DEVELOPMENT OF AN UNMANNED UNDERWATER REMOTELY OPERATED CRAWLER BASED ON WHEEL MECHANISM DESIGN

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A report submitted in partial fulfillment of the requirements for the degree of

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" I hereby declare that I have read through this report entitle "Development of an Unmanned Underwater Remotely Operated Crawler based on wheel mechanism design" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronic Engineering"

Signature :

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Date :

“I declare that this report entitle “Development of an Unmanned Underwater Remotely Operated Crawler based on Wheel Mechanism design” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.”

Signature :

Name : RASHIDAH BINTI OMAR

Date :

DEDICATION

To my beloved mother and father,

My supervisor,

And to all my friends

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere and gratitude to my supervisor En. Mohd Shahrieel Bin Mohd Aras for guidance throughout the progress of this project, for his germinal ideas, invaluable guidance, continuous encouragement and constant support. This thesis would not have been possible without her guidance. I really appreciate his consistent support from the first day. Furthermore, I would also like to acknowledge with much appreciation the crucial role of the staff of Faculty of Electrical Engineering, who gave the permission to use all required equipment and the necessary materials to complete the task "Development of an unmanned underwater remotely operated crawler based on wheel mechanism design". Also special thanks go to my friends, who help me to assemble the parts and gave suggestion about the task. Last but not least, many thanks to Pn. Fadilah Binti Abd Azis whose have invested their full effort in guiding me in achieving the goal. I acknowledge my sincere and my great appreciation goes to all my family members who have been so patient and support me all these years. Without their encouragement and love, I would not be able to undergo the pressure due to this project.

ABSTRACT

Underwater Remotely Operated Crawler (ROC) is one of the unmanned underwater robots. The development of an unmanned underwater ROC based on wheel mechanism design for monitoring application. To reduce the risk to human life when divers searching artifacts, underwater vehicles have more benefit which is they are able to operate at greater depths, possess less human liability and have longer working hours than any commercial divers. Besides that, the major problem with this kind of application crawler is travelling across uneven surface. While vehicle move uneven surface the crawler may be unstable so it affected the system progress. So the wheel of ROC is considered to be able travel on uneven surface. Other than that, the tethered underwater robot control manually by user using joystick. The ROC combines a standard 134mm high, 350mm wide and 400mm long remotely operated vehicle crawler. The Peripheral Interface Controller (PIC) is used to control the movement of this ROC. The ROC was design based in 3 goals maneuverability, performance and future industrial implementation. This method to make the robot function as well regarding to the objective and scope. As a result, the movement of the ROC will running in water by means of crawler system. A stable running is represented for the center of gravity and the center of buoyancy. Furthermore, this project also will give much benefit for related underwater industries and the range of applications where this ROC concept is best suited and outperforms others.

ABSTRAK

Kenderaan kawalan di dalam air adalah salah satu robot dalam air tanpa pemandu. Tujuan projek ini untuk membangunkan kenderaan tanpa pemandu dalam air berdasarkan reka bentuk mekanisme roda untuk aplikasi permantauan. Untuk mengurangkan risiko kepada nyawa manusia apabila penyelam mencari artifak, kenderaan dalam air mempunyai banyak faedah untuk beroperasi pada kedalaman lebih besar, memiliki kelebihan dari kekurangan manusia dan mempunyai lebih lama kerja daripada mana-mana penyelam yang komersial. Selain itu, salah satu masalah dalam aplikasi kenderaan dalam air adalah di permukaan yang tidak rata. Apabila kenderaan bergerak di permukaan yang tidak rata, kemungkinan kenderaan kawalan di dalam air tidak stabil yang akan mengakibatkan kemajuan pergerakkan sistem kenderaan. Oleh itu, roda kenderaan kawalan akan di pertimbangkan untuk bergerak di atas permukaan yang tidak rata. Selain itu, tali akan digunakan untuk kenderaan kawalan di dalam air secara manual oleh pengguna dengan menggunakan joysticks. Kenderaan kawalan di dalam air menggabungkan kenderaan biasanya 134mm tinggi, 350mm lebar dan 400mm panjang untuk aktiviti penyelidikan berganda dengan memilih bahan yang sesuai diperlukan untuk mengelakkan kenderaan terapung di dalam air itu. Peripheral Interface Controller (PIC) digunakan untuk mengawal pergerakan kenderaan ini. Kenderaan kawalan ini dicipta berdasarkan matlamat untuk pengandalian, prestasi dan perlaksanaan industri untuk masa depan. Kaedah ini untuk membuat robot berfungsi dan sehubungan dengan penyampaian objektif dan skop. Hasilnya, pergerakan kenderaan akan berjalan dalam air melalui sistem kenderaan kawalan. Kenderaan kawalan akan stabil apabila kenderaan itu ada pusat graviti dan pusat keampungan . Selain itu, dengan harapan projek ini juga akan memberikan banyak manfaat bagi industri yang berkaitan di bawah air dan pelbagai aplikasi di mana konsep kenderaan kawalan di dalam air adalah paling sesuai dan melebihi yang lain.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Unmanned underwater vehicles (UUV) are any vehicles that are able to operate underwater without a person on board. UUV are widely used around the world, both in military applications such as mine hunting and mine disposal. There are different kinds of UUV which are mainly divided into two categories which is Remotely and Autonomous Underwater Vehicles (AUV). These two categories can come in all sizes and shapes depending on the application. AUV which are operate independently of direct human input and AUV also often just move forward and steer the heading and depth with rudder like a torpedo, and country. There are several types of unmanned underwater remotely vehicles such as Remotely Operated Vehicle (ROV) and Remotely Operated Crawler (ROC). ROV can be steer in many directions since they usually have a motor act as thruster. ROV also are controlled by a human operator and it’s tethered either to a submarine, a surface vessel or a used in harbor and is thereby controlled by an operator [6]. While ROC are specialized vehicles that allow for underwater intervention by staying in direct contact with the seafloor.

