"I hereby declare that I have read through this report entitle "**Design and Development of an Autonomous Underwater Vehicle (AUV)**" 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 : .....

DESIGN AND DEVELOPMENT OF AN AUTONOMOUS UNDERWATER VEHICLE (AUV)

TAN WEI CHIANG

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

2016/2017

I declare that this report entitle "**Design and Development of an Autonomous Underwater Vehicle (AUV)**" 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 : TAN WEI CHIANG

Date : .....

To my beloved mother and father

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ABSTRACT

In underwater field, Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) are created to help human do marine research. AUV is an unmanned or fully sensors robotic vehicle that is using high technology to bring new capabilities to work in the subsea environment. One of the problems facing by AUV is the depth control since it may loss during surveillance because autonomously navigate in the sea. Thus, this project focused on the design and development of a low cost AUV with small size and high performance with its depth control. AUV need to be in small size to ease the mobility of the AUV when it performs tasks. Different speed will be used to test and evaluate the depth control since the depth also influenced by its speed. In designing the AUV, SolidWorks software is used and undergoes various simulation tests such as stress and strain test and stability by referring the center of mass. Next, the hardware that discussed and selected included frames, hull, enclosure box, propulsion and submersion that achieve a certain performance in terms of reliability and controllability. This project uses pressure sensor MPX5700AP as depth control to determine the depth of AUV submersion. AUV uses an AfroESC 30A to control the speed for Blue Robotics T200 thruster to move it along vertical and horizontal axis that automatic operate based on the programming coding. In this project, the scope of the study focused on the interface between mechanical and electrical design with the small size (70cm X 50cm X 30cm) made of acrylic that waterproof and the submerge range of depth in between 2 to 6 meters. The AUV is going to undergo a series of field test at the end to evaluate its ability and performance in the swimming pool task.

ABSTRAK

Dalam bidang bawah air, kenderaan kawalan jauh (ROV) dan kenderaan bawah air (AUV) yang dicipta untuk membantu manusia melakukan penyelidikan marin. AUV adalah kenderaan robotik tanpa pemandu atau sensor sepenuhnya yang menggunakan teknologi tinggi untuk membawa keupayaan baru untuk bekerja dalam persekitaran dasar laut. Salah satu masalah yang dihadapi oleh AUV adalah kawalan kedalaman kerana ia boleh kehilangan semasa pengawasan kerana autonomi mengemudi di laut. Oleh itu, projek ini memberi tumpuan kepada penciptaan dan pembuatan AUV yang kos rendah dengan saiz kecil dan berprestasi tinggi dengan kawalan kedalaman. AUV perlu direka dengan saiz kecil supaya memudahkan mobiliti AUV semasa ia melaksanakan tugas. Kelajuan yang berbeza digunakan untuk menguji dan menilai kawalan kedalaman kerana ia mempengaruhi kedalaman. Dalam mereka AUV, perisian Solidworks digunakan dan kemudian menjalankan pelbagai ujian simulasi terhadap AUV seperti ujian tekanan dan kestabilan dengan pusat jisim. Seterusnya, perkakasan yang dibincangkan dan dipilih termasuk rangka, badan kapal, kotak kepungan, pendorongan dan penenggelaman yang mencapai prestasi yang tertentu dari segi kebolehpercayaan dan keupayaan pengawalan. Projek ini menggunakan pengesan tekanan MPX5700AP untuk kawalan kedalaman bagi menentukan kedalaman AUV semasa menyelam. AUV menggunakan AfroESC 30A untuk mengawal kelajuan T200 penujah supaya bergerak sepanjang paksi menegak dan mendatar yang automatik beroperasi berdasarkan pengaturcaraan. Dalam projek ini, skop kajian memberi tumpuan kepada reka bentuk mekanikal dan elektrik dengan saiz kecil (70cm X 50cm X 30cm) diperbuat daripada akrilik yang berkalis air dan kedalaman di antara 2 hingga 6 meter. AUV akan menjalani satu siri ujian pada akhirnya untuk menilai keupayaan dan prestasinya dalam tugas-tugas yang disediakan di dalam kolam renang.

