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Small Scale Unmanned Underwater Remotely Operated Crawler (ROC)

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Abstract

This project is describes the development of underwater vehicle which is remotely operated crawler (ROC). The ROC is developed for the implementation of underwater surface floor and used as for rescuing application. This project is aim to reduce the risk the human life and to solve the disability of human to dive to the underwater for rescue and archeologist work in a longer period. Due to the underwater vehicle that can be operated in a larger depth and reducing the liability of the human life. Moreover, the main problem with this ROC application is to travelling under the uneven of the underwater floor and make sure it always have negative buoyant and a good stability to perform at uneven surface of underwater. Furthermore, the ROC need the overcome the obstacle of the underwater surface without any problem. Therefore, the design of ROC is based on four wheel mechanism to maneuver it at the uneven surface. Besides that, the ROC is tethered and control manually by using a joystick controller and the Peripheral Interface Controller (PIC) are used to control this ROC. This method is to fulfill the target of the project that are to develop and fabricate the ROC and to study the performance of the ROC in terms of controllability, stability and maneuverability. As a result, the movement of ROC is analyzing in order to gain the requirement of stability and the buoyancy in the water. Moreover, the development of the ROC can be tested in several experiments which includes overcome obstacle, controllability, and it performances to be operated on the surface floor of underwater. Hence, this project will gives the good impact and benefit related to the underwater industries and can be applied in the rescuing application in the future.

Keywords*: remotely operated crawler, small scale, wheel mechanism*

1. Introduction

Remotely Operated Crawler (ROC) is one of a type in the unmanned underwater vehicle that has the capability to be operating in underwater without having the human maneuver inside it. Nowadays, these vehicles are widely used by marine, military, and also used by archeologists which are most of the work that need to be done in the deep of undersea water. The unmanned underwater vehicle can classify by two categories which are Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV). The differences between both categories are the ROV operating and conducting by sending a signal input and that AUV will steer automatically with the command input. In order to satisfy the requirement and targeted of the vehicle maneuverability, this AUV system usually using the feedback controller. Whereas for the ROV is operated manually by human whether wireless or wired remote control. So, in this remotely operated has been divided in two which are Remotely Operated Vehicle (ROV) and Remotely Operated Crawler (ROC).

Thus, in this research is focused on the development of design and fabricate the unmanned underwater vehicle remotely operated crawler (ROC). Underwater Technology Research Group (UTeRG) from UTeM already done on the ROV, AUV, Glider and unmanned surface vehicle [1-8]. Now, this group focused on ROC. An underwater vehicle with crawler is a robot which running on land and sea without requiring input from a user. So it uses wheels for running on water. These wheels of crawler are self-sufficient, capable of making on-the-fly decisions, remove the human element, thereby, overcoming the disadvantages of the ROV [9-11]. Besides that, the performance that led to the choice of 4 wheel architecture of the crawler because of the generally ROC running stably when the ROC had an adequate weight in water

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and adequate center of gravity as well as the center of buoyancy. Thus, the wheel depends on the weight and the discrimination line is obtained with the weight and the buoyancy of the ROC, the water residence, the point of its application and the dimension of crawlers. So it's necessary to research the influence of the weight on the movability characteristic of the crawler system in order to possess adequate movability on the sea floor [12]. It is controlled and powered from the surface by using the remote control. The crawler offers a very stable platform for manipulating objects or for taking measurements. Additionally, crawlers lend themselves to long term work. The vehicle is controlled by a remote control cable from the boat and it's equipped with cameras as a feedback. This cable transfers the control signals and power between the control unit and the ROC [13, 14]. Therefore, this is why the ROC is very suitable to be implemented in rescuing application at underwater platform.

1.1. Differences between ROV and ROC

In the research of underwater vehicle, there are two types of remotely operated vehicle which are ROV and ROC. Both of these vehicles can carry instruments and monitoring observation for rescuing application. The main difference between the two vehicles is the ROC is designed to allow operating at direct contact with the seafloor, while the ROV cannot directly contact with the seafloor which more like a submarine application as tabulated in Table 1.