1.2 Research Background

This project is about the development and design of an unmanned underwater Remotely Operated Crawler (ROC) based on the wheel mechanism. An underwater vehicle with crawler is a robot which running on land and sea without requiring input from a user. So it use wheels to running on water. These wheel of crawler are self-sufficient, capable of making on-the-fly decisions, remove the human element, thereby, overcoming the disadvantages of ROV [7]. 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 and adequate center of gravity as well as center of buoyancy. Thus, the wheel depends on the weight and the discrimination line is obtained with the weight and the buoyancy of 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 crawler system in order to possess adequate movability on sea floor. It is controlled and powered from the surface by using remote control [8]. It is because the user can easily handle the underwater crawler to travel from its current location to another location specified with latitude and longitude coordinates. The crawler offers a very stable platform for manipulating object 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. This cable transfer the control signals and power between the surface unit and the ROC.

1.3 Motivation

Shipwrecks are the remains of a ship that has wrecked, which are found either beached on land or sunken to the seafloor. From research, the United Nation Educational, Scientific, and Cultural Organization estimates that a total of more than three million shipwrecks lie on the seafloor. The international Register of Sunken Ship also lists more than 112,000 ships as of June 2009 [9]. Back in the 1970's treasure hunting was at people start noticing the value of historic artifacts [9]. The act of treasure hunting over the last few decades lawsuits with individual states, the federal government and with other nations is beginning to flourish as technology advances with new techniques and methods of searching for and recovering artifacts deep underwater [9]. Whether it is the underwater archeologist striving to obtain information about some underwater artifact or marine salvage specialist trying to recover materials from a sunken ship.

Besides that, the international team of divers and archaeologists who are investigating the site of an ancient Greek ship that sank more than 2,000 years ago off the remote island of Antikythera, it also contains a treasure trove of artifacts. From research, at Antikythera have a cases where one of the divers died and two were paralyzed when their searching artifacts [10]. The ship is located at a depth unsafe for human divers — 55 meters (180 feet) [10]. It shows that at the Antikythera site is a treacherous one indeed. The team divers had to end their mission since there have a cases of death. It many possibility reasons such as the divers lose control in the depth sea, less breathing underwater, surrounding pressure drop and the air in lungs expands. Therefore, this motivates the project of development of an unmanned underwater remotely operated crawler.

Figure 1: The international team of divers and archaeologists who are investigating the site [10]

