THE INFLUENCE OF BLADE PARAMETERS CONFIGURATIONS ON THE PERFORMANCE OF THRUST POWER FOR AUV APPLICATION

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Hons.)

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DECLARATION

I declare that this project report entitled "The Influence of Blade Parameters Configurations on The Performance of Thrust Power for AUV Application" is the result of my own work except as cited in the references.

Signature : ....

Supervisor's Name : PHARAWUS A/L ACHUAN

Date : 14 JUNE 2019

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons).

Signature : ....

Name : DR. MASJURI BIN MUSA@OTHMAN

Date : 14 JUNE 2019

DEDICATION

To my beloved mother and father

Eput A/P Din Chom & Achuan A/L Din Proom

ABSTRACT

In general, the project revolves about the configuration and analysis of propeller blade parameters on the performance of thrust power for Autonomous Underwater Vehicle (AUV) application. The study and analysis carried out is intended to find the optimum propeller blade configuration for the AUV performance in terms of stream velocity output and thrust power. The technique of modeling and simulation by using Computer Aided Design (CAD) software to manipulate the parameters configurations that come out with 32 designs of blade propeller is the best methods to get the effective optimum designs. From the study conducted, there are only research on each parameters of propeller blade but no research on the blade parameters configuration was found. Therefore, Computer Fluid Dynamic (CFD) has been used in this project as a medium for analyzing new parameters configuration for optimum performance of propeller blade. The study goes on to produce a propeller blade with new parameters configuration for AUV which the optimum thrust power produced. In additional, the data generated by the CFD analysis and calculated thrust power has been studied and the design with optimum thrust power has been identify while further work is to run the experiment as a method to test theories and hypotheses about how physical processes of this analysis work.

ABSTRAK

Secara umum, projek ini menyentuh tentang konfigurasi dan analisis parameter bilah kipas mengenai prestasi kuasa tujah untuk aplikasi Kenderaan Bawah Air Autonomi (AUV). Kajian dan analisis yang dijalankan bertujuan untuk mencari konfigurasi bilah kipas yang optimum untuk prestasi AUV dari segi output aliran dan daya tujahan. Teknik pemodelan dan simulasi dengan menggunakan perisian Reka Bantu Peranti Komputer (CAD) untuk memanipulasi konfigurasi parameter yang keluar dengan 32 reka bentuk kipas adalah kaedah terbaik untuk mendapatkan reka bentuk optimum yang berkesan. Dari kajian yang dijalankan, hanya terdapat penyelidikan pada setiap parameter bilah kipas tetapi tidak ada penyelidikan pada konfigurasi parameter yang dijumpai. Oleh itu, Dynamic Fluid Computer (CFD) telah digunakan dalam projek ini sebagai medium untuk menganalisis konfigurasi parameter baru untuk prestasi optimum bilah kipas. Kajian ini menghasilkan bilah kipas dengan konfigurasi parameter baru untuk AUV yang dihasilkan oleh daya teras yang optimum. Di samping itu, data yang dihasilkan oleh analisis CFD dan kuasa tujahan dikira telah dikaji dan reka bentuk dengan kuasa teras optimum telah dikenalpasti manakala kerja selanjutnya adalah untuk menjalankan percubaan sebagai kaedah untuk menguji teori dan hipotesis tentang bagaimana proses fizikal analisis ini bekerja.

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In additional, I would like to thank my course mates for giving me their support, patience and encouragement to complete this project. Lastly, I would like to thank my family who always on my side and giving their full support from the beginning till the end.

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LIST OF SYMBOLS

T	-	Thrust
D	-	Propeller diameter
v	-	Velocity of incoming flow
ρ	-	Density of fluid
Δv	-	Additional velocity, acceleration by propeller
P	-	Thrust power
N	-	No. of blade
Θ	-	Blade angle
HTR	-	Hub to tip ratio (hub radius/propeller radius)
L	-	Nose cone length
R	-	Nose cone radius
v_o	-	Stream velocity outlet
g	-	Gravitational gravity
z	-	Elevation
p	-	Pressure
F	-	Thrust force
A	-	Surface area

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Autonomous Underwater Vehicle (AUV) was developed in 1957 by Stan Murphy and Bob Francois at the University of Washington to overcome the limitation of human capabilities into water especially deep sea. Deep sea in the ocean are very dangerous that sometimes can cause death to human. The AUV have created to explore and discover underwater world without make harm to human and at the same time reduce the limitation and increase the capabilities of human. Most of this vehicle have been used in military field, inspection of cracks on the underwater section of the ship, oil and gas industry, telecommunication and mineral exploration and the expedition to explorer under the deep ocean.