Table 1. Comparison between ROC and ROV

ROV	ROC
Only be operated in underwater	Can be operated at the seafloor of underwater
Actuated and maneuver by using propeller	Maneuver by using wheel application
Faster capability to travel through water	Better capability to perform at the seafloor

2. Maneuver System

Commonly all land vehicles or maneuver device that moving on the surface are all using wheels. The wheel is a circle and roundly shape component that has function to rotate in axial bearing of the vehicles. By applying these wheels can enable to moving the heavy object and transport the load at the same time easily. In this application of remotely operated crawler, usually using several types of mechanism which are crawler tires and crawler belt. Table 2 shows some of advantages and disadvantages between the tire, belt, and omni-wheel.

Table 2. Advantages and Disadvantages between the tire, belt, and omni-wheel.

Type of wheel crawler	Advantages	Disadvantages
Tire 	1. Have more efficiency in speed performances 2. Have less friction force on surface 3. Have more power and speed to maneuver	Have poor ability in turning in left and right at tight place
Belt 	1. Have an excellent climbing ability 2. Have good ability in turning at tight place	1. Complicated system 2. Very slow in turning
Omni-wheel 	Have the best ability in turning in all direction	1. High coat implementation 2. Less power and speed to maneuver

3. Modeling of Wheel Mechanism

In this crawler model, there are frictional force occur due to wheel rolling to contact the surface. In pure rolling motion, friction is required to catch and stop the sliding and slipping motion of wheel and can be guided easier as shown in Figure 1.

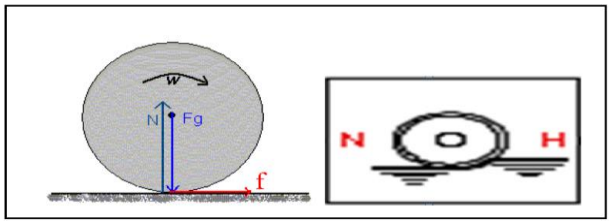

Figure 1. Frictional Force

Moreover, the frictional force is required to slow the wheel torque in order to decrease the angular velocity. Thus, the overall rolling friction results in a force at the center of the wheel and is parallel to the surface contact and is represented by Equation (1).

$$F = N_r \tag{1}$$

Where:

F = Rolling resistance force
N = Normal force
r = rolling resistance coefficient

The additional equation pressure and velocity of the crawler tires as follow:

$$F = \left(\frac{P}{P_o}\right)^{\alpha} \left(\frac{N}{N_o}\right)^{\beta} N_0 \,.\, (A + B|v_{hub}| + C{v_{hub}}^2) \tag{2}$$

Where:

P = Tire pressure
V_{hub}= Hub velocity
P_0=1 Pascal (Pa)
N_0= 1 Newton (N)

3.1. Belt

Another mechanism of wheels that been implement by other researcher are belt. This mechanism of tire as shown in Figure 2.

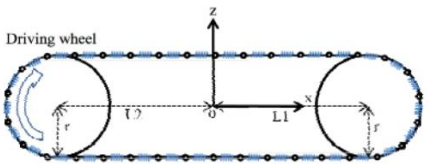

Figure 2. Driving-Belt Wheel Diagram [12]

The mechanism of the belting wheel is affected by external force which are gravity, line tension, normal component of reaction and external force to keep velocity. In actual operation of the crawler system, driven motors will be operated and controlled [9, 10]. Then the rotation

speed of driving wheels, which is treated as an input parameter. The equation of the motor is as follows:

$$m\ddot{x}_j = a_{xj}T_j + b_{xj}T_{j-1} + c_{xj}R_j + d_{xj}F_j + G_{xj} \quad (3)$$

$$m\ddot{z}_j = a_{zj}T_j + b_{zj}T_{j-1} + c_{zj}R_j + d_{zj}F_j + G_{zj} \quad (4)$$

