DESIGN AND ANALYSIS OF AN UNDERWATER PROPELLER BLADE

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in fulfilment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Design and Analysis of an Underwater Propeller Blade" is the result of my own except as cited in the references.

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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.

Signature : …………………………………….

Supervisor's Name : Dr. Shamsul Anuar bin Shamsuddin

Date : ……………………………………

DEDICATION

To my beloved mother (Mariyani Binti Mohd Isa) and

father (Muhammad Zailan bin Tugimin)

ABSTRACT

The details about the designing and simulating of an Autonomous Underwater Vehicle (AUV) propeller blade is shown in this final year project report. ROV is a tethered underwater mobile device which would able to work in any depths of water and has more abilities to perform mechanically, inspection and recording tasks. Propulsion plays a significant role in the movement of the ROV. The objective of this paper is to determine the important design factors that affecting propeller efficiency and to identify the velocity and thrust in order to determine the ROV propeller blade efficiency. Based on the literature review study, the number of blades, propeller diameter, rake angle, blade design or blade area and ducted propeller are very important parameter in order to design the optimum propeller. The best conceptual design was selected as it achieved highest value in concept evaluation. The new design of the propeller blade is based on the specification parameter of the existing thruster (T200 thruster by Blue Robotics) so that the diameter of the propeller blade of the new design same and it would able to fixed into existing T200 thruster. Solidworks is used to design the propeller blade and analyse some performance of it. In addition, ANSYS Fluent is also being used to analyse the meshing size and structural meshing of the propeller blade with its propeller domains. The efficiency of the propeller blade is calculated by using the mathematical formulation. It was found that from the calculation, the efficiency of the propeller blade is different with different rpm value. In addition, it was known that as the rpm, thrust coefficient and velocity inlet decreased, the efficiency of the propeller blade is increasing. At the speed of 31.42 rad/s, the efficiency of the propeller blade is 93.63% while at 183.25rad/s, the propeller efficiency is 92.91% and for 397.94 rad/s, the propeller efficiency is about 92.42%.

ABSTRAK

Reka bentuk dan simulasi mengenai bilah kipas Autonomi Kenderaan Bawah Air (AUV) ditunjukkan dengan lebih terperinci di dalam laporan projek akhir ini. ROV adalah peranti mudah alih bawah laut yang dapat bekerja di semua jenis kedalaman air dan mempunyai kemampuan untuk melaksanakan tugas mekanikal, pemeriksaan dan rakaman. Pengusiran memainkan peranan penting dalam pergerakan ROV. Objektif projek sarjana muda ini adalah untuk menentukan faktor reka bentuk penting yang mempengaruhi kecekapan bilah kipas dan untuk mengenal pasti hadlaju, teras dan kuasa untuk menentukan kecekapan bilah kipas ROV. Berdasaran kajian literiture, bilangan bilah, diamater kipas, sudut rake,reka bentu bilah atau luas kawasan bilah dan kipas ducted merupaan parameter yang sangat penting untuk mereka bentuk kipas yang lebih optimum. Reka bentuk konseptual terbaik dipilih kerana ia mencapai nilai tertinggi dalam penilaian konsep.Reka bentuk bilah kipas yang baru adalah berdasarkan parameter spesifikasi thruster yang sedia ada (T200 thruster oleh Blue Robotics) supaya nilai diameter baling kipas reka bentuk baru sama dan ia dapat disesuaikan ke dalam T200 thruster itu. Solidworks digunakan untuk mereka bentuk bilah kipas dan menganalisis beberapa prestasi. Di samping itu, ANSYS Fluent juga digunakan untuk menganalisis prestasi lain untuk menyelesaikan nilai parameter yang tidak diketahui untuk mencari kecekapan bilah kipas. Kecekapan bilah kipas dikira dengan menggunakan formulasi matematik.Berdasarakan projek ini, dapat diketahui apabila nilai rpm,pekali teras dan hadlaju masuk berkurang, nilai kecekapan bilah kipas semakin meningkat.Berdasarakan pengiraan yang dilakuan, kecekapan bilah kipas adalah berbeza dengan nilai rpm yang berbeza. Pada kelajuan 31.42 rad/s, kecekapan bilah kipas adalah sebanyak 93.63%. sementara untuk rpm 183.25 rad/s , nilai kecekapan bilah kipas adalah kira-kira sebanyak 92.91%. Sementara itu, pada 397.94 rad/s, kecekapan bilah kipas adalah 92.42%

