"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 complied the partial fulfillment 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)

KHOR LI ZHE

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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I declare that this report entitles "**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 the candidature of any other degree.

Signature : .....

Name : KHOR LI ZHE

Date : .....

To my beloved mother and father

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ABSTRACT

In the 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. AUVs had upgraded their technology abilities which able to explore in deep seas. In Malaysia, the studies of the underwater vehicle are still far behind compared to western countries by referring to the case plane crashed MH370. This tragedy motivated the development of underwater research project especially AUV. One of the problems facing AUV which is the depth control and navigation system 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 and high-performance AUV with its depth control. In designing the AUV, Solidworks software is used and then the design of AUV undergoes various simulation tests such as stress, strain and displacement test. Next, the hardware that discussed and selected included frame, hull, enclosure box, propulsion and submersion that achieve a certain performance in terms of reliability and controllability. This project uses pressure sensor as depth control to determine the depth of AUV submerge. AUV uses thruster to move it along a vertical and horizontal axis that automatically operate based on the programming coding. In this project, the scope of the study focused on the mechanical design with the size (42.25cm X 55.48cm X 42.56) cm that waterproof and the submerge range of depth about 3 meters.

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. AUV telah menaiktarafkan kebolehan teknologi mereka yang dapat meneroka ke dalam laut. Di Malaysia, kajian kenderaan dalam air masih jauh ketinggalan berbanding dengan negara-negara Barat dengan merujuk kepada pesawat MH370 yang terhempas. Tragedi ini mendorong pembangunan untuk projek penyelidikan dalam air terutama AUV. 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 dengan kos rendah dan berprestasi tinggi dengan kawalan kedalaman. Dalam mereka AUV, perisian Solidworks digunakan dan kemudian menjalankan pelbagai ujian simulasi terhadap AUV seperti ujian tekanan and ujian anjakan. 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 untuk kawalan kedalaman bagi menentukan kedalaman AUV semasa menyelam. AUV menggunakan penujah untuk bergerak sepanjang paksi menegak dan mendatar yang automatik beroperasi berdasarkan pengaturcaraan. Dalam projek ini, skop kajian memberi tumpuan kepada reka bentuk mekanikal dengan saiz (42.25cm X 55.48cm X 42.56 cm) yang berkalis air dan kedalaman sebanyak 3 meter.

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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
WHOI	-	Woods Hole Oceanographic Institute
USM	-	Universiti Sains Malaysia
IMU	-	Inertial Measurement Unit
COM	-	Center of Mass
PVC	-	Polyvinyl Chloride
HDPE	-	High-density polyethylene
ESC	-	Electronic speed controller
PLA	-	Poly Lactic Acid
VON	-	Von Mises Stress

CHAPTER 1

INTRODUCTION

1.1 Introduction

Robotic submarine such as Unmanned Underwater Vehicles (UUV) has been designed and developed for the past few decades in various country and now UUVs have received the attention from Malaysia in underwater technologies. Fundamentally, it can be ordered into two sorts which is Remotely Worked Vehicle (ROV) and Autonomous Underwater Vehicle (AUV). AUV is an augmentation of the ROV's innovation, whereby ROV is guided by a human from the surface of water by utilizing the controller. On the other hand, AUV is controlled by its onboard controller guided by built-in pre-programmed command. This research is very challenging as the AUV must able to navigate and complete the task given without a human driver and remain no destruction. AUV design and commonly in torpedo-like geometry that will allow the streamlined flow [1] of water across the AUV body during underwater operation. This vehicle will have the ability to pitch vertically down itself with a depth control system by using a pressure sensor. This vehicle has thrusters for longitudinal direction propulsion like surge, sway and yaw control, some other thruster will do the heave control which is “vertical” force to move along the depth direction. Figure 1.1 shows the classification of UUV, which consist of AUV and ROV.

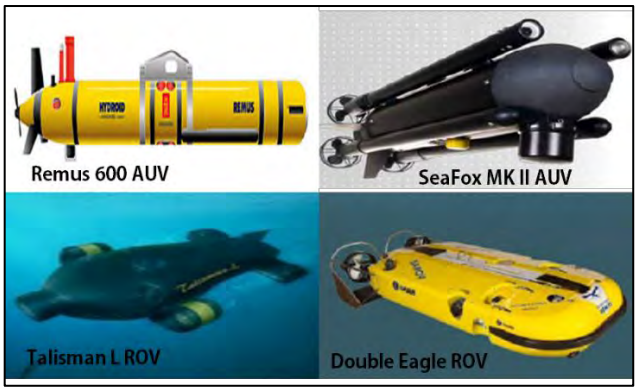

Figure 1.1: Types of Unmanned Underwater Vehicle [1]

This project is getting more and more important that shows the design implementation of an AUV for a multiplicity of research testbed platform in underwater technologies [2]. 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 size, the lightweight and the high maneuverability of this AUV are most important features that can make small AUV more suitable in shallow water to perform given tasks [3]. BlueROV is one of the remotely operated underwater vehicles from Blue Robotics product and consist of frame, watertight enclosure, thrusters, and speed controllers. This ROV is great when converting into AUV which is without human piloted.

