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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

ANALYSIS ON THE EFFECT OF WING GEOMETRY ON UNDERWATER GLIDER HYDRODYNAMICS

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ANALYSIS ON THE EFFECT OF WING GEOMETRY ON UNDERWATER GLIDER HYDRODYNAMICS

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing System Engineering)

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2017

DECLARATION

I declare that this thesis entitled "Analysis on the effect of wing geometry on Underwater Glider Hydrodynamics" 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 any other degree.

Signature : ....

Name : EENTRI A/P EH CHU

Date : 6/4/2017

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfilment of Master of Manufacturing Engineering (Manufacturing System Engineering).

Signature : ....

Supervisor Name : DR FAIRUL AZNI BIN JAFAR

Date : 6/4/2017

DEDICATION

To my beloved mother and father

ABSTRACT

Unmanned Underwater Vehicle (UUV) has proven very useful in applications including defense system, seabed pipeline inspection, surveillance and exploration. Fin system in Unmanned Underwater Vehicle (UUV) is one of the important components in UUV which will guide the navigation and influence the trajectory flow of UUV. However, current research conducted on the feasibility and possibility using flexible wing system in UUV is limited. The objective of this project is to propose few design concept wing system in UUV, to analyze and select a suitable design concept for the wing system by using Analytical Hierarchy Process (AHP) and evaluate the feasibility of the proposed design concept in Underwater Glider by SolidWorks simulation. Nowadays, adaptive and morphing structures in complex aerospace vehicle have experienced a huge research due to their ability to optimize the stability of spacecraft's navigation control. Such adaptive and morphing structures have been investigated heavily and put to use extensively in the spacecraft industry. However, there are some considerations and limitations on the design of flexible wing system due to the wing geometry and unknown hydrodynamics in underwater. One of the considerations is how to define which designs of flexible wing system is the most suitable in UUV. In this study, AHP method was used to investigate the most suitable design of flexible wing system of UUV. SolidWorks simulation was used to demonstrate the effect of wing geometry in terms of buoyancy force, UUV's speed, endurance of proposed flexible wing system and underwater hydrodynamic flow trajectory. The simulated results clearly demonstrate the feasibility of proposed flexible wing system in Underwater Glider.

ABSTRAK

Kenderaan dalam air tanpa pemandu (UUV) merupakan kenderaan yang sangat berguna dalam aplikasi sistem pertahanan, pemeriksaan saluran paip dasar laut, pengawasan dan penerokaan. Sistem sayap pada UUV adalah merupakan salah satu komponen penting dalam UUV yang akan membimbing navigasi dan mempengaruhi aliran trajektori UUV. Walaubagaimanapun, penyelidikan terkini yang dijalankan terhadap kemungkinan penggunaan sayap fleksibel pada UUV adalah terhad. Objektif projek ini adalah untuk mencadangkan beberapa konsep rekabentuk sistem sayap pada UUV, untuk menganallisa dan memilih konsep rekabentuk yang sesuai untuk sistem sayap dengan menggunakan Proses Analisis Hierarki (AHP) dan menilai kebolehlaksanaan konsep rekabentuk yang dipilih terhadap glider bawah air dengan menggunakan SolidWorks. Pada era ini, penyesuaian dan perubahan struktur di dalam kenderaan aeroangkasa kompleks telah dikaji kemampuan mereka untuk mengoptimumkan kestabilan kawalan navigasi kapal angkasa. Struktur penyesuaian dan perubahan tersebut telah dikaji sepenuhnya dan digunakan secara meluas dalam industri kapal angkasa. Walau bagaimanapun, penyelidikan yang dijalankan keatas sistem sayap fleksibel adalah terhad dalam aplikasi maritim. Terdapat beberapa pertimbangan dan had ke atas rekabentuk sistem sayap fleksibel kerana geometri sayap dan hidrodinamik tidak diketahui di dalam air. Salah satu pertimbangan adalah bagaimana untuk menentukan bentuk sistem sayap fleksibel yang paling sesuai pada UUV. Dalam kajian ini, kaedah AHP telah digunakan untuk memilih sistem sayap fleksibel UUV yang paling sesuai. Simulasi SolidWorks telah digunakan untuk menunjukkan kesan geometri sayap dari segi daya keapungan, kelajuan UUV ini. Hasil dapatan simulasi telah menunujukkan dengan baik akan keapungan sistem sayap fleksible yang dicadangkan dalam Glider bawah air.

