"I hereby declare that I have read through this report entitle "Underwater Remotely Operated Crawler (ROC) Leg-Like Wheel Design" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : .....

Supervisor's Name : DR. MOHD SHAHRIEEL BIN MOHD ARAS

Date : .....

UNDERWATER REMOTELY OPERAATED CRAWLER (ROC) LEG-LIKE WHEEL DESIGN

ANG LESLIE

A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017/2018

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Signature : .....……

Name : ANG LESLIE

Date : .....……

To my beloved mother and father

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ABSTRACT

Remotely Operated Crawler (ROC) is an underwater vehicle that used to explore the deep sea underwater field which categorized under Unmanned Underwater Vehicle (UUV). The aim of this study was to investigate the performance of the ROC on an uneven surface of seabed with the ability to operate in various condition of underwater environment, in particular focus on the designing of wheel mechanism to overcome any obstacle. SolidWorks software was used as a platform in designing the overview idea of the ROC with leg-like type wheel and the simulation test was done by using the application available in the software which is the SimulationXpress. The simulated wheel mechanism and other part of the ROC were able to withstand the pressure of the water within 3 meters of depth without any obvious deformation that able affect the performance of the ROC. This shows that the ROC with leg-like type wheel mechanism able to overcome obstacle without having to change the wheel frequently. The performance of the ROC then further investigate in term of velocity, overcoming obstacle, and maneuverability. The velocity of ROC were investigate with type of surface and type of medium. Then, the maximum height that ROC able to crawl over is 4cm. Lastly, the accuracy of changing direction without using sensor is 10%.

ABSTRAK

Crawler yang dikendalikan dari jauh (ROC) adalah kenderaan bawah laut yang digunakan untuk menerokai lapangan bawah laut yang dikategorikan di dalam Kenderaan Air Tanpa Manusia Air (UUV). Tujuan kajian ini adalah untuk mengkaji prestasi ROC di atas permukaan dasar laut yang tidak rata dengan keupayaan untuk beroperasi dalam pelbagai keadaan persekitaran bawah air, terutamanya fokus pada merancang mekanisme roda untuk mengatasi sebarang halangan. Perisian SolidWorks digunakan sebagai platform dalam merancang gambaran keseluruhan ROC dengan roda jenis seperti kaki dan ujian simulasi dilakukan dengan menggunakan aplikasi yang terdapat dalam perisian yang merupakan SimulationXpress. Mekanisme roda simulasi dan bahagian lain ROC mampu menahan tekanan air dengan kedalaman 3 meter tanpa sebarang perubahan bentuk yang jelas yang dapat mempengaruhi prestasi ROC. Ini menunjukkan bahawa ROC dengan mekanikal roda jenis seperti kaki boleh mengatasi halangan tanpa perlu menukar roda dengan kerap. Prestasi ROC kemudiannya menyiasat lebih lanjut dalam hal halaju, mengatasi halangan, dan kebolehlaksanaan. Halaju ROC telah disiasat dengan jenis permukaan dan jenis medium. Kemudian, ketinggian maksimum yang dapat dirangkul oleh ROC ialah 4cm. Terakhir, ketepatan perubahan arah tanpa menggunakan sensor adalah 10%.

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LIST OF ABBREVIATION

UTeM	-	University Teknikal Malaysia Melaka
UAV	-	Unmanned Aerial Vehicle
USV	-	Unmanned Surface Vehicle
UGV	-	Unmanned Ground Vehicle
UUV	-	Unmanned Underwater Vehicle
AUV	-	Autonomous Underwater Vehicle
ROV	-	Remotely Operated Vehicle
ROC	-	Remotely Operated Crawler

CHAPTER 1

INTRODUCTION

1.1 Introduction

An unmanned system is a machine or device that has been used by human since the last 10 years and more. This system is equipped with data processing units, sensors, automatic control, and communications systems. Unmanned Systems include Unmanned Aerial Vehicle(UAV) which operate in the air, Unmanned Ground Vehicle(UGV) which operate on land, Unmanned Surface Vehicle(USV) which operate on the surface of the sea, and Unmanned Underwater Vehicle(UUV) which operate below the surface of the sea. These system has the capability to operate in the field without having human maneuver it inside. It is also widely used by military, marine, air-force and other field which have the risk of taking human life[1].