1.4 Problem Statement and Significant of the Research

Nowadays, robot have been widely used in environment because capability to do work that dangerous to human especially in the seafloor. So, human no need to carry own air supply (oxygen) and protect their body from pressure and temperature under the water. Therefore, crawler robot perform tasks in underwater environments that are impossible for humans to investigate the problems in the seafloor, which human cannot directly interact with damaged equipment and it have limited capabilities in making the work underwater. Depth and pressure are related which mean at a depth of 33 feet (10meters), water pressure is 29.4 pounds per square inch [11]. For every additional 33 feet descends, the water pressure increases by one atmosphere [11]. Due to pressure depth, the deeper human goes, the more pressure is exerted on the whole body. That mean the divers working at greater depths require something stronger to avoid the body pressure impact. It is harder to get to the deepest parts of our seas and it has long been acknowledged that deep sea exploration is one of the most dangerous jobs on the market. As a result the sea-beds are cluttered with much that divers cannot reach or even see. A host of shipwrecks can be counted amongst all that can no longer be reached or found in a surprisingly large number of cases. To reduce the risk to human life especially when divers searching artifacts, underwater vehicles have more benefit which is they are able to operate at greater depths, possess less human liability and have longer working hours than any commercial divers. After some research, the problem in the deepest ocean the project will come out with new idea by using Remotely Operated Crawler (ROC) with wheel mechanism. One of the significant points that choose mechanism of wheel because by using four driven wheels can propel the vehicle while on land and on water. The vehicle then begins moving in the direction of its destination. However, a major problem with this kind of application is the crawler travelling across uneven surface. While vehicle move uneven surface the crawler may be unstable so it affected the system progress. So, to overcome the stability problem at uneven surface the structure of wheel is investigated of ROC by using the rough tires, wide surface and heavy body. Other than that, for long term time travelling uneven surface the power of the motor of crawler is considered. So, the crawler will be able to travel on uneven surface in underwater. In addition, the ROC is developed with motor in order to make the crawler move by using the DC motor. Crawler can move forward, reverse, right and left. This system indirectly can help the human to overcome the problems in underwater environments.

1.5 Objective

The main objective of this project is

1) To design and develop of unmanned underwater Remotely Operated Crawler for monitoring application.
2) To study the performances of the Remotely Operated Crawler in terms of stability, maneuverability, and velocity of the crawler.

1.6 Scope and Limitation

To conduct this project, there are several scope and limitation that are needed to be followed. Firstly, the depth of the testing prototype will be less than 2 meters. Other than that, the testing environment selected is controllable for control environment at Laboratory pool. Besides that, the design of ROC can only runs on an uneven surface such as rough of the surface which is made by 100% waterproof of the DC motors. The PVC has been chosen as the part material for sealing the DC motors. Thus, this may cause the ROC to have lower characteristics in power consumption which may contribute to low speed of emerge and submerged operation. The main supply for the system is 12V battery as power source. Other than that, PSC28A is also used as a main IC for controller. Thus, ROC can only perform movement for two degree of freedom which is the maneuverability consisted forward-reverse and left-right motion. Finally, the controller of the ROC is connected by wired to the land.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about literature review. The information was taken from books, journal, conferences, thesis, articles obtained from internet and others from the previous researches in how to development of an unmanned underwater ROC and design controller. Then, to validate the result the system identification method is proposed. These strategies have different approaches and techniques. So this chapter, it covers about the principles used, review of previous related work and summary of this project.

2.2 Unmanned underwater Remotely Operated Crawler based on wheel mechanism overview.

Before we go further study about the development of the vehicle in this topic; the overview of ROC part and controller design part of the ROC will be represented to overall in advance to common knowledge of the operation of ROC system. K-Chart overview in chapter 1 shows the overview of ROC such as material, motor, tire and also the controller system. There are two kinds of robots remotely used in deep sea are ROC and ROV. Both are marvels of engineering. The vehicles can carry instruments and monitoring observation. The main difference between the two vehicles is the ROC is specialized vehicles that allow for underwater intervention by staying direct contact with the seafloor while the ROV cannot directly contact with the seafloor. The ROV can reach the seafloor by applying deep mechanism to the ROV which is thruster, ballast tank, propeller and others. The mechanism of ROC does not have to use deep mechanism but instead it uses the wheels to be running on the seafloor. Other than that, ROC is directly contact with seafloor so it have negative buoyancy while ROV have slightly positive buoyancy because it does not directly contact with the seafloor. When the crawler is positioned at the negative buoyancy, the crawler offers a very stable platform for seabed mapping while the ROV is unstable. Therefore, the ROC is a better choice to be used for monitoring application on the seafloor.