The AUV in military has been created and plays an important job to counter the danger from underwater by using advanced control systems, navigation systems and sonars to protect and detect any harms or enemy. The vehicle can operate in both shallow and deep sea, and allows exact detection, classification and coordination of any searching objects while the controller and others crew remain in a safe place and distance. After the AUV has completed the mission, military officers can enter the area with detailed information of the threat.

Though still a very small part of AUV usage in commercial sector like oil and gas industry that has been operated over 100 years. Oil and gas industry supplies energy to human in form of petroleum and gaseous by drilling to the resource cover up underground such as deep sea and transport it by using pipelines. In order to work in deep water that has a dangerous environment and can harm the human to operate, a robot plays an important job. An

Autonomous Underwater Vehicle (AUV), which is a kind of a robot is used for equipment installation, operation and maintenance.

AUV can operate automatically and travels underwater by diving from the surface to deep sea and reverse. System of AUV can be compact, portable and small or they can be long-endurance and very large systems. Autonomous Underwater Vehicle basically bring power such as batteries, fuel cells or rechargeable solar power onboard in the body that design aerodynamically like a sub-marine. The power onboard are uses to operate all sensors on the AUV and to move the propellers or thrusters. Certain AUV minimize energy demands by allowing buoyancy and gravity to impel them and can reach shallow sea that boats can't and deep that human divers or other vehicles can't. AUV are safe from bad weather once deployed and underwater.

To enable AUV move in water, propellers or thrusters play an important role. Propellers is a mechanical device consists of several twisted and air-foil shaped blades that rotates and produce pressure differential between the blades to accelerate the fluid and provide thrust in opposite direction to propel the AUV. There are several parameters of blades will affect the performance of propeller need to be consider such as the radius of blade, the chord of the propeller and radius of hub.

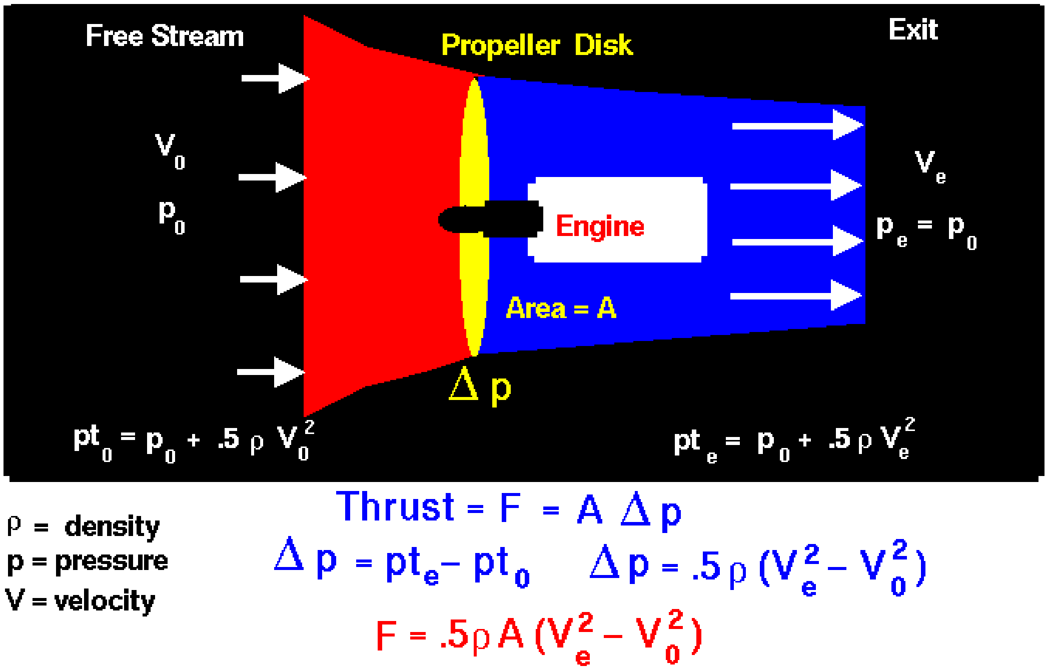

Figure 1.1: Propeller Thrust (Source: grc.nasa)

There are several terms used to describe performance properties and characteristics of propeller of AUV. It is important considering all terms to ensure high system efficiency to provide great performance to the AUV. Bernoulli's principle and Newton's third law are used to modelled the operation of propeller.