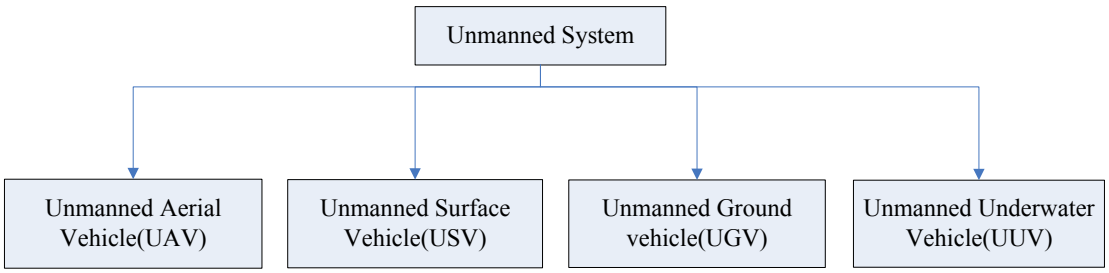

Figure 1.1: Classification of Unmanned System

The Earth's surface is covered by land and water. In fact, 71% of the Earth's surface is covered with water. There are infinite area that still yet to uncovered. The whole underwater terrain of the sea are still unknown especially deep sea terrain and until today it is still not completely mapped. Most of the deep sea creatures also yet to discovered by human. Thus, various underwater technology were developed as a

tool to help human to uncover it and work to observe and inspect the deep sea such as Autonomous Underwater Vehicle (AUV), Underwater Remotely Operated Vehicle (ROV), Underwater Remotely Operated Crawler(ROC), sonar and submarine [2].

Nowadays, Autonomous Underwater Vehicle(AUV) and Underwater Remotely Operated Vehicle(ROV) are tremendously been used to observe and inspect the deep sea. These underwater technology are widely used in the underwater industry as it can maneuver to it desire place yet it cannot inspect the seafloor. Underwater Remotely Crawler(ROC) may help to inspect the seafloor since this system stay on the ground of the sea at all time. Thus, this research is focused on the development of designing and constructing a Underwater Remotely Operated Crawler(ROC).

Underwater Remotely Operated Crawler(ROC) is one of the unmanned system that operate manually underwater by wired remote control or wireless remote control that controlled by human which located above the sea surface. By understanding the name given to this system which is ROC shows that this system only operates on the seafloor. Thus, this system needed to stay on the ground of the sea at all time by overcoming the buoyancy force acted on it. The design should also preventing it from wheelie by having an equilibrium center of gravity. There are various type of wheel crawler that can be consider for having it as a design for the ROC movement. These wheel crawler has its own advantages and disadvantages.

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

Figure 1.2: Advantages and Disadvantages of wheel mechanism[1]

For a ROC to overcome the terrain of seabed it should have all the listed out advantages based on the Figure 1.2. Thus, this research aim is to used a suitable design of wheel crawler by having more efficiency in speed performances, an excellent climbing ability and ability in turning in all direction at a tight space.

1.2 Motivation

Figure 1.3: Graph of E&A spend with exploration share of upstream capax by years[3]

By referring the graph on Figure 1.3 show that profit of oil and gas exploration on year 2015 reduce until year 2016. This show that many people especially investor will not wanting to involve themself on oil and gas exploration. Then on year 2017, it is expected that the profit of oil and gas exploration will increase by years. Wood Mackenzie's analysis of the 2017 global exploration outlook shows that exploration in 2017 will continue its transformation to a smaller and more efficient industry[3]. As big exploration used up to much cost like drilling. A smaller exploration would needed smaller technology thus using less cost. This show that smaller UUV to reduce the cost of exploration. Drilling at random place to find oil and gas would increase the cost of exploration. Instead use an underwater vehicle like ROC would help to observe the area before drill. ROC also can help to inspect the terrain and mapped out the surface to avoid damaging the drill bit. This technology maneuver will be handle by people on the surface of the sea, it show that this operation would not risk diver lives as the temperature of the water at deep sea is

low. Thus, this kind of incident can save many explorer lives which motivates people to study and do research on ROC.

1.3 Problem Statement

ROV has been widely used in underwater industry for deep sea exploration. Evan so, how well a system or technology function would still have few limitation same goes to ROV. The main limitation of ROV is the usage on the seafloor. ROV also has certain depth that is limit which would not allow it to direct contact with the seafloor. The disorder of the seafloor makes ROV even harder to maneuver around and the thruster on ROV would blow the sand or mud which reduce visualization on surrounding. Stability of ROV also one of the limitation due to environment disturbance such as sea waves and unexpected underwater current condition. Thus, ROC is the most suitable to operate on the seafloor.

Table 1.1: Comparison between ROV and ROC[1]

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

The main concern on operating the ROC is the wheel mechanism. The wheel is the main part which allow the ROC to function properly. Some wheel mechanism makes the ROC unable to climb over the obstacle while some wheel mechanism stop functioning due the pebbles in environment. The ROC with a crawler system tends to wheelie more in water medium than on land[2]. As ROC start to crawl over an obstacle with high speed, it will experience unstable as the front wheel start to crawl over the obstacle. This shows that the wheel position plays an important role as it will affect the center of gravity of the ROC. The maximum height that ROC able to crawl over an obstacle depends on the wheel structure. Without knowing the maximum height that the ROC can crawl over would damage its component either electronic or mechanical parts. The pressure acted on the wheel would decrease the speed of ROC. This would increases the time of ROC in operating on the seafloor

and wasted the battery usage. Lastly the accuracy of changing in direction to avoid any unwanted collision that would damage the ROC.

