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Conceptual Design of Remotely Operated Underwater Vehicle

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Abstract

Research in the underwater of the sea is a very interesting field. However, due to the difficulties and dangerous condition, human activities under the sea water are limited. Thus, a dedicated tool or device such as a Remotely Operated Underwater Vehicle (ROV) is required in helping human to perform these research activities. This paper presents design and construction of ROV, which differ depending on its applications. Some of the ROV's classifications include micro, mini, general, light work class, heavy work class and burial ROV. Therefore, it is essential to identify the design concept and the classification of a new proposed ROV for underwater application. Several main sub-modules need to be considered during the development of ROV, which include structured/ frame and fitting, control unit/CPU, monitoring system (camera), buoyancy and propulsion system. Each module needs to be properly designed so that the ROV can work as planned. This paper presents a concept design of the ROV including its specifications, before the main development and fabrication work can be carried out. The proposed ROV is designed so that it can operate with low resistance. In order to visualize this concept, 3D CAD models had been generated. An external flow analysis of the ROV had also been performed.

Keywords: *ROV:* Underwater; External Flow; Underwater Robotics

1. INTRODUCTION

In the last four decades, underwater robotic vehicles (URVs) have seen improvement and tremendous growth in use. Many are used for underwater inspection of subsea cables, oil and gas installations, structures, pipelines and also in seafloor observation (Antonelli, 2014). They are essential at depths where the use of human divers is impractical. Due to durability and capability, URV application is more suitable to be used in these conditions.

Traditionally, URVs can be broadly classified into remotely operated vehicle (ROV) and autonomous underwater vehicle (AUV), depending on their designed tasks and modes of operations. AUVs are robots which have no remote control mechanism. They are programmed to perform certain tasks independently of direct human control.

ROVs are remotely controlled vehicles, which can be divided into five categories known as Class 1 (Pure Observations Vehicle), Class 2 (Observation Vehicle with Payload Capability), Class 3 (Work Class Vehicle), Class 4 (Towed or bottom crawled vehicle) and Class 5 (specialised prototype or development vehicles)(Christ & Wernli Sr, 2013). A ROV typically comprises of several main components such as the structure of the ROV itself, a launch and recovery system (LARS), a power supply pack, operation console, various monitors and the human pilot. An ROV is controlled by sending signals down a tethering cable which at the same time is also used to supply power to the ROV.

This paper highlights the conceptual design of a ROV planned to be used for underwater application. The first part of the paper discusses the design objectives of the ROV, where all the necessary considerations in developing the ROV are explained. The second section describes the conceptual design of the ROV itself, where a CAD (computer aided design) drawing for the ROV is presented. The third section in this paper explains the flow analysis on the proposed design of the ROV, where a computational fluid dynamics (CFD) analysis is used to see the appropriateness of the design and to improve the water flow around the ROV for water drag improvement.

2. ROV DESIGN

2.1 Design Consideration

It is important to consider every aspect of ROV elements to avoid over-design of the vehicle. A proper design consideration would be able to produce a cost effective operation of ROV. The main element that needs to be emphasized in designing a ROV is the propulsion system (Christ & Wernli Sr, 2013; Ramaswamy, 2002). The propulsion system needs to have a high thrust-to-physical size/drag and power input ratios. Every component of the propulsion system needs to be selected carefully as the more thrusters power required, the heavier the propulsion system on the ROV will be. All parts of the ROV system will grow exponentially larger with the power requirement continuing to increase.

Another aspect is the location and number of thrusters installed on the ROV as they will determine the characteristics of the vehicle in water. Generally, three thrusters ROV will have fore/aft and yaw motion; four thrusters ROV will have additional lateral thrust; five thrusters ROV will have thrust in any horizontal direction. Placing the thrusters off the longitudinal axis of the vehicle will allow a better turning moment. Figure 1 shows the effect of numbers and thrusters location on an ROV.

Another important element that needs to be considered in designing an ROV is the selection of tethering management system (TMS). The selected TMS needs to be able to provide sufficient power in operating the ROV from its electrical source as well as transmitting video and data to the surface (Christ & Wernli Sr, 2013). Another aspect in selecting TMS is the cable used should be strong enough for the purpose of recovering the ROV in case of emergency.

The types and numbers of sensor to be installed on an ROV also need to be selected carefully. These may contribute to the additional cost and weight in the development of the ROV. Typical sensors installed on an ROV are sonar based sensors, temperature sensors, altitude sensors and GPS.