This project focuses on converting a BlueROV mechanical design into an AUV design. Development of autonomous vehicle required an onboard computer and doing the task base on the command that set in programming. Furthermore, a depth controller for AUV and navigation controller also needs to be integrated into the vehicle. This ROV-AUV conversion needs to be held in Underwater Technology Research Lab at Ute for experimental test and fabrication purposes. Developing an AUV need a mechanical body construction by using Solidwork software for further 3D fabrication, and construct an electrical and electronic circuit design, and follow by 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. However, the outcome of this project should be a small, highly transportable and low-cost AUV, constructed to participate in AUV competitions and to provide a platform for future research. For purposes of economy, it is based on a former BlueROV, which was the product of BlueRobotics. Following modifications and conversion, navigation and depth sensor implementation, as well as motion control with the help of actuators controlled by onboard controller make the vehicle able to perform mission tasks autonomously. The conversion of this ROV to AUV is the first project constructed in this lab. The project is to save the cost by developing a new AUV. The conversion will add more features to the vehicle with direction drag minimize, design in symmetry, optimized thruster positioning, stability and optimizing AUV performance [4].

Next, by referring to plane crashed case, MH370 which crash into the Indian Ocean. Malaysia needs to use technology from Australian country due to lack of technologies to detect splinter of the plane. Malaysia required paying the commercial aid to relevant countries, while they actually used this chance to continue their further research [5]. Thus, the consequence of this project develops an AUV with highly transportable, small size and low-cost AUV to join in any AUV competitions like Malaysia AUV Challenge, Singapore AUV Challenge and Innovate. The project starts with design and fabricates following modifications, the addition of basic sensor and common movement control.

1.3 Problem statement

Designing and developed an 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. AUVs are now being used for a variety of tasks, including oceanographic surveys, demining, and bathymetric data collection in marine and riverine environments. Accurate navigation is essential to ensure the accuracy of the gathered data for these applications. Underwater communications are low bandwidth and unreliable, and there is no access to a global positioning system. Past approaches to solving the AUV localization problem have employed expensive inertial sensors, used installed beacons in the region of interest, or required periodic surfacing of the AUV [6]. While these methods are very expensive and large scale vehicle.

Motion control of AUV is very important because this may cause underwater vehicle loss during surveillance because autonomously navigate in the underwater seabed which is unpredictable and inherently dangerous. In motion control which includes heave, sway, surge and yaw of an AUV are particularly dangerous in horizontal and vertical trajectory due to easier get inspected structure damage by crashing to the stone and bottom of the seabed. Thus, this project is developing to solve by improving the current AUV performance in terms of motion control and efficiency.

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 a 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 the Indian Ocean should be a warning to everyone about the importance of improving the technology in Malaysia [5].

1.4 Objective

Three objectives that required to achieved during this FYP

1. To design and develop of Autonomous Underwater Vehicle (AUV) and based on Remotely Operated Vehicle (BlueROV).
2. To integrate the depth sensor and IMU sensor into AUV to follows the desired set point.
3. To investigate the performances of AUV in terms of speed.

1.5 Scope

a) Less than 70 cm × 50 cm × 50 cm and the weight is less than 40 kg in air.
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 limited depth of a swimming pool.
g) The maximum duration of the AUV activity in underwater is 1 hour per cycle to prevent humidity hazards.
h) The electronic parts used are microcontroller Arduino UNO, pressure sensor MPX5700AP, GY-80 IMU sensor and speed controller (ESC)
i) GY-80 IMU sensor is used as input for the one-axis tilt balancing mechanism of the AUV.

1.6 Organization of Report

Chapter 1 is the introduction and some motivation of the project. The introduction is to overview some basic operation of an underwater vehicle and the different between ROV and AUV. Thus motivation is based on current problem statement that needs to be solved.

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 was chosen that were developed. There are comparisons between the shape and materials of mechanical parts.

Chapter 4 are results and discussion that described several in the SolidWorks to help fabricate the AUV's parts. 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.

In Chapter 5, conclusion for the entire progress for this project. There are additionally a few proposals for future work and suggestions for the coming semester.