Where

m = Mass of j_{th} jth lump
$\ddot{x}_j, \ddot{z}_j$ = Acceleration of j_{th} lumped mass in x and z direction, respectively
T_j =tension in segment between j_{th} and (j+1)th lumped mass
R_j = Normal Component of reaction in j_{th} lumped mass
F_j = External force to keep velocity in j_{th} lumped mass
U_j, V_j =Gravity force in j_{th} lumped mass
$a_{xj}, b_{xj}, c_{xj}, d_{xj}$= Function of x_j

4. Result and Discussion

4.1. Development of ROC (SolidWorks)

The first steps in this design this project by implementing the uses of the SolidWorks 2013 software. This software is used as solid modeling and utilizes a parametric features based approach which in three dimension space in order to develop and design the model or assembly parts. Therefore, the user can easily design this project and assemble it part by part effectively. Moreover Simulation Xpress is an analysis tool that has implemented in SolidWorks software package that giving abilities to do some basic stress analysis and many more test analysis on the material part of the design project. Thus, the user can determine whether the material is suitable to use as the analysis test on the material strength can be conducted.

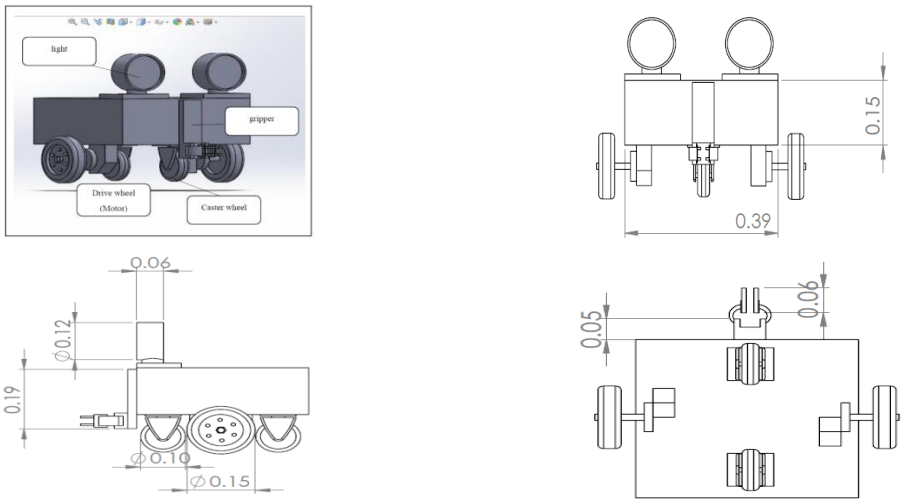

Figure 3. ROC Design Using SolidWorks

4.2. Fabrication of Mechanical Parts of ROC (Hardware)

After confirmed the design process of the ROC, the first part is to fabricate the frame body of the project. The material that has been chosen is 1 inch of hollow type square metal. The metal is chosen because it can withstand the underwater pressure due to its hardness and brittle characteristic. Thus, the frame was develop by weld in order to make the frame structure is strong and solid to handle the pressure of underwater. The cover body for the ROC is a

plastic material which is acrylic that has attributes of light weight and easy to shape. Therefore, the square shape of body structure of ROC is develop by referring the design that has been made in the SolidWorks software. The square shape design is used because it is easier to develop the shape or structure of hardware and cut the cost of the project.

To maneuver the ROC, two pieces of 6 inches of wheels is selected as the driven wheel. This driven wheel then attached to the power window by using the fabricated shaft that has been made. The power window motor is chosen to drive the ROC because of its features that is already partially waterproof design. Thus, it only needs a few part of the ROC that need to be seal. After that, two caster wheels is added to the ROC in order to improve the effectiveness and impact of the ROC to maneuver or turn to left and right direction. Therefore, the movement of the ROC to move left and right direction can be operated at the best performance by it has capability to make one complete round turning due to the aid of the caster wheels.