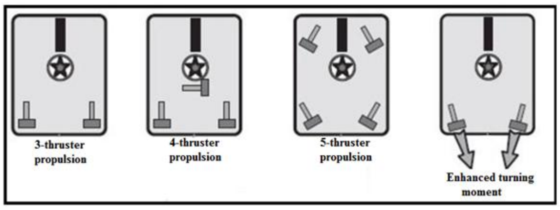

Figure 1. Thrusters position (Christ & Wernli Sr, 2013).

Material selection during ROV construction also affects the strength integrity and buoyancy of an ROV. Thus, the construction materials need to be selected properly. The selection of material depends on the desired operating depth of the ROV. Typical materials used in assisting the buoyancy of the ROV are glass, acrylics, glass reinforced plastics, synthetics foam, synthetics rubbers, titanium, steel and aluminium. Table 1 shows the design objective for the conceptual design of the ROV.

Table1. Design Objective

Description	Constraint
Camera	HD camera for live video (colour)
Duration of ROV tasking	2 hours minimum
Hull	Non pressurised
Lighting	LED
Operational depth	50 metres
Onboard Power	Step down 24V DC
Pay loads	As required i.e sonar, temperature, altitude, GPS etc.
Power supply	Bench top
Pilot control	Joystick
Propulsion	3 x thrusters
Speed (dived)	3 Knots (1.5 m/s) maximum
Tether/umbilical	100 metres
Weight	Maximum 8kg

2.2 Design Concept

This section presents the design concept of the ROV, with emphasis on external flow analysis. There have been various designs of ROV developed by previous researchers (Dama & Tosunoglu, 2011; Joordens, 2009; Rust, 2010). They can be categorised into two basic types. The first type has a box shape, and the second one looks more stylish, more aerodynamic and has sleeker designs. These types of ROV are designed based on intended application or missions. The first type, 'Work Class' (WC) ROV, is designed more for working ability and less for the speed (Figure 2).

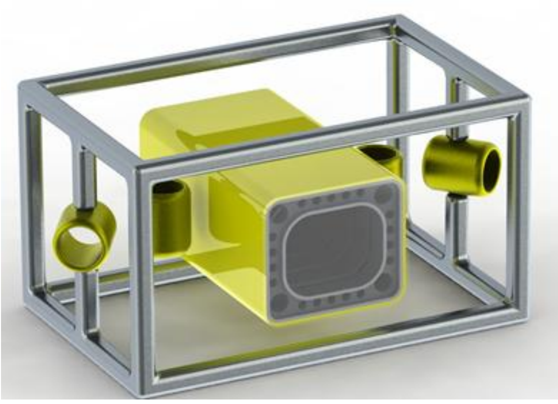

Figure 2. Concept design of ROV based on 'Work Class' type

This type is usually designed as a stable platform for its special tools and normally has slower moving speed. Some smaller WC ROVs have higher speeds in water over 4.7 km/hr or about 1.2 m/s and have high voltage power and large thrusters.

The stylishly designed ROVs usually have fewer tools onboard. They mostly have one video camera for monitoring or survey applications. Figure 3 shows an example of observation ROV known as the Eye Ball. It has lower stability but higher manoeuvrability, and depends on the power and thrusters with slightly higher speed.

Figure 3. ROV based on 'Eye Ball' type (Leverington, 2012)

2.3 Design Specification

A URV must be waterproof, robust, reliable, easy to operate and able to move in 3 dimension. For During the design process, performance specifications of the URV need to be defined. These specifications are often split up into categories, which are appropriate to the type of robot to be designed. With definition to performance, an underwater ROV (Remotely Operated Vehicle) normally has the features of structural support, mobility, actions, distance, effectiveness and interactions.

This paper proposes an ROV conceptual design that can operate up to 50 meters depth. The size is limited to 500mm x 500mm x 500mm and has ability to move up and down, as well as having 360 degree rotation. The ROV should be able to operate at slow speed and go up to 1.5 m/s. It should be able to perform monitoring and observation mission using video camera. Special tools including sensors, sonar, sampling device are to be installed in the ROV. Thus, the type of ROV suitable for this mission is a combination between WorkClass and EyeBall types.

Figure 4 shows the proposed ROV design**Error! Reference source not found.**. It has 3 thrusters to provide fore and aft movement, as well as yaw motion. The proposed ROV has the capability of monitoring the underwater environment at the depth of 50 metres. It is equipped with a video camera with the lighting source from light emitting diodes. The upper part of the concept ROV acts as a hull which provides the buoyancy to the ROV. The lower compartment of the ROV is comprised of all the necessary hardware such as microcontrollers and power supply.