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LIST OF ABBREVIATION

UTeM	-	Universiti Teknikal Malaysia Melaka
AUV	-	Autonomous Underwater Vehicle
ROV	-	Remotely Operated Vehicle
OOS	-	Ocean Observation System
UUV	-	Unmanned Underwater Vehicle
ONR	-	Office of Naval Research
MIT	-	Massachusetts of Washington
USM	-	Universiti Sains Malaysia
IMU	-	Inertial Measurement Unit
CAD	-	Computer-Aided Design
COM	-	Center of Mass

CHAPTER 1

INTRODUCTION

1.1 Introduction

Generally, Unmanned Underwater Vehicles (UUV) have been designed and developed in various countries, including Malaysia for the past ten years in marine technology. It can be categorized into two forms which are Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) with the almost the same function as shown in Figure 1.1. Figure 1.2 shows the classification of UUV. AUV is basically an extension of the ROV's technology. The ROV is controlled by the human from the controller and needs navigation control on the surface of the core ship, whereas the AUV is controlled by its on-board controller guided by build-in pre-programmed instructions with free from a chain [1-2]. The common AUV has a submarine or torpedo shape with a minimum of one thruster for forward, backward and rudders adjust left and right direction.

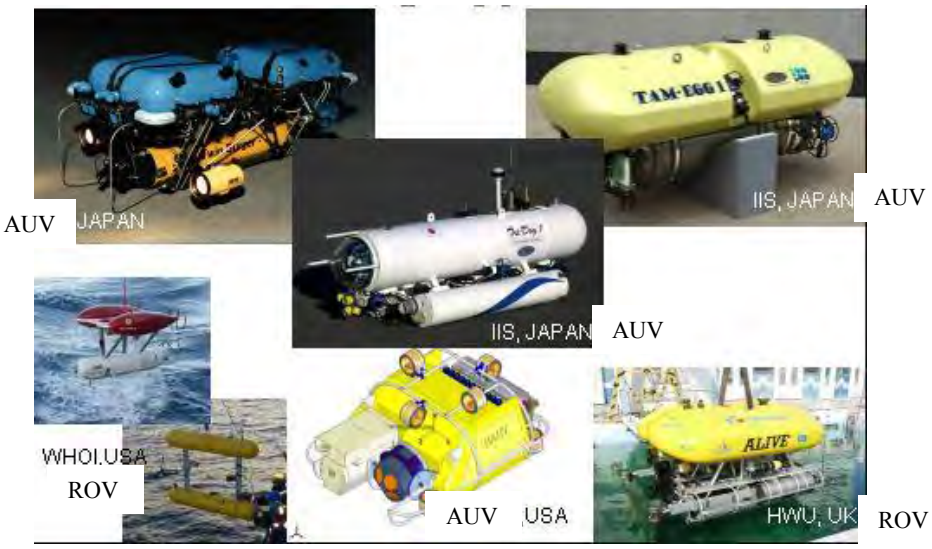

Figure 1.1: Types of Underwater Vehicle [1]

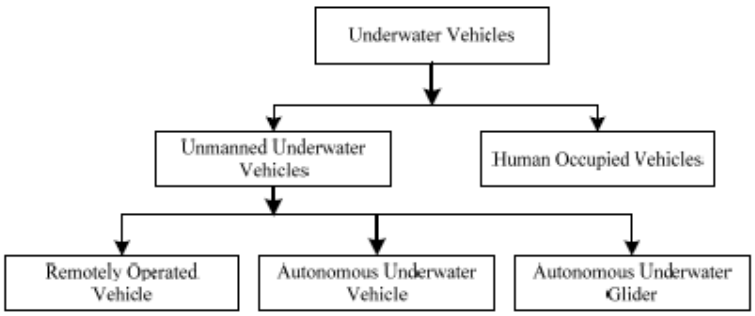

Figure 1.2: Classification of Underwater Vehicle [2]

Formerly, underwater vehicle has been used in a limited number of tasks. With further research and development, it able to reduces the limitation and increase the capability to do more tasks. Today, most of AUV can be seen in military field include mine detection, topography, search, observation mission, oiled and gas industry and some of the expeditions to explore under the deep sea as shown in Figure 1.3 [3].