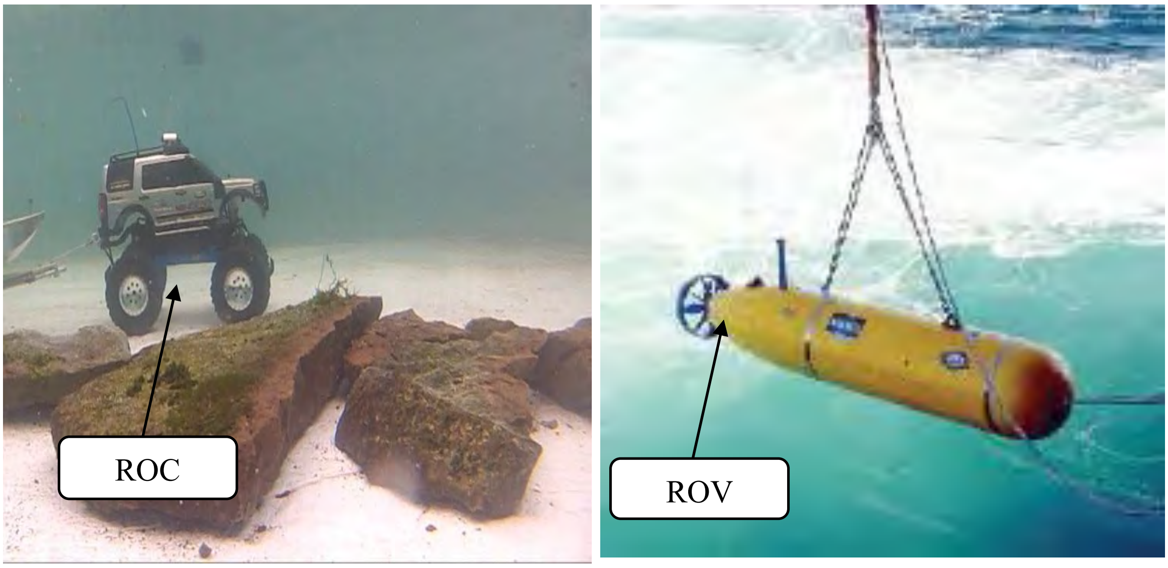

Figure 2.1: Overview of ROC and ROV

2.3 Related Journal

In the paper done by [1], the author designed a system which consists of flipper type crawler system at sea to verify running performance on sandy or irregular steep terrain seafloor. To expand the activity of research and development on the seafloor, especially survey, sampling or work on an irregular terrain seafloor, it becomes necessary to develop a function of the ROC to move and keep station. The external force acting on a crawler belt are velocity, line tension, normal reaction and external force to maintain velocity. Also, the crawler system should have the capability to move on the sandy seafloor or on the irregular terrain seafloor to search for an adequate sampling point or material. To achieve adequate mobility of the crawler systems when running on the seafloor, there is also of necessity to develop an additional advanced mechanism because the seafloor is irregular, bumpy or sloping terrain. The system could run on the rock with more than 30 degree slope. There is generally a limited height of a bump to run or climb up. The weight of the ROC in water are 191 N, revolution rate for drive motor of 1500 r/min, initial speed of 0.149 m/s and height of 65 mm. When ROC start to climb up the drive motor could be large torque because of the lack of a feedback system. Development of an advanced crawler ROV will proceed to expand the activities.

Figure 2.2: Small size flipper type crawler ROV running on the steep rock reef [1]

In the paper done by [2], the author designed a system which consists the gearmotor drive underwater ROC in crawling. One of the most innovative ROC operating under the seas today is the Little Benthic Crawler (LBC™) ROC from Seabotix. The LBC features a dual vertical thruster configuration for precise rolling movement in water and stabilization at depths down to 30 m (100 ft.). Using the lateral function on the system's joystick, the operators initiate the LBC into a roll. When the LBC attaches to a surface, it can be "driven" instead of "flown." Engaging the same controls used to fly the LBC through the water, the operator can drive the LBC with the motor-driven wheels. The drive mechanism was engineered to promote traction, straight-line tracking during inspections, and the highest possible torque for maximum operating capability with one gearmotor for each of the four wheels. By developing 360 oz.in. of torque at 40 rpm, the Pittman gear motors can drive the LBC at speeds up to 30 m/min (100 ft/min), which allows for underwater inspections to be performed quickly, especially important in situations where time may be critical. Then, a four-wheel drive system took over, enabling the LBC to drive with sufficient traction on the hull and on a steady course as directed. That vehicle have high resolution video and sonar image and provide valuable sensor and image data that connect with tether for the remotely the LBC.