Figure 4. Concept design of ROV based on combination of 'WorkClass and 'EyeBall' types

3.FLOW ANALYSIS

Basically, an ROV is propelled by thrusters, which consist of motors and propellers. Thrusters take the electrical energy from the battery and transform it into mechanical energy or motion. More energy is consumed to move ROV at higher speed. In order to reduce the energy used to propel the ROV, the main body has to be aerodynamically designed. Aerodynamic body design can reduce the flow resistance during ROV operation. In this study, an external flow analysis of different designs had been performed to determine the flow resistance of the body design.

Two initial designs as depicted in Figure 5 had been analysed to determine the total force resistance. The designs were modelled using 3D CAD SolidWork software. Design A has larger compartment volumes on top and at both sides compared to Design B. Design B has a more stylish shape on top and in the front side. External flow analysis was performed to both designs, where velocities as well as relative pressure contour had been plotted. The analysis was carried out using computational fluid dynamic (CFD) code of Flow Simulation module in SolidWork platform.

Figure 5. Design A (left) and Design B (right).

Both ROV designs had been analysed to determine the effect of the design on the external flow. The ROVs were run in water with density of 1000 kg/m^3 at 1.2 m/s and in depth of 50m. The flow stream was at –Y axis. Figure 6 shows the velocity contour in the centre section of both designs. The figure shows that larger area of lower velocity was generated at downstream of Design A compared to Design B. Meanwhile, relative pressure in similar section was found to be lower at Design B (Figure 7). This was due to the design of the body shape that promoted the pressure influence.

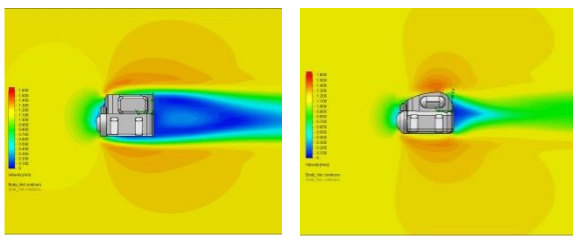

Figure 6. Velocity contour at the centre of ROV (left: Design A) (right: Design B)

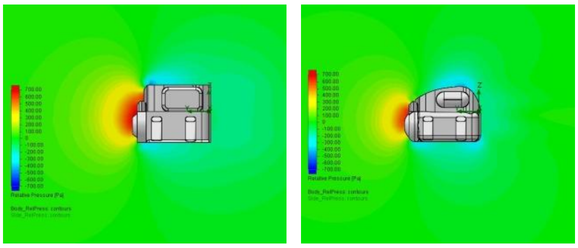

Figure 7. Relative Pressure contour at the centre of ROV (left: Design A) (right: Design B)

Figure 8 shows that the downstream velocity at the side of ROV of Design A was lower than Design B. The larger volume of upper compartment promoted higher flow resistant compared to Design B. This is clearly shown in Figure 9, where the relative pressure was found to be higher at upstream of Design A compared to Design B. Based on the CFD simulation result, Design B produced less flow resistance compared to Design A. The simulated total Force at Y-axis for Design A and B were 86.8N and 66.3N. Therefore, by changing the design of main body and reshaping the upper compartment of the ROV, 20.5N of resistance force could be reduced. Thus, this reduction promoted lower energy consumption to move the ROV.

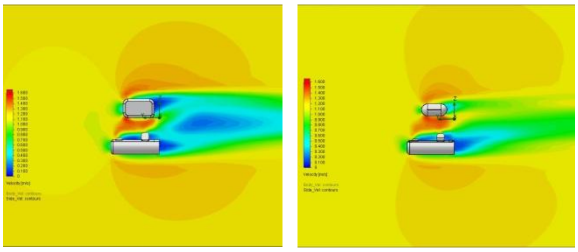

Figure 8. Velocity contour at the side of ROV (left: Design A) (right: Design B)

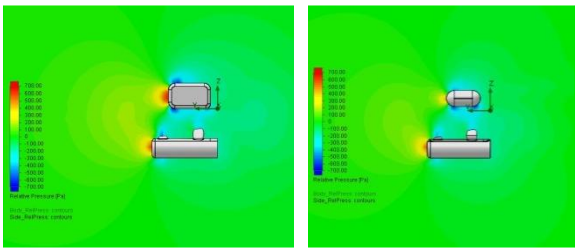

Figure 9. Relative Pressure contour at the side of ROV (left: Design A) (right: Design B)

4. CONCLUSIONS

A conceptual design for a monitoring ROV has been presented in this paper. The design emphasizes on some vital criteria, such as function (to be determined later depending on which design class the ROV falls in), types of materials, instrumentations, number of thrusters, power supply and tethering management system. The external flow analysis conducted on the proposed ROV design indicated that Design B has the ability to reduce flow resistance, thus lowering the energy required to move the ROV.

6. ACKNOWLEDGEMENT

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