

## DESIGN AND DEVELOPMENT OF UNDERWATER ROBOT FOR CLEANING PROCESS

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**ABSTRACT:** This paper shows the conception and growth of an underwater robot for cleaning operation that can help human beings to perform cleaning tasks underwater. Unmanned underwater vehicles can cut down the danger to human life in term of underwater cleaning job where a human can dive and descent at a certain depth and is not able to stay there in a longer period of time. Underwater Robot for cleaning process was a combination between underwater robot such as Remotely Operated Vehicles (ROV) and cleaning part called Underwater Cleaning Robot (UCR). The main objective of this project was to develop a cleaning tool attached to the ROV to demonstrate the performance of the cleaning procedure as in water treatment operations. By the invention of this UCR, more underwater cleaning job can be done without involving human life. This project began with a design using Solidworks software to capture the dynamics of a newly fabricated UCR. The UCR can perform the cleaning task and this project can give much benefit to the related underwater business especially for the cleaning process.

**KEYWORDS:** *Remotely Operated Vehicle, Underwater Cleaning Robot (UCR), cleaning process.*

## **1.0 INTRODUCTION**

Over the years, the engineers and scientists have struggled to create a machine or a robot that can help human beings in performing tasks involving underwater situations. Furthermore, shipping industry or catfish pond entrepreneurs face problems in cleaning purposes. For example, to clean the bottom of the vessel, a locksmith should dive under water to do the cleaning. Besides, to collect the rubbish under the sea, divers should dive to the ocean floor to collect it. This process takes a long time and can endanger humans lives.

These projects were focusing on designing and developing an underwater robot for a cleaning process. An underwater vehicle is a robot which travels underwater without requiring input from an operator. Underwater vehicle constitutes part of a larger group of undersea systems known as unmanned underwater vehicles. It is controlled and powered from the surface by an operator / pilot through an umbilical or remote control [1]. Hence, the operator can handle the underwater vehicle robot easily to move to any direction for cleaning process. The Underwater Robot for Cleaning Process (UCR) is a robot that is designed for cleaning purposes work under the sea. The main purpose of the creation of this robot is to perform operations that are harmful to humans as the depth of a high pressure can affect the human body. In the current state, most of the underwater cleaning job is done by human such as cleaning the bottom of the vessel, submarine as well as swimming pool [2]. Basically, this robot is using thruster as an actuator part and more likely as Remotely Operated Vehicle (ROV) that uses remote as a controller and is able to successfully complete a cleaning job. This UCR will use a motor pump to suck dirt in the water at any pool and transfer it to the filter division, which contains some filtering material to isolate the impurities and dirt in the water. This cleaning process requires two motor pumps in which one motor pump will be installed at the intake side of the filter and the rest at the outlet side in order to force the water from the filtering division to come out.

Other than that, the underwater vehicles should have installed the cleaning part as this is a major reason for doing this project. This UCR should be able to perform some cleaning job in the pool or water reservoirs in the laboratory in order to fulfil the objective and scope of this project. By the invention of this underwater vehicle, more underwater cleaning job can be done without risking human life and, on the other hand, the number of human casualty in the sea can be reduced.

Based on three journals [3-5], all projects are related to the underwater cleaning task using different ways. Two of them operate in fully automated, which requires some programming language while the other one operates manually, which requires a pilot to control the whole system. The cleaning tools, method and area of cleaning are also different based on the purpose

design and their capability. From the comparison that has been made in [3-5], the Underwater Cleaning Robot (UCR) for cleaning process will be created. This UCR used a manual controller and a pumping system to clean the water. The frame body of this project utilized aluminium material. There are 6 thrusters used for the UCR propulsion system. The control board used was PSC28A from Cytron Technologies because this board have build-in requirements that were needed for UCR.

## 2.0 METHODOLOGY

This is the first phase of implementing this project. The first design of UCR using SolidWorks 2013 software can provide the basic structure of the UCR and ease the task of building hardware parts. The software allows users to easily pull in a three-dimensional view. By using this software, users can also measure the material strength in every part of the body frame of the UCR and other equipment installed [6].