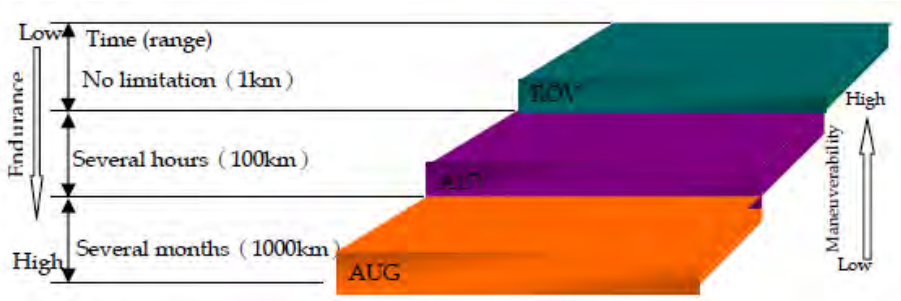

Figure 1.3: Performances of three Underwater Vehicles [3]

This project is getting more and more important that shows the design implementation of an AUV for a multiplicity of research test bed platform in underwater technologies [4]. In shallow water, the use of large AUV is not practical since the larger object has more inertia when moving around in the water and it is difficult to avoid obstacles. Thus, small AUV more suitable in shallow water to perform tasks due to its ease of mobility as well as compact without limiting its functionality and long lasting power [2].

This project focuses on mechanical design and depth controller for AUV. To complete this need to develop low cost AUV and fabrication for AUV in Underwater Technology Research Lab at UTeM. The subparts of developing an AUV are mechanical body construction, electrical and electronic circuit designing, AUV test run and report writing.

1.2 Motivation

In Malaysia, the underwater vehicle still not widely studied and investigated. Malaysia still considered far behind as compared to western countries due to some limitations like Ocean, underwater knowledge, high and efficient sensor technology. Western countries have many researchers, engineers and scientist who keeping design and develop unmanned vehicles for the underwater exploration purpose as shown in Figure 1.4. However, Malaysia still lack of knowledge and technology to carry out this AUV project.

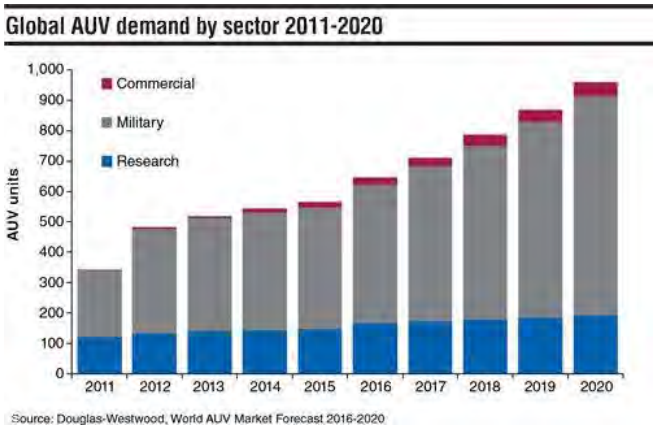

Figure 1.4: Forecast Global AUV demand by sector [4]

The ocean still has a lot of unidentified quantities which occupied approximately 71% of the surface of the Earth. So, there have many studies and growth about the underwater field include marine life environment and marine resources research and so on. The AUV investigation and navigation is not sufficient because underwater has low transparency and hard to observe the whole underwater life in detail [5].