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AHP	-	Analytic Hierarchy Process
AUV	-	Autonomous Underwater Vehicle
kg	-	Kilogram
mm	-	Milimeter
m	-	Meter
ROV	-	Remotely Operated Underwater Vehicle
UG	-	Underwater Glider
UUV	-	Unmanned Underwater Vehicle

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter describes the purpose of this project generally. Started with problem according to current issues, and translated it into problem statement. Then, the objectives of the project are established to overcome the problem statement. Project scopes will state all the scopes and limitation on this project.

1.1 Motivation

Malaysia is situated at the strategic position in region of Southeast Asia and Singapore, South China Sea and Sulu Sea. Malacca Strait is conclude as a narrow and shallow water area with average 53km depth where south of strait has average 40km depth more shallow than northern, average depth about 66km. There are many of the maritime activities available along the strait. Henry (1989), this strait seeks adequate protection to avoid piracy and influences due to highest priorities of marine resource defend and protection.

Zoran et al. (2002) stated that Unmanned Underwater Vehicle (UUV) is useful in ocean technology which are consist a lot of ocean activities, such as defense system, seabed pipeline inspection, surveillance and exploration. Flexible wing or adaptive morphing structures are wisely used in navigation control system of aerospace's vehicle. In oceanography, fixed wing system of UUV mainly is to stabile the vehicle where the stability of UUV always influenced by unknown hydrodynamics in the sea (Eriksen et al., 2001). However, current research conducted on the feasibility and possibility using flexible wing system in UUV is limited. Nowadays, adaptive and morphing structures in complex aerospace vehicle have experienced a huge research due to their ability to optimize the stability of spacecraft's navigation control.

In this project, Analytic Hierarchy Process (AHP) is used to choose the most suitable design of wing system of UUV. According to Saaty (2008), the main advantage of

AHP over others multi criteria method are its flexibility which act as decision maker since it has the ability to do a consistency test. Generally, consistency test is result by straightforward data which name with "comparison pair-wise".

Lastly, in order to demonstrate the performance of the selection wing system which produces by AHP method, SolidWorks simulation will be done. Simulation will carry out to investigate the flow trajectory of selected wing system in UUV in terms of wing geometry, buoyancy force, UUV's speed, endurance of selected wing system and underwater hydrodynamic flow trajectory. The simulated results should clearly demonstrate the feasibility of proposed wing system in Underwater Glider.

1.2 Problem Statement

Current technology has allowed UUV to excel at tasks including deep-sea diving, high-speed motion and long distance traversal. The low-speed, high maneuverability operations required of many near-shore, and littoral zone missions present different mobility challenges that may require different solutions. Flexible fins are an attractive alternative to thrusters for overcoming the difficulties associated with low-speed maneuverability in the presence of ocean currents and near-shore obstacles.

However, flexible fin system is a concept that has limited research in the area of maritime applications. There are some considerations and limitations on the design of flexible wing system due to the wing geometry and unknown hydrodynamics in underwater. One of the considerations is how to define which designs of flexible wing system is the most suitable in UUV. Therefore, a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology must be carried out to investigate the suitable design of flexible wing system in UUV. Then, the design must be proven though a simulation, based on the demonstration of the effect of wing geometry, underwater hydrodynamic and underwater pressure flow trajectory before it can be implemented in UUV.

1.3 Objectives

The objective of this project is:

i. To propose few design concept wing system in UUV.

ii. To analyze and select a suitable design concept for the wing system by using Analytical Hierarchy Process.

iii. To evaluate the feasibility of the proposed design concept in Underwater Glider by SolidWorks simulation.

1.4 Scope of Project

There will be four types of flexible wing system that are going to be proposed in this research work. The main scope of this project is analysing the effect of Wing Geometry on Underwater Glider Hydrodynamics. AHP method is used to investigate the most suitable design of the wing system in UUV by considering the wing's performance in terms of:

i) Controllability

ii) Material

iii) Position

In order to evaluate the performance of selected wing system, SolidWorks is used to demonstrate and simulate the flow trajectory. Only simulation analysis will be carried out and no experimental analysis will be done. Analysis done by considering the following parameter in simulation results:

i) Pressure

ii) Buoyancy

iii) Speed

iv) Depth

1.5 Significant of Study

The method and result of this project can be referred to UTeM UUV research group in order to do a selection not only wing system but the others part of UUV. Furthermore, the result of this project can be implemented in UTeM UUV obstacle avoidance system in the future.

1.6 Thesis Structure

Chapter 1 is the introduction of the project. Under this chapter, there have six subtitles which are motivation, problem statement, objectives, scope, significant of study and thesis structure.