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LIST OF ABBREVIATIONS

ROV	-	Remote Operated Underwater Vehicle
AUV	-	Autonomous Underwater Vehicle
CFD	-	Computational Fluid Dynamics
BEM	-	Boundary Element Method
BAR	-	Blade Area Ratio
2D	-	Two Dimension
3D	-	Three Dimension

LIST OF SYMBOLS

D, d	-	Diameter
R, r	-	Radius
$\dot{m}$	-	Mass Flow Rate
T	-	Thrust of the Propeller
Q	-	Torque Produced by the Propeller
A_o	-	Surface Area of the Propeller Blade
V_A	-	Inlet velocity
V_B	-	Velocity against the Thrust of the Propeller
V_C	-	Outlet velocity
n	-	Rotational Speed
P_D	-	Power obtained by the propeller
J	-	Advance Ratio
C_T	-	Thrust Coefficient
C_Q	-	Torque Coefficient
ρ	-	Density of the Water
η_o, η_i	=	Propeller Blade Efficiency

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, scientists always find the best solution to get themselves or their instruments into a very specific parts in order to understand the ocean. They have to develop the underwater vehicle to make the research in an easy way. Traditionally, the researchers need to use ships to take a photo of the depths and to collect samples of water, rock, and marine life. However, in modern life, they do some innovation such as remote-controlled vehicles, autonomous, and towed robots.

Underwater vehicles are classified as either Manned, Remotely Operated Underwater Vehicles (ROV) and Autonomous Underwater Vehicle (AUV). They are submersible vehicle that can be assigned to do certain task underwater. The underwater vehicle also provides the functions necessary to serve as undersea tools for science and industry.

Manned submersibles are underwater vehicles that are controlled by human operators. These allow scientists to dive into the deep ocean and collect data or make observations first hand.

A remotely-operated underwater vehicle (ROV) is safe and controlled by an operator who remains out of the water which is this robot was controlled by a person on the surface. An ROV may contain a video camera, lights, sonar systems, and an articulating arm.

However, different with autonomously-operated underwater vehicle (AUV) which is designed to work without an operator and without a direct connection to the surface. These AUV are normally designed for a particular application and are pre-programmed to operate definite particular tasks. Figure 1.1, 1.2 and 1.3 show the example design of the manned submersible, Remote Operated Underwater Vehicle (ROV) and autonomous operated underwater vehicle (AUV) respectively.

All these underwater vehicles need a propulsion from the thruster to move themself. The design of the propeller blade inside the thruster is very important to ensure the underwater vehicle would able to move in efficient way. S. O. Oladokun (2015) believes that the propeller blade would able to move the ship against resistant of water which is this propeller converts engine torque into propulsive force or thrust and produce forward motion. In propeller design, it is important to ensure that it drives the vessel efficiently.

Figure 1.1: Manned Submersible Underwater Vehicle

Figure 1.2: Remote Operated Underwater Vehicle (ROV)

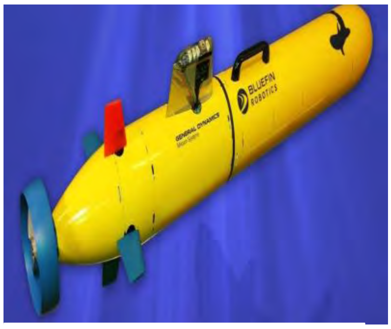

Figure 1.3: Autonomous Operated Underwater Vehicle (AUV)

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1.2 Problem Statement

Lately, the ROV evolution has focussed on smaller size and higher efficient energy technology. The propeller blade of ROV is very important in producing a more efficient horizontal and vertical manoeuvre. However, the number of research on designing and manufacturing marine propeller is less. Most of them depend on the propeller of the airplane for propulsion as off the shelf propeller is more sensible because it is cheaper and easy to replace. Yet the use of airplane propeller in marine vehicle is not suitable because the density of air is 1000 times less than water (D'Epagnier, 2006).

The thruster and propeller blade itself have an electric motor that attached to it which it gives the underwater robot as a propulsion device. These enable the robot to make a movement and have the ability to against sea water resistance. If the efficiency of the propeller blade is low, the underwater vehicle would not able to move faster in an efficient way. Plus, underwater vehicle will have a low ability to against the sea water resistance (Maghareh, 2017)

Therefore, it is important for this research to clearly show the steps of the advance method in ROV propeller development which will promote engineers to adapt and continue the new design. The research of the propeller is important in order to know the best design based on the previous lesson. So, based on the research and process learning, the improvement of the propeller blade can be made referring to the standard criteria and parameter consideration.