1.7 Summary

AUV is a very important water application that will give a lot of benefits. Conversion of ROV in UTeM Underwater Lab is very important for the previous designed ROV to become a new technology AUV. It summarized that the AUV platform is very limited in Malaysia because the requirement component specification is very critical like a 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

Autonomous Underwater Vehicle are generally battery powered and convey its own particular computer. This locally available computer is the necessity for their self-governing conduct. They pick up data from their sensors for route and mission assignments. The Autonomous Underwater Vehicle advancement started in the 1960s at the College of Washington and made substantial jumps in the mid-1990s with the sponsorship of Massachusetts Establishment of Innovation (MIT) and the Workplace of Maritime Exploration (ONR). The MIT AUV Lab created the AUV which could be complete numerous underwater missions. MIT has now developed the Odyssey IV which is the latest iteration of AUV in MIT. Another institute which is Woods Hole Oceanographic Institute (WHOI) also played important roles in design and development AUV. Their fleet of AUVs are the cutting edge of underwater autonomy and with the worldwide capability WHOI has, their work is some of the most highly respected oceanographic research in the world. This important research drives AUV development forward every year and with more advanced technologies and features.

AUVs have numerous purposes. Most involve research but others can involve search and rescues, object identification, water sampling, mapping, communication, and control research. AUVs can go places where is to too dangerous or expensive for humans to go. They can take numerous samples for research without human interaction. Although AUVs are expensive pieces of hardware, the information they gather can be invaluable.

2.2 Theories and Principle Apply

There are several theories and principles are required to discuss during AUV design processes like density, the center of gravity, buoyancy, stability, hydrostatic pressure, and mass of the vehicle. 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 to an object (kilograms, Kg) whereas Volume is the quantity of space taken up by a quantity of matter (cubic meters,m^3). Basically, density can be used to define or determine the substance. This is important to relate the type of material use and its density. As all the parameters in the model are based on the physical parameters of the motor, propeller, and fluid density (***p*** = l000 kg/m3) need to consider [7]. By knowing the density of the material use and we can select the best and suitable material for AUV. Density control is very important to allow AUV in good depth control and motion control. Figure 2.0 shows the difference between different materials.

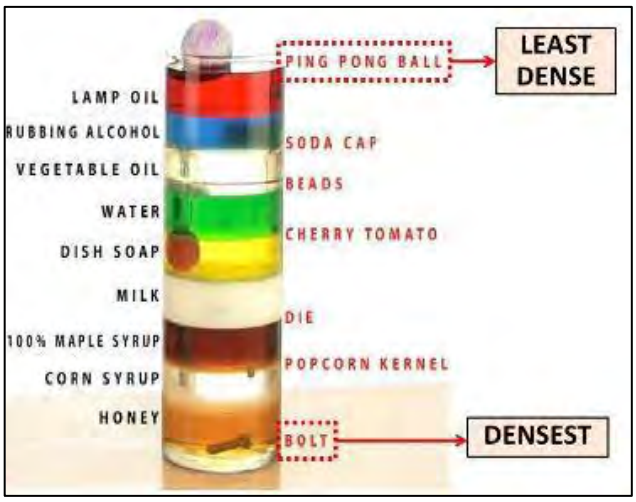

Figure 2.1: Density of different material [7]

2.2.2 Center of Mass

Center of mass is defined as the mass-weighted average of the positions of particles and the center of mass is a statement of the spatial arrangement of mass. Basically, the center of mass is the distribution of mass in a particular object. For the underwater vehicle is very important to have an accurate center of mass this is because of differential actuation is obtained by making the propellers of each pair of motors, horizontals, and verticals, actuate with different forces to obtain torques about the center of mass [3]. Center of mass will easily affect when designing a manipulator to the body of AUV. Thus the stability and balancing of the vehicle are depending on the center of mass of the whole structure design of the AUV. Figure 2.1 shows the plump line method to draw center of mass.

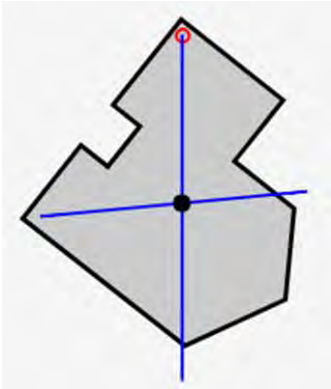

Figure 2.2: Plump line method

2.2.3 Buoyancy

Buoyancy or Buoyant force is a natural phenomenon that occurs according to Pascal's Principle. This principle states that the pressure is a function of the static fluid pressure which is dependent on the vertical location at which the pressure occurs. According to 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 another word, an AUV is submerged in 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 [8].