DESIGN AND DEVELOPMENT OF AUTONOMOUS UNDERWATER VEHICLE (TUAH 4.0) FOR UNDERWATER MONITORING APPLICATION

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DESIGN AND DEVELOPMENT OF AUTONOMOUS UNDERWATER VEHICLE (TUAH 4.0) FOR UNDERWATER MONITORING APPLICATION

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DECLARATION

I declare that this thesis entitled "DESIGN AND DEVELOPMENT OF AUTONOMOUS UNDERWATER VEHICLE (TUAH 4.0) FOR UNDERWATER MONITORING APPLICATION "is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : --

Name : --

Date : --

APPROVAL

I hereby declare that I have checked this report entitled “DESIGN AND DEVELOPMENT OF AUTONOMOUS UNDERWATER VEHICLE (TUAH 4.0) FOR UNDERWATER MONITORING APPLICATION” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Underwater vehicle has been developed and improved for decades in various designs and new innovations. Autonomous underwater vehicle (AUV) is also known as unmanned underwater vehicle is operated with little to no human intervention, conducts mission automatically and returns to a pre-programmed location by using integrated program. Underwater vehicle application and development still not widely apply and studied although Malaysia is a nation which surrounded by seas and full with rivers and lacks. An AUV that can help in underwater monitoring and searching is needed to make the operation easier as well in danger situation underwater. This project is focused on designing a new design of AUV named TUAH 4.0 for underwater monitoring application. TUAH 4.0 is designed using SolidWorks software and undergoes simulation such as center of mass, stress and strain test. A special frame design named X-wing type frame is developed for TUAH 4.0. TUAH 4.0 is operated with 6 thrusters which enable 5 degree of freedom motion. Sensors such as inertia measurement unit and depth sensor are used to control the movement of the TUAH 4.0 as feedback. TUAH 4.0 is controlled by Arduino MEGA and Raspberry PI 3 B+. Experiments are performed to verify the TUAH 4.0's performance such as speed, heading and depth control. The maximum speed for TUAH 4.0 is $0.53ms^{-1}$with maximum PWM set at 1800. TUAH 4.0 can submerged maximum depth of 3 meters due to limitation of the swimming pool. The yaw and pitch control system of TUAH 4.0 is developed using bang-bang controller method for heading control. Correcting angle can be set from $\pm 10^{o}$ to $\pm 20^{o}$ for the heading control. TUAH 4.0 can maintain well straight line movement and desired depth control. TUAH 4.0 is successfully developed.

ABSTRAK

Kenderaan dalam air telah dimajukan dan dibangunkan selama beberapa dekad dalam pelbagai reka bentuk dan inovasi baru. Autonomi kenderaan dalam air (AUV) juga dikenali sebagai kenderaan dalam air tanpa pemandu dikendalikan dengan sedikit atau tiada campur tangan manusia, menjalankan misi secara automatik dan kembali ke lokasi yang pra-diprogramkan dengan menggunakan program bersepadu. Permohonan dan pembangunan kenderaan dalam air masih tidak meluas dikenakan dan dibelajar walaupun Malaysia adalah sebuah negara yang dikelilingi oleh laut dan penuh dengan sungai dan kekurangan. AUV yang boleh membantu dalam pemantauan air dan pencarian diperlukan untuk memudahkan operasi yang bahaya dalam air. Projek ini memberi tumpuan kepada mereka bentuk dan membangunkan AUV yang bernama TUAH 4.0 untuk aplikasi pemantauan air. TUAH 4.0 adalah direka menggunakan perisian SolidWorks dan menjalani simulasi seperti pusat jisim, tekanan dan ketegangan. TUAH 4.0 ini dikendalikan dengan 6 tujahan yang membolehkan darjah 5 gerakan kebebasan. Sensor seperti unit pengukuran inersia dan sensor kedalaman digunakan untuk mengawal pergerakan TUAH 4.0 sebagai maklum balas. TUAH 4.0 dikawal oleh Arduino MEGA dan Raspberry PI 3 B+. Eksperimen dilakukan untuk mengesahkan prestasi TUAH 4.0 seperti kelajuan dan kedalaman. Kelajuan tertinggi TUAH 4.0 ialah $0.53ms^{-1}$ dengan PWM tertinggi 1800. TUAH 4.0 boleh menyelam kedalaman maksimum 3 meter kerana batasan kolam renang.Sistem kawalan yaw dan pitch TUAH 4.0 dibangunkan menggunakan kaedah pengawal bang-bang untuk mengendalikan kawalan. Sudut pembetulan boleh ditetapkan dari $\pm 10^{o}$ hingga $\pm 20^{o}$ untuk kawalan tajuk. TUAH 4.0 boleh mengekalkan pergerakan garis lurus dan kawalan kedalaman yang diinginkan.TUAH 4.0 berjaya dibangunkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
AUV	-	Autonomous Underwater Vehicle
ROV	-	Remotely Operated Vehicle
IMU	-	Inertial Measurement Unit
ESC	-	Electronic speed controller
FOS	-	Factor of safety
COM	-	Centre of mass
PVC	-	Polyvinyl Chloride
PLA	-	Polylacitc Acid
VON	-	Von Mises Stress
m	-	Mass
V	-	Volume
F_b	-	Buoyant force
ρ	-	density
g	-	Gravitation acceleration
T	-	Torque
HP	-	Horsepower
RPM	-	Rotation per minute
F_h	-	Hydrostatic force
d	-	Depth
A	-	Surface area
r	-	Radius
F	-	Force
PWM	-	Pulse Width Modulation