### 2.1 Electronic Part Construction

To control the electronic and electrical part that were installed on UCR such as thruster and cleaning equipment, a control box that contained electronic circuit as a brain of the whole UCR system needed to be installed either by DIY method or plug and play method. For this UCR, PSC28A controller board manufactured by Cytron Technologies was used as a main controller. For smooth operation of the system, the PSC28A board should be used together with PS2 controller [9]. According to the datasheet provide by Cytron, this circuit is directly connected with input and output port / units. The input port is the PS2 controller and the output ports are the motor for the thruster, water pump for ballast tank and cleaning pump [7].

### 2.2 PSC28A Controller Board

The PSC28A is a circuit board that plays as an interface between PS2 controller and another device that needs to be controlled as shown in Figure 1. It could be connected either through microcontroller or directly to I/O device. The PSC28A does not also require a programming language to perform because the program is inserted inside the PIC microcontroller [7].

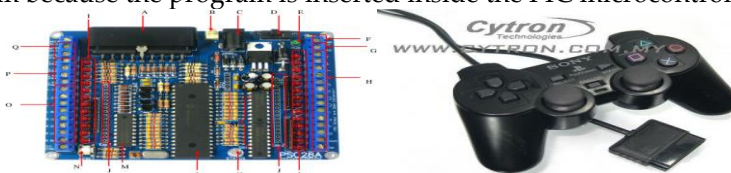


Figure 1: PSC28A controller board and PS2 controller [7]

### **2.3 Electronic Wiring**

Figure 2 shows the electronic Assembly details which was required for UCR in order to make it work properly. The 12V battery with 3A current power supply was used to supply current and voltage to 6 DC motors for 6 thrusters and water pump. The relay for H-Bridge circuit in was triggered in order to control the movement of the thruster as well as the water pump. Only 5V was required by the PSC28A controller board to power it up. The PSC28A is a circuit board play as an interface between PS2 controller and another device that needs to be controlled.

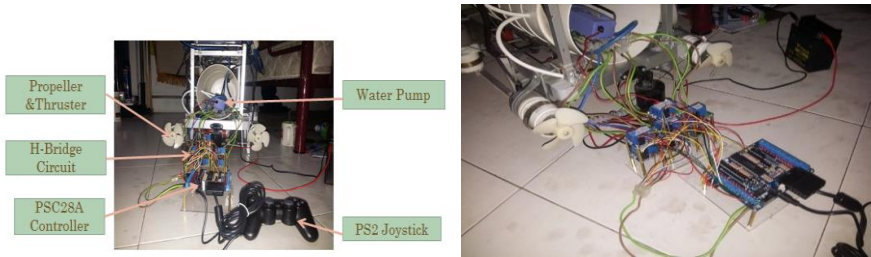


Figure 2: Electronic Assembly Details

To implement this project, all 6 DC motor for thruster along with water pump (for ballast tank) were wired to the H-Bridge circuit. The H-Bridge circuit board contained 2 single poles 4 throw relay in which each one of it was used either for forward and reverse motion of the thruster and water pump. With this proper connection, every movement like left, right, submerge or float of UCR was possible. This H-Bridge was wired to PSC28A as the relay required 5V power. At the same time, the input signal from the H-Bridge was connected to the PSC28A output terminal. This is important because that was the only way the signal from PS2 joystick controller could be sent directly to the device that needed to be controlled.

### **2.4 Motor Driver**

L293D is an H-Bridge motor driver which is used to drive a DC motor by using the signal that is generated by a PIC microcontroller as shown in Figure 3. This H-Bridge motor driver enabled voltage to be applied to cross a load (motor) in both directions. The main purpose of using this H-Bridge driver was to control DC motor in both directions either to run in clockwise or counterclockwise. The movement of DC motor could be applied using a combination of transistors and motor in H-Bridge driver in which the transistors would allow current to pass through in one direction only. This led the motor to run either forward or backward according to the position of transistors [8].