1.4 Objective

The purposes of developing an underwater Remotely Operated Crawler (ROC) during this FYP are as follows:

1. To design and develop wheel mechanism of Remotely Operated Crawler (ROC) that suitable in any underwater terrain.
2. To investigate the performances of Remotely Operated Crawler (ROC) in terms of speed, overcoming obstacle and maneuverability.

1.5 Scope

The scope of this project are limited into a few aspects. First of all, the crawler would have only two degree of freedom(DOF) for maneuver. The motion would consist of forward-reverse and left-right and also it can turn. This project is focusing on the wheel mechanism of ROC that able to crawl on 3 main surface which is smooth surface, rough surface and uneven surface. Then, the motion of crawling over an obstacle is tested on land which to investigate the performance of ROC in term of overcoming obstacle. The maximum height of the obstacle for the ROC to test on would be 10cm only as the size of prototype ROC should be small. The controller would be using wire as wireless controller need to provide suitable frequency for the receiver to receive signal form transmitter underwater. The cable from controller to ROC would be about 4 meter long as the water depth is 2 meter high. For underwater test, the speed and overcoming obstacle performance of the ROC result is use to compare with the result on land. This is to understand the different medium that acted on the ROC with its wheel performance. The wheel of the ROC will be high durability and shock resistance. This is because of the experiment on the field either on land or underwater is extreme that could cause unwanted collision. The cable will be waterproof high durability as it may snap when the ROC is maneuver on land and underwater.

1.6 Organisation of Report

The whole chapter 2 is about literature review that described the background theory and comparison design of this project. The background theory consist of factors that affect the ROC while the comparison design consist of discussion on different type of mechanical design based on publish paper. Then, chapter 3 is about methodology of this project that shows how ROC would be design based on the literature review on comparison design. Next, chapter 4 is about the result and discussion based on the analysis of this project. Finally, on chapter 5 is about conclusion of this whole project based on result and discussion. There are also some recommendation for future study of this project.

1.7 Summary

This chapter show the important of a ROC in underwater industry which help human to avoid risking their life. Still the use of ROC in underwater industry is limited because of the specification of designing of ROC required component which is very crucial such as imbalance movement of ROC and waterproof matter. For this technology to fully embrace by underwater industry, the ROC should be design with low cost, high performance in long term and environment friendly.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed about literature review. It consists of theory and principle apply on ROC, mechanical design by comparing each ROC design from publish paper, and comparing power supply and software being used. The information is been taken by books and publish paper that related to ROC. Then, the comparison is being discuss to choose the best method to archive the objective of this project.

2.2 Theory and Principle

Before designing the ROC, must first understand the theory and principle which required. The theory and principle of designing ROC consist of density, buoyancy, hydrostatic pressure, environment forces, and hydrodynamic.

2.2.1 Density

Density of substance or material is define as mass over volume. Mass is the measurement of matter in an object whereas the SI unit is kg. Volume is the amount of space occupied by substance in an object whereas the SI unit is m^3. Thus, the SI unit of density is kg/m^3.

Table 2.1: Densities of some common substances[4]

Substance	*Density* g/cm³	*Density* kg/m³
platinum	21	21×10^3
gold	19	19×10^3
mercury	14	14×10^3
lead	11	11×10^3
steel	7.9	7.9×10^3
average density of the earth	5.5	5.5×10^3
glass, brick, stone and concrete	approx. 2.6	2.6×10^3
water	1.0	1.0×10^3
ice	0.92	920
alcohol, petrol and paraffin oil	approx. 0.8	800
oak wood	0.65	650
cork	0.24	240
expanded polystyrene	approx. 16×10^{-3}	16
air (at sea level)	1.3×10^{-3}	1.3

The density of a ROC should be higher than density of water to ensure the ROC stay sinking at all time.

2.2.2 Hydrostatic Pressure

Hydrostatic pressure is a type of pressure that exerted by a equilibrium point surrounding the fluid due to gravity forces. As depth that measured from the surface of the fluid is increases, the weight of fluid exerting on it with downward force will also increases same as the pressure on it. The reason pressure will increases due to increases of force is Pascal's Law stated that:

$$P = \frac{F}{A} \quad (1) \tag{2.1}$$

$F =$ Force acting on the object

$P =$ Pressure acting on the object

$A =$ Surface area of the object

By using definition of force:

$$F = mg \quad (2) \tag{2.2}$$

$F =$ Force given to object

$m =$ Mass of fluid

$g =$ Gravitational acceleration of fluid