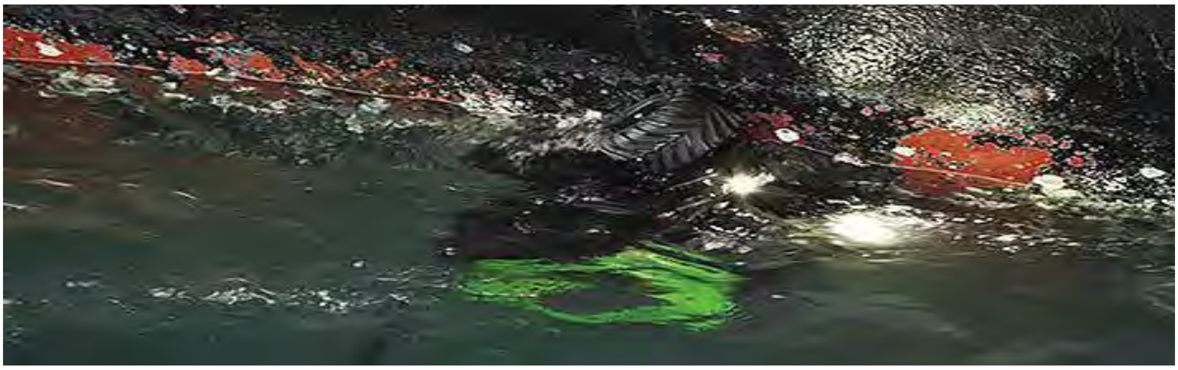

Figure 2.3: Gear motor drive underwater crawler [2]

In the paper done by [3], the author designed a system which consist of hybrid robot crawler or flyer for use in underwater archeology. At Florida Institute of Technology a hybrid remotely operated crawler has been developed for archaeological and scientific activities within coastal regions of the ocean. This hybrid vehicle combines a standard 40-cm high, 53-cm wide, 71-cm long remotely operated vehicle (ROV) flyer with a 1.0-m high, 1.52-m wide, 2.8-m long remotely operated vehicle crawler for multiple research activities such as underwater archaeology documentation and artifact removal. RG-III's underwater capabilities include the recovery of lost valuables with sensitive structures, visually examining underwater scenarios, high maneuverability at depth, and the ability to translate its position while neutrally buoyant in the mid-level depths. The control system of the crawler is split into two categories which is digital and analog. The digital system in the crawler uses Arduino micro-controllers. This acts as central controller on the crawler that delivers messages to controllers attached to each of the onboard the crawler. The tether management system introduce a larger housing for extend tether length as well guide the roller and allowing for better operation.

Figure 2.4: RG-III Crawler [3]

In the paper done by [4], the author designed a system which design of a small-scale autonomous amphibious vehicle. A detailed design of an autonomous amphibious vehicle (AAV) capable of traversing across aquatic and terrestrial environments. For a variety of reasons traversing to such places is important. Some examples include analyzing water samples in possibly contaminated environments, mapping out landmarks and the geology of an area, search and rescue, delivering items/tools from one location to another, security surveillance, and filming animals in their natural environments. To propel it underwater, two of the six wheel-legs have a propeller shape. The orientation of the wheel-legs changes to control walking direction as well as swimming direction. It describes a simple PID controller that uses as the input. The modular buoyancy attachments have used in order to allow the AAV to float on water necessary. Four paddle wheels propel the AAV across land and over water. Buoyancy attachments increase the buoyancy of the vehicle and are modular which means they can be used as needed. Ultrasonic sensors are located in front and they ensure the AAV can detect any obstacles along the way.

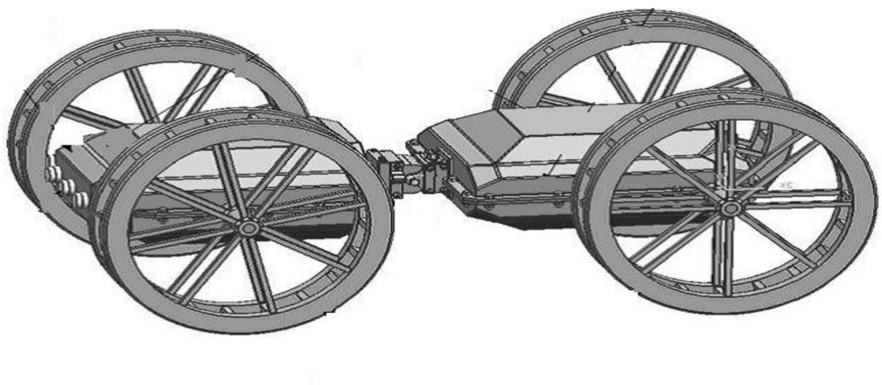

Figure 2.5: Autonomous Amphibious Vehicle