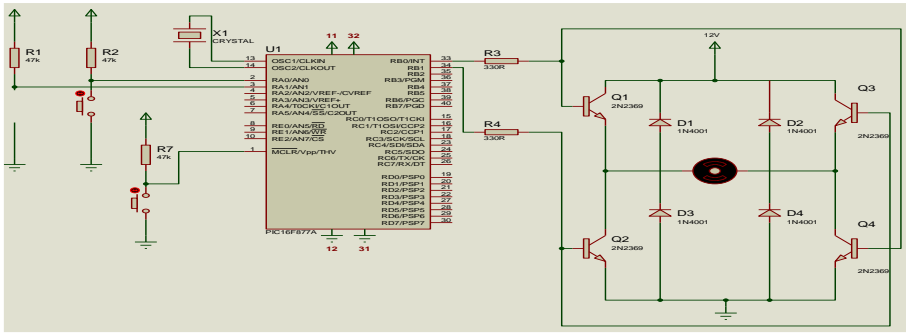


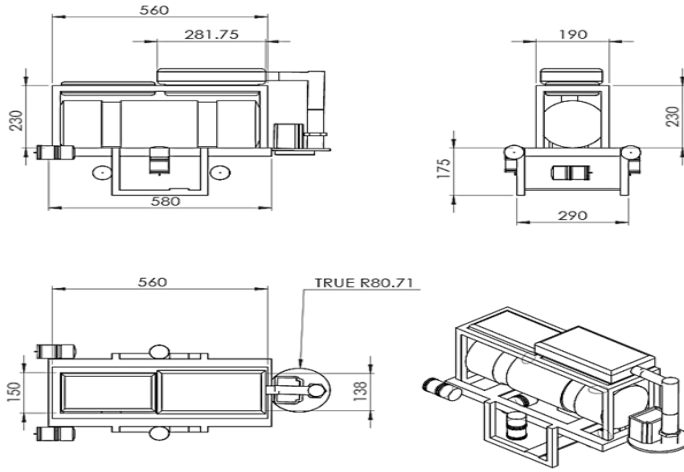
Figure 3: H-Bridge circuit

## 2.5 Cleaning Process Section

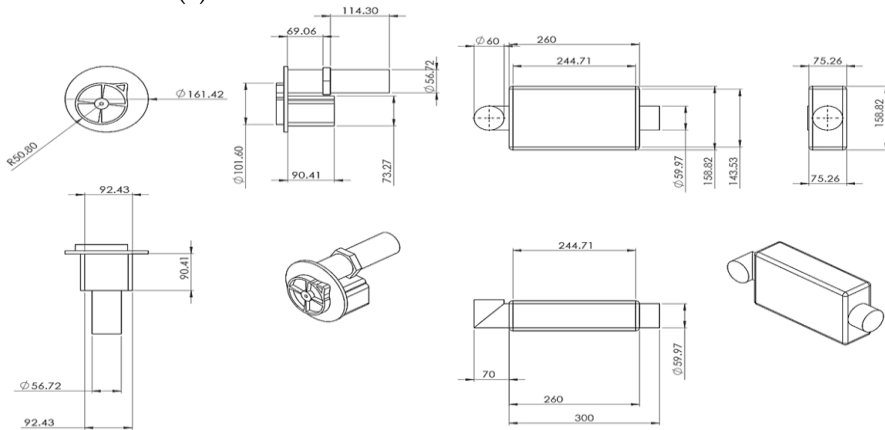
In order to build this project, the cleaning method should be the primary part that needs to be focused on. Based on literature, the water cleaning using sucking method is commonly used. Hence, this method was employed for this study. The dirt contained in the pool water was drawn and filtered using a filter that consists of several layers of filter material using high-powered vacuum or pump motors. This process continued until the water in the pond / pool changed a little from the previous cleaning. Part of this cleaning tools would be installed on the UCR and UCR would be controlled to move across the pond to speed up the cleaning process. This cleaning tool could also clean the most of the bottom surface of the pool at the same time. In order to make this cleaning method perform efficiently, there were several parts that needed to be studied.

## 3.0 RESULTS AND DISCUSSION

This section will describe and discuss the results and analysis. First, the results based on the design of the project by using SolidWorks software as shown in Figure 4 (a) - (c). Figure 4 (a) and (b) shows the project design with a different position of view using Solidworks. The open frame UCR design was developed because this configuration has been widely adopted by commercial ROV. This is because of its simplicity, robust, easy to maintain, more stable compared with closed hull and cheaper. Figure 4 (c) shows the parameter design of underwater cleaning robot.