1.3 Objective

The goals of this final year project are as follows:

1. To determine the important design factors that affect propeller efficiency.
2. To identify the velocity and total thrust of propeller blade in order to determine the ROV propeller blade efficiency.

1.4 SCOPE OF PROJECT

This research focuses on the hydrodynamic performance of the ROV where an efficient propeller is needed to be found using the designing and stimulating of the propeller blade in order to produce a reliable propulsion system.

The scopes of the study on ROVs propeller blade are:

i. To study the design process of ROVs propellers
ii. To design and modelling a propeller blade for ROVs referring to design parameters.
iii. To analyse the velocity and total thrust of the propeller blade using Computational Fluid Dynamics (CFD)
iv. To calculate the propeller efficiency using mathematical modelling.

CHAPTER 2

LITERITURE REVIEW

2.1 Introduction

Most of the literature review on propeller blade is full with experimental and analytical data that related with performance information and the design criteria. A propeller turns the engine power into the operating force of the ship and usually the propellers are used as propulsions and used to progress significant dive to propel the vehicle at its operational speed and RPM (B. Harish et al. 2015). I. Anthony et al. (2013) state that the propeller is a type of a fan that transmits power by converting rotational motion into thrust.

Propeller dynamics can be represented by both Bernoulli's principle and Newton's third law. A propeller is sometimes known as screw which it is actually can have a single blade, but in practice there always more than one in order to make the forces involved is balanced (Anthony et al. 2013). These authors have explored their study about the propeller blade efficiency and knowing that a propeller with blade area ratio of 0.55 has the open water efficiency about 73%.

Usual propeller blade geometry is shown in Fig.2.1.1 which profiles some of the terms used in designing an underwater propeller system. The propeller type, geometrical and performance parameters like radial velocity, thrust coefficient and others impressed the ship propeller.