Bernoulli's principle,

$$\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$$

Where:

- **v** is the fluid flow speed,
- **g** is the gravitational gravity,

- **z** is the elevation,
- **p** is the pressure,
- **ρ** is the density of the fluid.

While Newton's third law states that all forces between two objects exist in same magnitude but opposite direction. In the Figure 1.2, a boy is pulling a rope that is attached to an elephant with force F_A then elephant at the same time pulling a rope that is attached to a boy with force F_B, and the two forces are equal in magnitude but opposite in direction, $F_A = -F_B$.

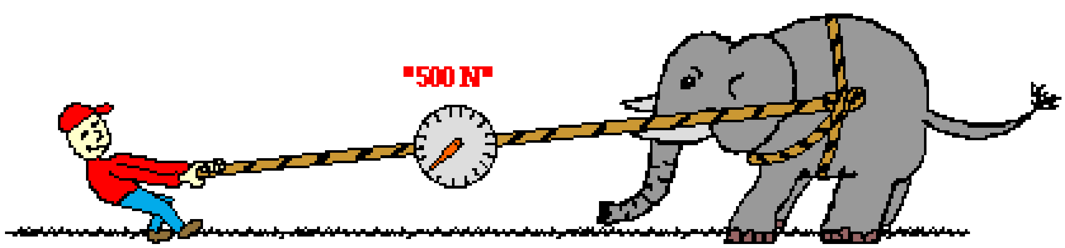

Figure 1.2: Example of Newton's Third Law (Source: physicsclassroom.com/class/newtlaws/Lesson-4/Newton-s-Third-Law)

1.2 PROBLEM STATEMENT

Nowadays, the development of AUV have been focus more on how to design the AUV with more portable and more compact with more energy efficiency innovation. To move the AUV, propeller been used to produce the efficient vertical and horizontal movement. There are a lot of research on the airplane propeller but development research on designing and manufacturing new marine propeller is still low. While the data or design from airplane propeller research is not suitable to use in marine vehicle because the different of the density of medium which is the density of water is 1000 times higher than air (D'Epagnier, 2006). Meanwhile the fabrication of a customize propeller is much more expensive compare to buying the existing propeller.

On the other hand, the development of new concepts in propeller designing has shown a significant improvement in the design method that could enhance the process of propeller designing. However, the impact of development has yet not shown due to the innovators and designers end at the traditional technique that has gone through loads of researches and were validated, which is much more reliable and were implemented for plenty of times.

The velocity of propeller is the main key to improve the movement performance of AUV. The design of blades with all parameters on propeller is most important to achieve a efficient movement of AUV. Therefore, it is important for this research to clearly show the best parameters of blades for optimum performance of AUV.

1.3 OBJECTIVE

The objective of this project is:

1. To identify the average outlet flow velocity based on blade parameters configurations which affected the performance (thrust power) of AUV.

1.4 SCOPE OF PROJECT

The scopes of this project are as follows:

1. To develop a blade parameters configurations for Autonomous Underwater Vehicle (AUV) by using Computer-Aided Design (CAD).
2. To do Computational Fluid Dynamic (CFD) simulation analysis on the blade parameters configurations to identify the average outlet flow velocity based on the blade parameters such as number of blades, blade angle, hub to tip ratio and nose cone.
3. To identify the optimum blade configuration for the AUV performance (thrust power).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is devoted to a review of literature. The past developments in propeller for AUV will be discussed. Different methods will be covered, their shortcomings and advantages addressed, all with the goal of selecting the appropriate performance prediction method to use in this analysis. This section also will be focused on the review of propeller optimization methods with the same goal in mind of selecting the appropriate method for this present study. Past work performed in the field specifically focusing on research performed on type of blade, number of blades, blade angle, hub to tip ratio, nose cone of propeller and design of duct is covered. This section will also provide a brief introduction into a variety of materials and present their capabilities and limitations and CFD analysis. A summary of the conclusions reached in the process of the review will be presented.

2.2 Propeller Physical

The radius of the propeller is the distance between the tip of the blade and the centre of the hub (Duelley, 2010). The chord of the propeller is a straight-line distance between the leading edge and the trailing edge at a blade section of the propeller (Duelley, 2010). Figure 2.1 shows the nomenclature of the propeller as described.