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Underwater is still not completely explored fully and not easily accessible by humans. Underwater vehicle has been developed and improved for decades in various designs and new innovations. There two major type of underwater vehicle such as remotely operated vehicle (ROV) and autonomous underwater vehicle (AUV). ROV is an unoccupied underwater robot that connected to a ship or terminal via cables. The cables transmit signals and commands for controlling and feedbacks of the ROV allowing remote navigation. AUV is also known as unmanned underwater vehicle which is very suitable for survey missions. AUV is operated with little to no operator intervention. AUV can conducts mission automatically and returns to a pre-programmed location by using integrated program. AUV is a more advanced system compared to ROV. AUV are controlled by onboard sensors such as sonar, depth sensor and inertia measurement unit (IMU). AUV has thrusters, propellers or wings to control its motions. Size of the underwater vehicle is crucial when completing operations in shallow water or constricted environment.

The project main focused on designing new design of AUV (TUAH 4.0) which based on previous products that have been developed by the UTeM Underwater Research Laboratory such as TUAH 1.0 and TUAH 2.0. The improvements are on better thruster placement, speed and motion control. Experimental tests are done to verify the performance of the new AUV (TUAH 4.0).

1.2 Motivations

Underwater vehicle application and development still not widely apply and studied although Malaysia is a nation which surrounded by seas and full with rivers and lacks. In the incident of MH370 crashing into the ocean and currently nowhere to be found, Malaysia is aided by other countries especially Australia for their underwater vehicle technologies to search for the missing plane under the sea because Malaysia still unable to conduct the searching using its own technology. [1] Although underwater searching can also been done by human divers, accident can be happened that can endanger the life of the divers. For example in the incident of a South Korean ferry that sank in April 2014, one civilian diver died after becoming unconscious as searching for the remains of dozens aboard the ferry under the sea. [2] Six Fire and Rescue Department divers died while on a rescue mission for a teen who was feared drowned after falling into a mining pond in Taman Putra Perdana, Puchong, in October 2018. [3].

An underwater vehicle such as autonomous underwater vehicle (AUV) that can help in underwater monitoring and searching is needed to make the operation easier as well in danger situation. The project is to development an AUV which is small and low cost that can be used for research and competitions such as Malaysia AUV Challenge and Singapore AUV Challenge.

1.3 Problem Statement

Designing and developing underwater vehicle has been improved in term of design and technology through the decades. Studies on AUV in Malaysia are less compare to popular drones and robots. Autonomous Underwater Vehicle (AUV) is has been used in survey operation and underwater monitoring. Power management for an AUV is important so that the underwater operation time will be longer. Developing and buying an AUV is expensive. Sensors used in AUV are costly. [4] Design and analysis on AUV using specific software is not studied in details.