(a) Different view of UCR with dimension



(b) Hose for cleaning system

(c) Cleaning system storage

Figure 4: Parameter of design

### 3.1 Center of Gravity

The UCR used two thrusters for submerge and float movement. The thruster must be placed at the center of the UCR so that submerge and float motion can be conducted efficiently as shown in Figure 5. In order to place the thruster at the center of the gravity, the UCR must be in stable condition as the stability can affect the vertical movement of the UCR. The center of gravity of the UCR can be found by using Solid Work 2013 as shown in Figure 6.

Center of mass X : 423 mm, Y: 7.45 mm, Z: -467 mm



Figure 5: Prototype of UCR

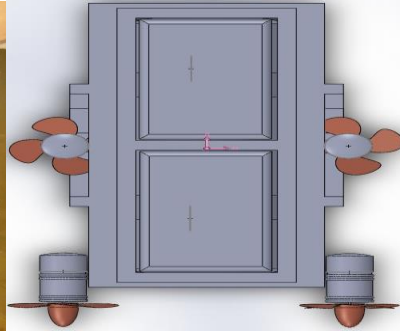


Figure 6: Center of Gravity UCR

### 3.2 Weight Estimation

The UCR must be floated at underwater level to ensure it can easily float and submerge. In order to do that, the weight of UCR was calculated. The buoyant theory states that, the force act vertically upward to the centroid of UCR and it can be defined mathematically by using Archimedes' principle as shown below [9]:

$$F_b = \gamma_f V_d \quad (1)$$

Where,

$F_b$  =Buoyant force , $\gamma_f$  = Specific weight of the fluid,  $v_d$ =Displaced volume of the fluid

In theory, when an object is floating, it displaces a sufficient volume of fluid to balance its height [10]. The application of the equation of static equilibrium in the vertical direction,  $\sum F_v = 0$ . In this case it is assumed that the object is in rest mode in fluid and the positive direction of the upward. The neutral buoyancy is exited when the body of an object stays in position wherever it is submerged in a fluid [11].

When an object is floating,

$$F_b = w = \gamma_f V_d \quad (2)$$

To submerge an object, an external force is required and the force buoyancy is:

$$F_b = w + F_e = \gamma_f V_d + F_e \quad (3)$$

The weight estimation of UCR should be calculated to ensure the UCR can be floated under a water level as needed. The whole part of UCR such as thruster, body frame, lamp, and a cleaning tool is already submerged when it is placed into the water so that an external force acts on the parts.

#### 3.2.1 Pressure Hull

Figure 7 shows the free body diagram for pressure hull. The unit is in millimeter.

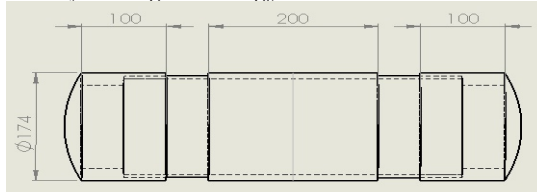


Figure 7: Pressure Hull free body diagram

$$\sum F_v = 0 \quad (4)$$

$$F_b = F_e + w \quad (5)$$

$$W = 2.512 \text{ kg} \quad F_b = \gamma_f + V_d \quad (6)$$

$$\sum V_{dTotal} = V_{di} + V_{dii} + V_{diii} \quad (7)$$

$$r = 87 \text{ mm}$$

$$V_{di} = \frac{1}{2} \left( \frac{4}{3} \pi r^3 \right) + \pi r^2 \quad (8)$$

$$= \frac{2}{3} \pi (87^3) + \pi (87^2) 100$$

$$= 3.757 \times 10^6 \text{ mm}^3$$

$$V_{dii} = \pi r^2 l \quad (9)$$

$$= \pi (87^2) (300)$$

$$= 7.133 \times 10^6 \text{ mm}^3$$

$$V_{diii} = V_{di}$$

$$= 3.757 \times 10^6 \text{ mm}^3$$

$$V_{dTotal} = 3.757 \times 10^6 \text{ mm}^3 + 7.133 \times 10^6 \text{ mm}^3 + 3.757 \times 10^6 \text{ mm}^3$$