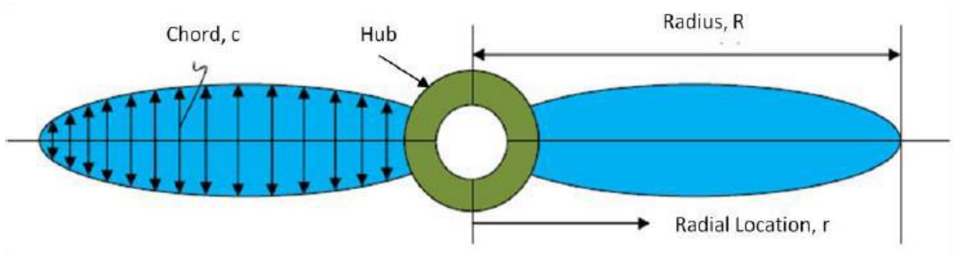

Figure 2.1: Propeller nomenclature (Source: Duelley, 2010 and Schultz, 2009)

Camber of the propeller is the maximum distance from the mean line to the chord lines. The maximum thickness of the blade is measured in a normal to the chord line (Ferrando, 2012). The optimum performance of ideal propeller would be infinitely thin so that it is more hydrodynamic (Duelley, 2010). However, this is unrealistic and impossible to be achieved because it is not manufacturability, durability and efficient. Low thickness profile has the risk of breaking or bending when the blade is handled roughly as shown in Figure 2.2 (Duelley, 2010).

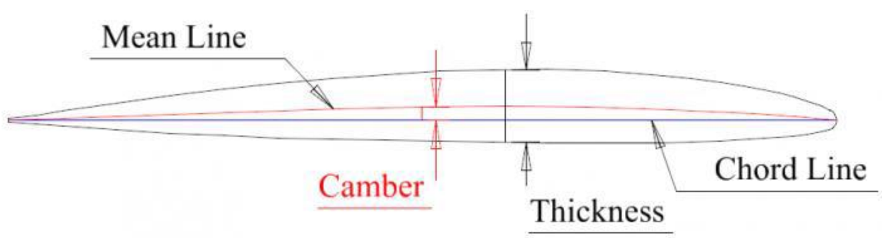

Figure 2.2: The cross section of the blade. (Source: International Towing Tank Conference, 2011)

Besides, the blade is classified into two, which is the leading edge and the trailing edge which is outlined on the Figure 2.3. Leading edge is the first part that contact with water when it is rotating while trailing edge is the last part of the blade that contact with the water. From Figure 2.4, it can clearly be seen that the pressure face of the propeller where it has high pressure at that part. The suction back has low pressure which is the cause of the AUV to move forward.

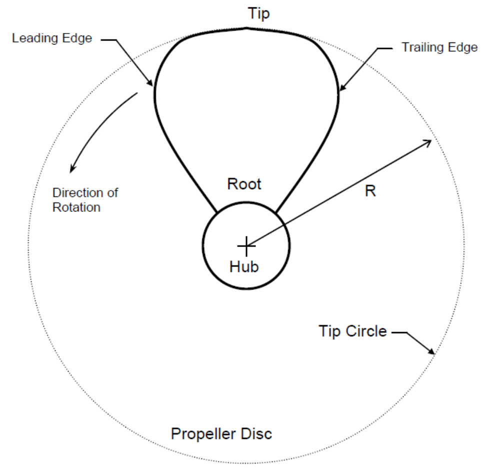

Figure 2.3: Basic propeller geometry. (Source: US Navy)

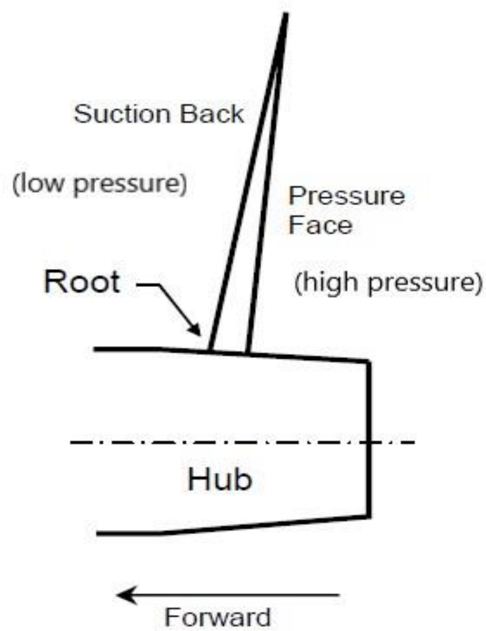

Figure 2.4: The pressure face and suction back (Source: US Navy)

Pitch is a measurement of the distance of propeller would move parallel to the direction of motion when it rotates at one revolution (Duelley, 2010). High pitch over diameter ratio can