As to improve power management, low power and higher efficient thrusters are needed. Smart placement of thrusters and aerodynamic frame design are important to increase performance such as stabilization. Autonomous motion control of the AUV is aided by the feedback of sensors. The sensors are to let the AUV notice its current environment and react to it by the control system. The AUV should be achieving certain amount of motions such as surge (moving forward and backward on the X-axis), sway (moving left and right on the Y-axis), Heave (Moving up and down on the Z-axis), Roll (tilting side to side on the X-axis), Pitch (tilting forward and backward on the Y-axis) and Yaw (turning left and right on the Z-axis). The AUV should be navigate by itself throughout the task.

The disadvantages that TUAH 1.0 and TUAH 2.0 are the lack of pitching control. The lack of pitching control causes TUAH 2.0 pitching is fully maintain by the centre of mass which is very not stable. It will lead to operation failure due to drifting of the heading angle of the AUV. A better rotational motion control has to be introduced to TUAH 4.0 to solve this problem.

Water proofing of AUV is difficult. The structure of the AUV should be able to withstand pressure underwater. Electrical components of the AUV have to be water-proofed or water-resistant to avoid any short circuit that can eventually damage the AUV and render the underwater operation unsuccessful. The size of the AUV should small and transportable.

1.4 Objectives

Three objectives that are required to be achieved during this project

1) To design and analysis an autonomous underwater vehicle (AUV) by using SolidWorks software

2) To develop and fabricate a stabilization system for the AUV’s yaw, roll and pitch control by using microcontroller and integrated sensors for underwater monitoring application.

3) To analyze the overall performances of AUV in terms of speed, heading control and depth control.

1.5 Scope and limitations

1) The autonomous underwater vehicle (AUV) is controlled by Arduino MEGA which consist of 54 digital I/O pins and 16 analog inputs

2) The autonomous underwater vehicle (AUV) consisted of 6 T100 Thrusters. The thruster capable of rotating in minimum speed of 300 rev/min and up to maximum speed of 4200 rev/min. The thruster operates between 6 to 16 volts.

3) The stabilization system consists 6 Degree of Freedom (DoF) Inertia measurement unit (IMU) and depth sensor.

4) The autonomous underwater vehicle (AUV) is waterproof under 3 meter depth. All components excluding the thrusters are placed inside the pressure hull.

5) The autonomous underwater vehicle (AUV) is built with dimension based on Malaysia AUV challenge 2018.

6) The autonomous underwater vehicle (AUV) will be tested at controlled environment such as lab tank and swimming pool.

1.6 Organization of Report

Chapter 1 is the introduction and some motivation of the project. The introduction is to introduce the basic feature of an AUV. Motivation are based on current problem statement that needs to be solved. Objectives and scope of the project are given.

Chapter 2 is literature review which described the theory needed to complete the project. Comparison between designs of AUVs are discussed in details. Mechanical, electrical and software descriptions are between described.

Chapter 3 is methodology gives description of the hardware and software design of the project. Details on procedure for simulations and experiments are explained in details.

Chapter 4 is results and discussion that described the overall project outcome in term of design and development of the AUV. Simulations and experiments results are been analysed and discussed in full scale

Chapter 5 is conclusion form the completion of the project. There are additionally suggestions for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Autonomous Underwater Vehicle (AUV) has a big range of application in scientific research, military, commercial and rescue all around the world. AUV are mostly powered by battery which is small and portable and consists of some computer system inside. With this computing power and the aid of sensors, AUV can collects data throughout the mission. AUVs can also make decisions on their own, changing their mission profile based on environmental data they receive through sensors. There are many institutes and companies which is focused on AUV research and development. ECA group from France designs and provides long-endurance AUV solutions for underwater missions up to 3000m depths. Woods Hole Oceanographic Institution (WHOI) which produced many variety of innovative AUV design throughout the years.

2.2 Theories and Principle Apply

There are theories and principles that needed to be discussed and taken into use during the development of the design of the AUV.

2.2.1 Density

Density is the measure of mass per volume of an object or medium shown in (2-1). Density is very important for the material used for the construction on the AUV especially the hull and frame of it. In the medium which has free moving particles, higher density will sink to bottom of the medium and lower density will float to the surface of the medium due to gravity. AUV which mostly operates in the water (p = l000 kg/m3) and seawater (p = l030 kg/m3) have to maintain and control its overall density so that the AUV can maneuver without too much resistant caused by the difference in density.