$$= 14.647 \times 10^6 \text{ mm}^3$$

$$\text{Water, } \gamma_f = 9.81 \times 10^3 \text{ N/m}^3$$

$$f_{bl} = \left( \frac{9.81 \times 10^3}{\text{m}^3} \right) (14.647 \times 10^6 \text{ mm}^3) \left( \frac{1 \text{ m}^3}{10^9 \text{ mm}^3} \right)$$

$$= 143.69 \text{ N}$$

$$F_{el} = F_{bl} - w_1 \quad (10)$$

$$= 143.69 - (2.512 \times 9.81)$$

$$= 119.047 \text{ N}$$

### 3.2.2 Ballast Tank

Figure 8 shows the free body diagram for ballast tank. The unit is in millimeter.

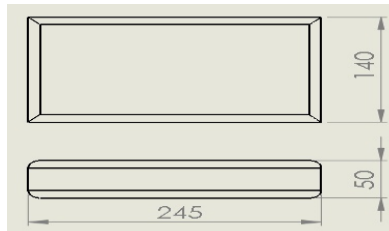


Figure 8: Ballast Tank Free Body Diagram

$$\sum F_v = 0 \quad (11)$$

$$F_b = F_e + w \quad (12)$$

$$W = 0.5 \text{ kg}$$

$$F_b = \gamma_f + V_d \quad (13)$$

$$V_d = l \times w \times h \quad (14)$$



$$\begin{aligned}
&= 140 \times 245 \times 50 \\
&= 1.715 \times 10^6 \text{ mm}^3 \\
f_b &= w = 2 \left( \frac{9.81 \times 10^3}{\text{m}^3} \right) (1.715 \times 10^6 \text{ mm}^3) \left( \frac{1 \text{ m}^3}{10^9 \text{ mm}^3} \right) \\
&= 33.648 \text{ N} \\
F_{e2} &= F_b - w \quad (15) \\
&= 33.648 - (0.5 \times 9.81) \\
&= 28.743 \text{ N}
\end{aligned}$$

### 3.2.3 Thruster

Figure 9 shows the free body diagram for the thruster. The unit is in millimeter.

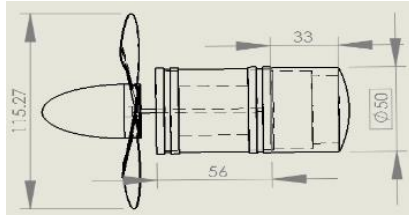


Figure 9: Thruster Free Body Diagram

$$\begin{aligned}
\sum F_v &= 0 \quad (16) \\
F_b &= F_e + w \quad (17) \\
w &= 0.4 \text{ kg} \\
F_b &= \gamma_f + V_d \quad (18) \\
\sum V_{dTotal} &= V_{di} + V_{dii} \quad (19) \\
r &= 25 \text{ mm} \\
V_{di} &= \pi r^2 l \quad (20) \\
&= \pi(25^2) (56) \\
&= 109.95 \times 10^3 \text{ mm}^3 \\
V_{dii} &= \pi r^2 l \quad (21) \\
&= \pi(25^2) (33) \\
&= 64.79 \times 10^6 \text{ mm}^3 \\
\sum V_{dTotal} &= 109.95 \times 10^3 \text{ mm}^3 + 64.79 \times 10^6 \text{ mm}^3 \\
&= 174.74 \times 10^3 \text{ mm}^3 \\
\text{Water, } \gamma_f &= 9.81 \times 10^3 \text{ N/m}^3
\end{aligned}$$

6 Thruster

$$\begin{aligned}
f_b &= 6 \left( \frac{9.81 \times 10^3}{\text{m}^3} \right) (174.74 \times 10^3 \text{ mm}^3) \left( \frac{1 \text{ m}^3}{10^9 \text{ mm}^3} \right) \\
&= 10.28 \text{ N} \\
F_{e2} &= F_b - w \quad (22) \\
&= 10.28 - (0.4 \times 6 \times 9.81) \\
&= 13.26 \text{ N}
\end{aligned}$$

### 3.2.4 Filter Container

Figure 10 shows the free body diagram for Filter containers. The unit is in millimeter.