In order to control the maneuverability of this remotely operated crawler, the electronic configuration control box is needed. In this electronic control box contains the connection of the DC motor, sensors, and the PSC28A control circuit by Cytron [15]. The function of controller circuit of PSC28A is it has built in connection between input of the Play Station 2 (PS2) controller joystick and the output as to control the DC motor to maneuver the ROC. By referring the datasheet of controller circuit, some modification on this connection of circuit need to be done which is by adding the motor driver to control the speed and motion of motor as shown in Figure 5.

Figure 4. Fabrication Process of ROC

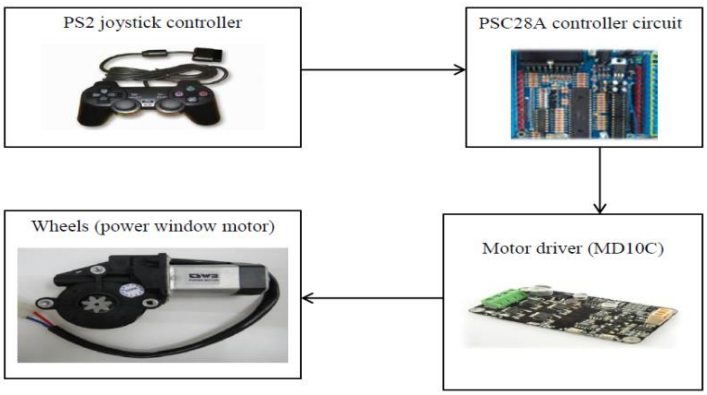

Figure 5. Block Diagram of Control System of ROC

4.3. Design ROC Features

Thus, a diagram of design using Solidworks software will be determine the range of measurement of the ROC shown in Figure 6. The good design is important because it can influence and affect the buoyancy of the ROC body. Therefore, if the weight of ROC is greater than the buoyancy force that acting in it, so it will have negative buoyant. Thus, the ROC will submerge effectively at the bottom of the laboratory test pool. Hence, since to fulfill the requirement in term of the stability and buoyant force in the water the design is been chosen is flat and square shape since it has Table 3 shows a description of details about the features of the designed ROC.

Table 3. Specification of ROC

Description	Details Specification
Length	395 mm
Height	150 mm
Width	395 mm
Weight	9.2 kg
Type of wheels	Tire (Hard tire & round wheels)
Motor type	Power window Motor
Voltage for motor	12 V
Material	Steel (frame) / Acrylic (body cover)
Accessories	LED Lamp / Manual Gripper

Figure 6. Testing of ROC

5. Conclusion

This section will conclude all the progress and outcomes of the project. This covers all conclusions of the project of the design and development of the remotely operated crawler that includes the objectives, methodology and the analysis data for the project. In addition, the recommendation for the project also was state in order to improve this project for future works and future modification to the project system. As for conclusion, the first objective is for this

project which is to do the design and development of the crawler in terms of mechanical parts and electronic part of the system. Therefore, after done the research part at the literature review part, the method is done by designing the crawler by using the SolidWorks software. The next step is to fabricate and develop the crawler by choosing a suitable material that can sustain and support the pressure from underwater. As for the electronic part, to control the maneuverability of the crawler, the PSC28A circuit controller which is connected with the PS2 joystick controller is used as for control system of the ROC. Hence, the first objective of the project was achieved by completing the design and the fabrication of the crawler.

Furthermore, the second objective that needs to fulfill is to analyze the performance of the ROC in terms of velocity, maneuverability and stability. Thus, a few experiments were conducted to achieve the performance of the crawler. In terms of maneuverability and velocity, the crawler is test in the experiment to maneuver the crawler at the land and underwater surface. Therefore, the crawler has capable to operate in all four directions which are forward, reverse, turn to left and turn to right direction. Moreover, the crawler is successfully be operates in several different terrain and also operates in underwater floor surface without having problem. In term of stability, the test has been carried out by releasing the ROC into the lab water tank and the crawler has submerged direct into the floor of water tank with a stable condition. At the same time, Archimedes principle and the buoyancy force can be analyze and determine during that experiment. Therefore, the second objective in the project also has been achieved successfully.

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