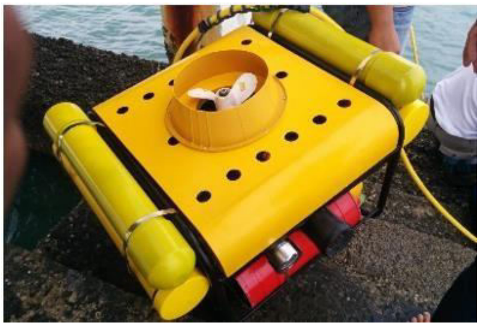

Figure-7. The fabricated MIROV prototype.

BUOYANCY ELEMENT AND CENTROID OF MIROV

Syntactic foam is the best choice to use as buoyancy module for deep water applications. This foam is merely an air or micro balloon assembly coated inside a resin body. The density and durability of the foam is the best for the deeper depths due to the amount of trapped air within the resin structure. This material suitable can use for dive up to 5000 metre. However, this material is absolutely expensive and normallyuse and associates with bigger bottomless-diving ROV systems. However MIROV consider small and surface diving vehicle, the capability of diving just p to 30 metres. So, for this model the buoyancy module or ballast fabricated to associates with this model just using inexpensive material polyvinyl chloride (PVC) tubing. The PVC tubing are fabricated as ballasts and sealed with the special glue to ensure not leaking during diving test up to 15 meters for this study. Table-1 shows the capability of Polyvinyl Chloride (PVC) tubing and Syntactic Foam Block for use as buoyancy module for ROV.

Figure-8 shows the MIROV design, the blue colour dot/ indication at the picture shows the centroid of the fabricated body. This position or coordinate is calculated using the mathematical formulas as in Equation. 2. The coordinate (x, y, z) is shown in Table-2. The centre of gravity (COG) of MIROV is the point from which the weight of the body acts and where the entire body mass is assumed to be focused. The centre of gravity for MIROV was calculated by using an appropriate mathematical formula in Equation. 1.However, through the design stage using the Solid Works ® software, the centre of the gravity are calculated automatically using the software. Form the Table-3, its shows the different between autos calculated by software and manually calculated using the mathematical formula. The different percentage of this calculated values are shows in the Table-3. While Figure-9 shows the autos calculated position of COG at MIROV using SolidWorks®, it indicates in red square box.

Table-1. Capability of syntactic foam and PVC tubing as buoyancy module for ROV.

Features	Type of Buoyancy module	
	PVC tubing	**Syntactic foam block**
Application	Shallow water	Deep water
Resistance	High	Very high
Depth Rating	5 m – 30 m	Up to 5000 m
Strength	Moderately high	High Compressive
Cost	Inexpensive	Very Expensive

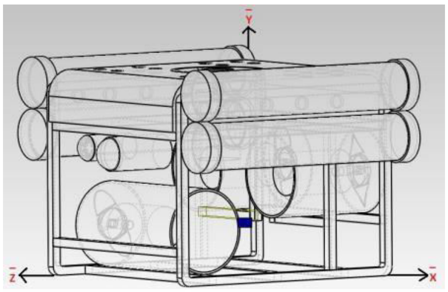

Figure-8. The COG using mathematical formula for MIROV indicates in blue colour dot.

Table-2. Centroid of MIROV prototype.

Coordinate	Dimension
$\bar{X}$	200. 42 mm (20cm)
$\bar{Y}$	94.47 mm (9.4cm)
$\bar{Z}$	222.52 mm (22.2cm)

Table-3. Centre of gravity of the MIROV body.

Coordinate by mathematical formula	Coordinate autos calculate by SolidWork®	Difference (%)
$\bar{X} = 26.22\ cm$	$\bar{X} = 25.59cm$	2.4
$\bar{Y} = 23.89\ cm$	$\bar{Y} = 24.8cm$	3.7
$\bar{Z} = 29.42\ cm$	$\bar{Z} = 31.37cm$	6.4

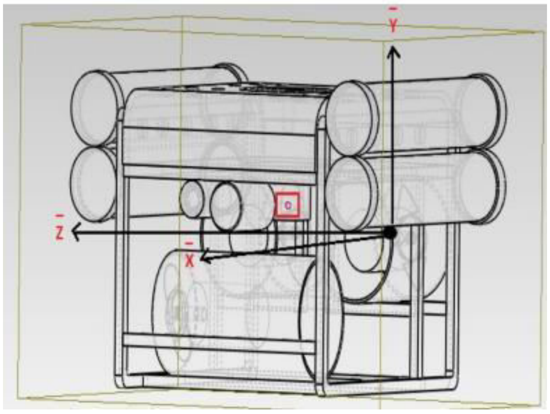

Figure-9. The COG using SolidWorks® for MIROV indicates in red square colour.

CONCLUSIONS

This study successfully fabricated the ROV known MIROV. The buoyancy module has studied using mathematical formula and autos calculated by SolidWorks® software. The different of the coordinate systems are show by percentage different. For real prototype of MIROV, the centroid during the field test need to adjust a bit due to actual obstacles in the sea. This adjustable and fitting used the weighing cube need to be done to ensure the steady state during submerging and floating the ROV. However, this calculation of COG either by mathematical formula and autos calculated by SolidWorks® software helping a lot in term to ensure the stability of the system during sea trial. It's also give a good response in stable manoeuvring the position of MIROV in underwater.

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