Next, by referring to plane crashed case, MH370 which happen in the Indian Ocean. Malaysia needs to use technology from Australian country due to lack of technologies to detect splinter of the plane. Malaysia required to pay the commercial aid to relevant countries, while they actually used this chance to continue their further research [27].

Thus, the consequence of this project develops an AUV with low cost and good performance ready to join in any AUV competitions like Singapore AUV Challenge and Innovate. The project starts by design and fabricate following modifications, addition of basic sensor and common movement control.

1.3 Problem Statement

During the past few decades, a lot of engineers design and developed underwater vehicle to explore the depths of the deep sea and used in supervising marine environment and marine ocean life. Since the technology is getting an advance, integrated sensors AUV has been developing for advance growth in the military field by GPS and regulate the presence of mines in the seabed. Every 10m diving will raise one atmospheric pressure cause the water pressure stop from being stepped into the deep sea easily [6].

The AUV design is limited because the mechanical parts of AUV body must be strong enough to withstand the deep water pressure. Its body should be designed with hydrodynamic shape to ensure reduced the drag force exerted on it that will cause more power consumption. In Malaysia, the study of underwater technology lags behind western countries like USA, Russia, Japan and others. The tragedy MH370 submerge into Indian Ocean should be a warning to everyone about the importance of improving the technology in Malaysia [27].

AUV may loss during surveillance because autonomously navigate in the underwater seabed which is unpredictable and inherently dangerous. In depth motion control, AUV is particularly dangerous in vertical trajectory due to easier get inspected structure damage by crashing the bottom of the seabed. Thus, this project is developing to solve by improving the current AUV performance in terms of depth control and efficiency.

1.4 Objectives

Three objectives that required to achieved during this FYP;

1. To design and develop an AUV that able to float and submerge stabilized for underwater application.
2. To design a depth controller of the AUV at the desired depth with zero overshoot.
3. To study by evaluating and analysis the performance of an AUV in terms of maneuverability and movement.

1.5 Scope

The scopes and limitations of this project are:

a. The AUV is required in small size, dimension less than 70cm X 50cm X 50cm and lightweight less than 30Kg.
b. Power should be self-contained and tethers of any sort are not allowed.
c. The voltage of the power source used by each AUV should not exceed 24VDC.
d. AUV must be designed and developed with no danger of any kind to anyone or anything at the venue.
e. AUV has to swim underwater without surfacing or touching the bottom or wall.
f. The depth rating of the AUV is less than 3 meters from the water surface due to the limitation depth of a swimming pool and water leakage inside the hull.
g. The maximum duration for the AUV activity in underwater is 1 hour per cycle to prevent humidity hazards.
h. The microcontroller used is Arduino Mega, due to it has high processing power and up to 54 General Purpose Input Output pins.
i. Arduino Mega, MPX5700AP, 10 DOF IMU and ESC are tested for electronic sensor performance in underwater as shown in Figure 1.5.
j. 10 DOF IMU sensor is used as input for the tilt balancing mechanism of the AUV.
k. Increase the downward force (weight) acting on AUV to reduce the power used by thruster to submerge.

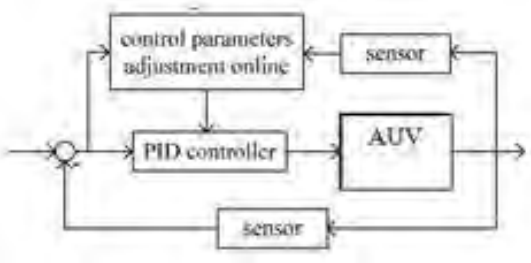

Figure 1.5: The Simple Block Diagram for AUV [3]

1.6 Organisation of Report

Chapter 2 is literature review which described the background theory which needed for this project. It also discussed the factors affecting an AUV followed by the mechanical design and electronic design. There are also the discussion and comparison between the previous AUVs project. For Chapter 3, methodology gives hardware in mechanical and electronic design and offerings the assembly AUV design chosen that were developed. There are comparisons between the shape and materials for mechanical parts.