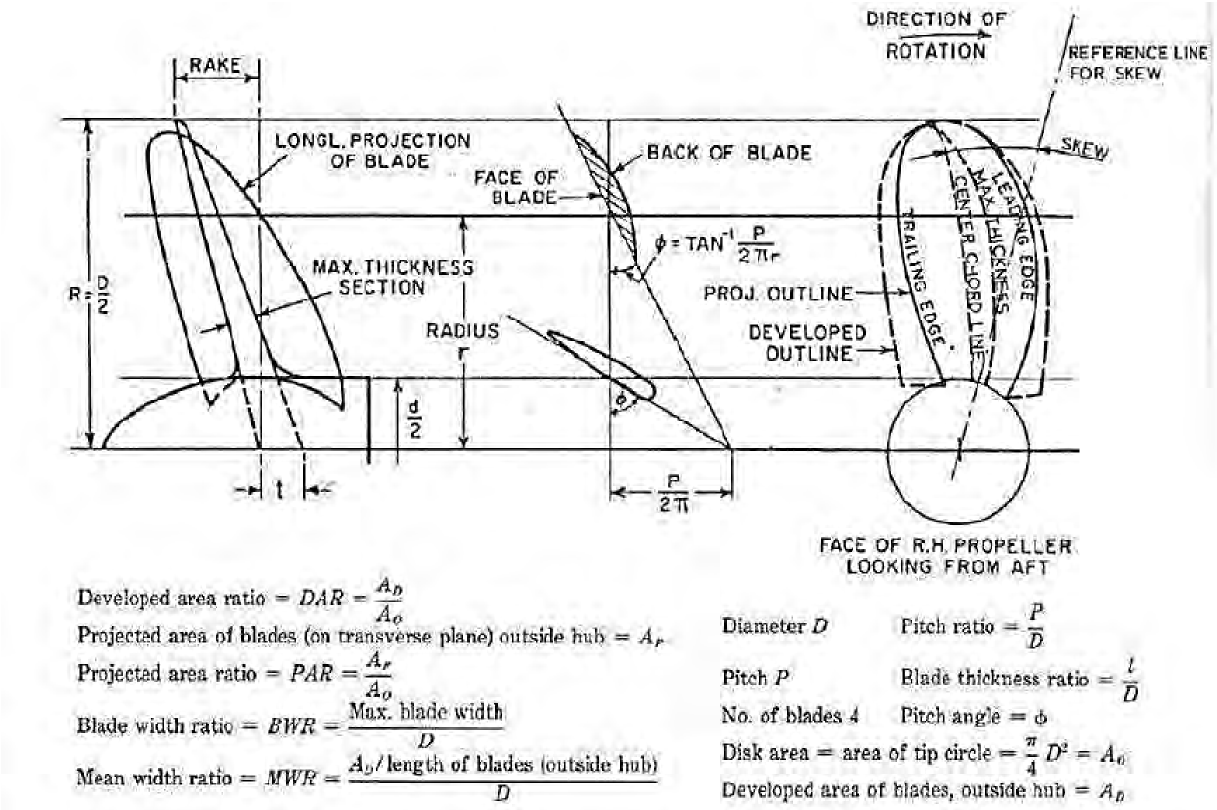

Figure 2.1.1: Typical propeller drawing (Anthony et al. 2013)

2.2 Design Analysis and Considerations

Anthony et al. (2013) focused the propeller design analysis at obtaining least power requirements, cavitation, noise, vibration and supreme efficiency conditions at a sufficient revolution. Ekinci (2011) believed that there are two methods are commonly used in propeller design which are by using the diagrams obtained from open water propeller experiments for systematic propeller series and mathematical methods (lifting line, lifting surface, vortex-lattice, BEM (boundary element method) based on circulation theory.

2.3 Parameter Analysis

Propeller diameter, number of blades and propeller speed is the parameters that supply foundation for the propeller blade. Meanwhile, the multi-combination of these three parameters will result in different efficiencies. Therefore, D'Epagnier et al. (2007) make a further study of the parameter that is important to know the propeller optimization.

2.3.1 Number of blades

Mutalib et al. (2015) mention that the most frequent marine propellers are designed to decrease the noise sound such as three or four bladed marine propellers. The number of blades selected will impact the level of unsteady forces working on them. Optimum open water potency will increase with increase within the range of blades by considering the efficiency of propeller blade.

2.3.2 Propeller diameter

Matt (2015) claims that the selected propeller diameter and pitch is important where it contribute in the propeller's ability to absorb power, the engine's ability to produce power, and either it properly matched at the engine's rated rpm.

These author also state that the huge diameter and a shallow pitch of propeller blade may be used, or a smaller diameter and a steeper pitch, to produce the equal load on the engine. However, if it going so much in either method through, the efficiency of the propeller will be decrease.

In a terrible tiny diameter, steep pitch propeller tends to place a lot of work into spinning the water flow, and fewer into accelerating fast away from the boat. Besides that, even in fixed rpm, if the diameter is increase too much, the pitch should be created terribly shallow, and efficiency once more decrease.

2.3.3 Blade area and blade design

Blade area ratio (BAR) is the magnitude relation or ratio of the whole area of the blades, divided by the whole area of the propeller. This blade area ratio might affect the propeller efficiency and thrust making performance. Blade design may become the minor consideration in selecting the propeller design. However, the blade area ratio may effected by the blade design. Therefore, the different blade design may affect the efficiency of the propeller blade itself. Lee et al. (2010) had design technique for greater performance of the marine propellers with an optimum propeller performance. These authors was adjusting expanded areas of the propeller blade. Results show that efficiency can be grow up to over 2% by decreased the blade area. Table 2.3.3 shows the comparison result for parent propeller, design propeller (7% decreased) and design propeller (14% decreased).

Figure 2.3.3 (a) Parent propeller (Lee et al. 2010)

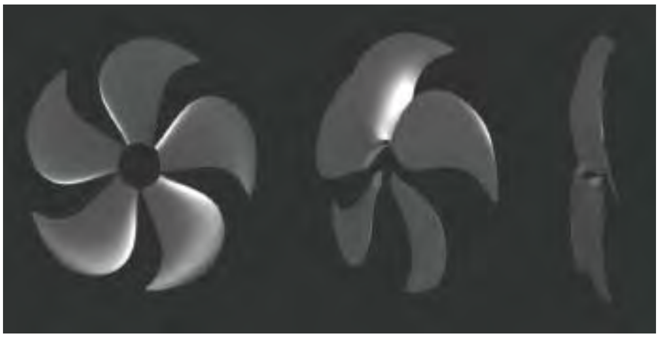

Figure 2.3.3 (b): Design Propeller (7% decreased) (Lee et al. 2010)