Chapter 2 is all about literature review. This chapter comprises information about the Unmanned Underwater Vehicle (UUV), Analytical Hierarchy Process (AHP) and SolidWorks simulation.

Chapter 3 describes important information regarding AHP and SolidWorks simulation. Develop an AHP hierarchical framework for the selection of wing system.

Chapter 4 describes the step to construct an AHP, select the suitable design concept and evaluate the feasibility of the proposed design concept in Underwater Glider by using SolidWorks simulation.

Chapter 5 is all about the conclusion of the project.

CHAPTER 2

LITERATURE REVIEW

This chapter describes more information regarding unmanned underwater, underwater glider, fin system, AHP and SolidWorks Simulation. All the knowledge from research will be used as references for this project.

2.1 Unmanned Underwater Vehicle (UUV)

UUV has been used in many applications including defense system, seabed pipeline inspection and surveillance application. UUV is a robot that travels without any an operator in the water. An unmanned underwater vehicle such as Remotely Operated Underwater Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) does not need existing of human inside the vehicle to control it. ROV was control by human from distance using radio or electric signal while AUVs are programmed on the surface of water, then it will navigate through the water on their own and collecting the data.

According to Russon (2014), Unmanned Submarines or Unmanned Underwater Vehicle, were crucial in order to find the black box of Air France Flight in Atlantic Ocean in the year of 2009. Remus 6000 as shown in Figure 2.1 is the only submarine vehicle that can perform deep water searching operation, and it also used to search MH370 flight from Malaysian Airlines. Table 2.1 describes the differences in specification between ship, ROV, AUV and UUV.

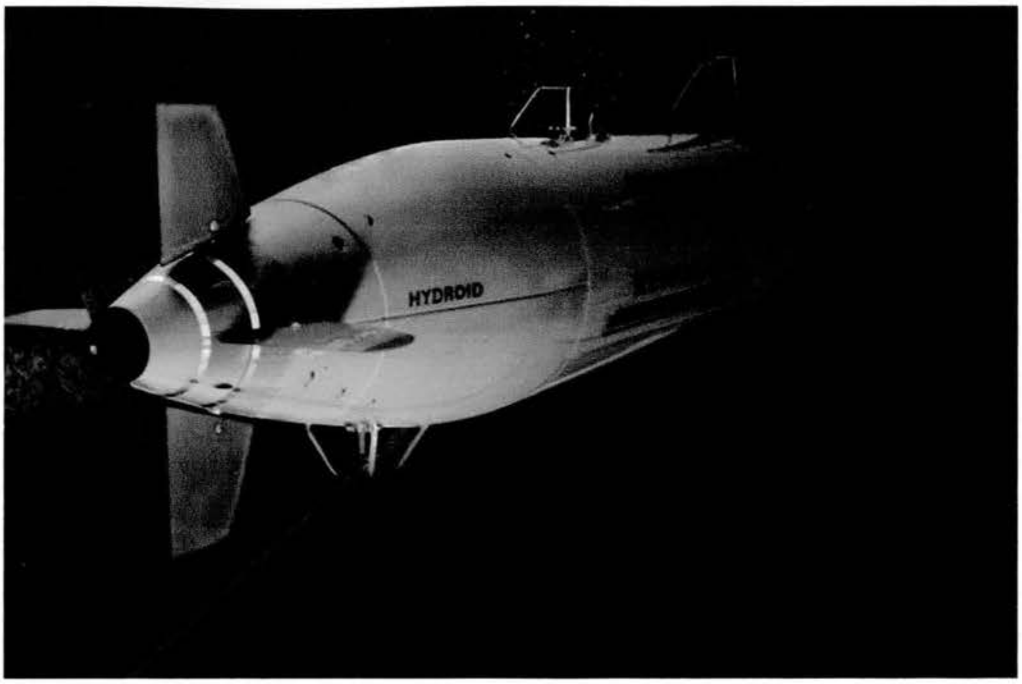

Figure 2.1: Remus 6000 Underwater Submarines (Russon, 2014).

Table 2.1: Comparison on Type of Unmanned Underwater Vehicle (Eriksen et al., 2001)

Unmanned Underwater Vehicle	**Specifications**
Submersible Towed by Ship	Ship act as platforms for various sensor suites attached to the vehicle frame
ROV	It connect directly to the mother ship or subsea satellite platform through a tied power and communication cable that controlled directly by a remote operator
UUV	Require some communication level to complete its assigned mission
AUV	Have modified tethered like fiber-optic cable or none