Chapter 4 are results and discussion that described several simulations in the SolidWorks Xpress to help investigate the AUV. The simulation can be done through the SolidWorks toolbox to show the center of mass and stress-strain tests. Also, several tests on AUV in the swimming pool are to perform its performance. For Chapter 5, conclusion reviews the whole information in details for this project. There are also some suggestions for future work and recommendations.

1.7 Summary

This chapter concludes that the importance of an AUV in the water application. It summarized that the AUV platform is very limited because the requirement component specification is very critical like waterproof issue, imperfect accuracy and error. It focuses more on the new propulsion systems and batteries with high capacitance. The key to this enabling technology is the development of the optimum sensing and platform required, which are low cost, highly reliable, robust and environmentally friendly.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

It presents the background theory which required during the course in the previous study related to Autonomous Underwater Vehicle (AUV). The first section deals with theories and principles for design any types underwater vehicle. Next, it discussed mechanical design for underwater vehicles and also basic electronic information based on researchers' findings.

In early 1957, Stan Murphy, Bob Francois success to develop the first AUV and later on, Terry Ewart continued the project at the University of Washington. AUV development began in the 1960s at the University of Washington and made very large leaps in the early 1990s with the backing of Massachusetts Institute of Technology (MIT) and the Office of Naval Research (ONR). Next, more and more submersibles are designed and fabricated for different function as shown in Figure 2.1 [1, 2].

Figure 2.1: MIT Odyssey IV [2]

Generally, a submersible vehicle is no more a new impression. The first American submarine was called "Turtle" which built at Saybrook, in 1775 by David Bushnell and his brother, Ezra. In November of 1879, the Reverend George W. Garrett developed the first practical powered submarine, "Resurgam". It was powered by a Lamm 'fireless' steam engine, and could travel for some ten hours of power stored in an insulated tank.

2.2 Theories and Principle Apply

There are several theories and principles are required to discuss during AUV design processes like density, gravity and buoyancy, stability, pressure, hydrodynamic damping and added mass. The vehicle's ability to submerge is influence by buoyancy and density.

2.2.1 Density

Density is defined as the mass of an object per its volume. Mass is the quantity of matter confined in an object (kilograms, Kg) whereas Volume is the quantity of space taken up by a quantity of matter (cubic meters, m^3). Commonly, density can be used to define or determine the substance. This is important in determining how different materials interact when mixed together for AUV mechanical design as shown in Figure 2.2.

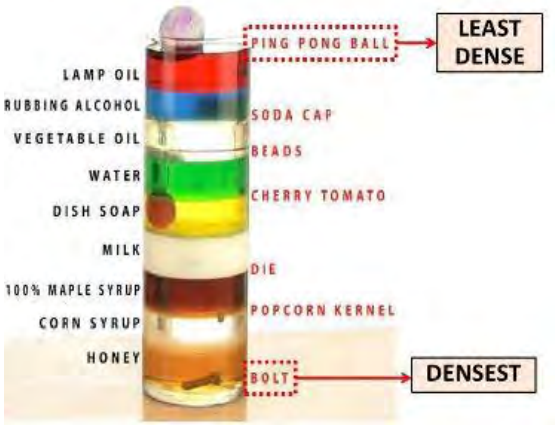

Figure 2.2: Density Test [8]

2.2.2 Buoyancy and Gravity (Archimedes principle)

Greek philosopher Archimedes discovered the Archimedes Principle, which proves the object absolutely or partially immersed in a liquid will exist by a buoyancy force which same as the weight of the water it dislocates. In other word, an AUV is submerged into underwater either fully or partially, there exists upward force on AUV that is same as the weight of the underwater that is displaced by the AUV [7].