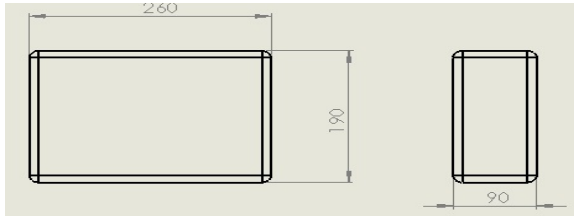


Figure 10: Filter Containers Free Body Diagram

$$\sum F_v = 0 \quad (23)$$

$$F_b = F_e + w \quad (24)$$

$$W = 1.5kg$$

$$F_b = \gamma_f + V_d \quad (25)$$

$$V_d = l \times w \times h \quad (26)$$

$$= 260 \times 190 \times 90$$

$$= 4.446 \times 10^6 \text{ mm}^3$$

$$f_b = w = \left( \frac{9.81 \times 10^3}{\text{m}^3} \right) (4.446 \times 10^6 \text{ mm}^3) \left( \frac{1 \text{ m}^3}{10^3 \text{ mm}^3} \right)$$

$$= 43.615 \text{ N}$$

$$F_{e2} = F_b - w \quad (27)$$

$$= 43.615 - (1.5 \times 9.81)$$

$$= 28.9 \text{ N}$$

Total weight,

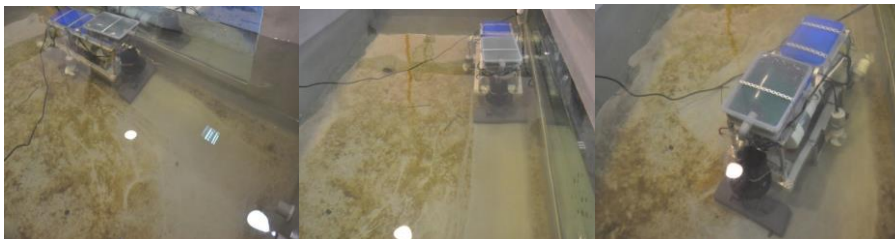
$$W_T = W_1 + W_2 + W_3 + W_4$$

$$= 143.69 + 33.648 + 10.28 + 43.615$$

$$= 231.233 \text{ N}$$

Newton to Kilogram,

$$m = 23.57 \text{ kg}$$



(a)

(b)

(c)

Figure 11: Cleaning Process Test

During the project, some problem occurs whereby the pressure hull that contained an electronic part was burnt due to a leakage occurred during the experiment as shown in Figure 11. This disaster led to the malfunction of the whole system of UCR. As a result, the whole electronic component needed to be replaced with new ones. To avert that catastrophe from happening in future, more glue and adhesive and other necessary objects were applied. This project did not cover the effectiveness of the cleaning process ,yet can be

proposed on future works. This project focused more on design and development of UCR.

## 4.0 CONCLUSION

The underwater vehicle is one of the important developments in underwater research. This continuous research will guide the human being to know more about underwater lifestyle and based along the knowledge gained, the human can constantly make up new technologies that hold the capabilities in terms of an underwater condition. This technology will enable human to explore, visit as well as exploit place that humans could not otherwise go and replace the human job for cleaning tasks in order to avoid human life risk. The main objective of this project has been achieved where the Underwater Cleaning Robot (UCR) is able to do the cleaning task and some underwater motion as required. The UCR functionality such as forward-reverse left and right turn, float and submerge along with its cleaning method can be easily controlled by using a PS2 joystick controller where the PS2 joystick controller is wired to the PSC28A main controller board. The UCR can submerge into any condition of the water that is less than 3-meter depth. The Solidworks software and mathematical analysis for every part in the UCR are useful in designing the UCR. This design gives more clarification on how to build the cleaning method for UCR. Hence, several ideas are produced in terms of cleaning puddle water, collecting garbage at the bottom surface of a pool or cleaning the side wall of a pool. In future works, the effectiveness of the cleaning process of the UCR will be tested..

## ACKNOWLEDGMENTS

We wish to express our gratitude to **Universiti Teknikal Malaysia Melaka (UTeM)**. Special appreciation and gratitude to Underwater Technology Research Group (UTeRG), Centre of Research and Innovation Management (CRIM) and to Faculty of Electrical Engineering from UTeM for giving the financial and moral support in completing this project successfully.

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