

COMPUTATIONAL DYNAMICS ANALYSIS OF PROPELLER
WITH AND WITHOUT FINS

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A report submitted in partial fulfillment of the requirements for the award of the degree
of Bachelor of Mechanical Engineering with Automotive

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedicated to my family

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ABSTRACT

The project objectives are to ensure that the simulation results are valid by comparison with the Standard Series Data and compare the performance of propeller with and without fins, based on Computational Fluid Dynamics (CFD) analysis. The propeller is based on Wageningen B3.55 series and made from aluminium alloy. Theoretically the fins on the back side of propeller blade will increase the thrust produce by the propeller. The methodology of this project can be divide to three parts depends on the software used; PolyWorks, SolidWorks and CosmosFloWorks. The propeller is divided into two, with and without fins. A propeller with two fins in the format of PolyWorks file after the propeller had through 3D scan process is provided, thus further 3D modeling process using PolyWorks had to be made. Other than to process the propeller to desired shape, 3D modeling also used to smoothen the surface, eliminate any defects like hole and gaps on the surface of propeller. SolidWorks is important software in this project not only because it can read the IGES file format from PolyWorks, also CosmosFloWorks is the plug-in for SolidWorks. The function of CosmosFloWorks is to analyze the performance of propellers where the value of thrust and torque is taken. Thrust is the force produced at a given speed when propeller rotates and torque is the moment act on the propeller blades. The value of thrust and torque from Standard Series Data and analysis of propeller without fins is compared to make sure the data from analysis is valid. It is observed that the value of thrust from Standard Series Data is higher than the thrust value from propeller without fins around 4.3% and 2.6% for torque. The velocity of boat is set from 3 knots to 7 knots and the slippage is not considered in the analysis. The average increase of thrust by the propeller with fins compare to propeller without fins is around 9.1% and 4.4% for torque value.

ABSTRAK

Objektif projek ini adalah untuk memastikan keputusan daripada simulasi adalah sah melalui perbandingan antara 'Standard Series Data' dan prestasi kincir tanpa sirip berdasarkan kaedah analisis 'Computational Fluid Dynamics (CFD)'. Kincir yang digunakan dalam projek ini adalah berdasarkan siri model Wageningen B3.55 dan dibuat daripada aloi aluminium. Secara teori, sirip di permukaan belakang kincir akan menambahkan penghasilan jumlah daya oleh kincir. Metodologi projek ini dibahagikan kepada tiga bahagian bergantung kepada perisian yang digunakan; PolyWorks, SolidWorks and CosmosFloWorks. Kincir akan dibahagikan kepada dua iaitu dengan sirip dan tanpa sirip. Kincir dengan sirip diperolehi selepas daripada proses '3D scan', oleh itu proses permodelan 3D lebih lanjut harus dilakukan menggunakan PolyWorks. Selain daripada mengubah model ke bentuk yang dikehendaki, proses permodelan 3D juga digunakan untuk meratakan permukaan, menghapuskan sebarang kecacatan seperti lubang-lubang dan ruang-ruang pada permukaan kincir. SolidWorks adalah perisian yang penting bukan sahaja kerana ia dapat membaca file IGES daripada PolyWorks, malah CosmosFloWorks juga adalah plug-in kepada SolidWorks. Fungsi CosmosFloWorks adalah menganalisa prestasi kincir yang mana nilai daya tujahan dan tork yang dihasilkan dikira. Daya tujahan adalah daya yang dihasilkan oleh apabila kincir berputar pada kelajuan yang ditetapkan dan tork adalah daya putaran yang bertindak pada bilah kincir. Nilai daya tujahan dan tork daripada 'Standard Series Data' dibandingkan dengan nilai tersebut daripada analisis untuk memastikan keputusan daripada analisis boleh diterima. Dapat diperhatikan bahawa jumlah daya tujahan daripada 'Standard Series Data' adalah lebih tinggi daripada analisis sekitar sebanyak 4.3% dan 2.6% untuk tork. Halaju boat dalam projek adalah ditetapkan dari 3 knot ke 7 knot dan nilai gelinciran oleh kincir tidak diambil kira dalam analisis. Kincir dengan sirip meningkatkan daya tujahan sebanyak sekitar 9.1% dan tork sekitar 4.4% lebih tinggi daripada kincir tanpa sirip.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Ship propulsion at the required sea speed occurs with the help of a propulsion device. The most common propulsor is the propeller, which converts engine torque to ship thrust, accelerating the fluid in which it works. The propeller plays an important role in the interaction between ship, engine and propulsor. Conventional propellers are mounted on a shaft and operate behind ship's hull.

Actually the propulsion of propeller is a very complex process that include knowledge in fluid dynamics, physics, metallurgy, naval architecture, mechanical and marine engineering. A lot of considerations has to be made and calculated using various theories such as momentum theory, blade element theory and thin aerofoil theory. However as the technology develop, new and easier analysis of performance of propeller can be made by using Computational Fluid Dynamics (CFD) analysis method.

1.2 PROBLEM STATEMENTS

Today, conventional marine propellers remain the standard propulsion mechanism for surface ships and underwater vehicles. The performance of the propeller is depend on various factors including their geometry and dimensions. Small changes of geometry would reasonably affecting the performance by decrease or increase the value of torque and thrust of propeller.

Existing propeller produce thrust and torque to enable the boat to move. However, the conventional design of propeller did not produce enough thrust. Therefore, new design needs to be produce such as the additional fins at the blades.

1.3 OBJECTIVES OF THE PROJECT

The main objective of this project is to conduct the computational fluid dynamic analysis of propeller. The overall objectives are:

- i. To ensure that the simulation results is valid by comparison with the Standard Series Data.
- ii. To compare and investigate the performance of propeller with and without fins.

1.4 SCOPE OF STUDY

This project concentrates on the performance of the propeller when attached with fins. The scopes of study are as follows:

- (i) 3D modeling using PolyWorks
- (ii) Computational fluid dynamics analysis using SolidWorks and CosmosFloWorks.

1.5 OVERVIEW OF THE REPORT

Chapter 1 gives the brief the content and background of the project. The problem statement, scope of study and objectives are also discussed in this chapter.

Chapter 2 discuss about the basic nomenclature of propeller in terms of performance, types, performance characteristics and failure of marine propellers. Also definition of Computational Fluid Dynamics (CFD) analysis and software used in this project elaborated in this chapter.

Chapter 3 presents the flowchart, 3D modeling process and analysis operation involve in this project.

Chapter 4 explaining the result obtains from chapter 3 and discussion. This is including data presentations using graph, flow trajectories and others.

Chapter 5 presents the conclusions of the project. Suggestions and recommendations for the future work are put forward in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of the marine propeller, definition of Computational Fluid Dynamics (CFD) analysis, performance characteristics of propeller, software involve in this project and the background of propeller with invention. The review is fairly detailed so that the present research effort can be properly modified to add to the present body of literature as well as to justify the scope and direction of present research effort.

2.2 REVIEW OF PROPELLER

2.2.1 Basic Nomenclatures of Propeller in Terms of Performance.

Diameter

Diameter is crucial geometric parameters in determining the amount of power that a propeller can absorb and deliver, thus determining the thrust available for propulsion. Usually the diameter is proportional to the efficiency of propeller, but in high speed vessels larger diameters equates high drag. For typical vessels a small increase in diameter translates into a dramatic increase in thrust and torque load on the engine shaft, thus the larger the diameter the slower the propeller will turn, limited by structural loading and engine rating.

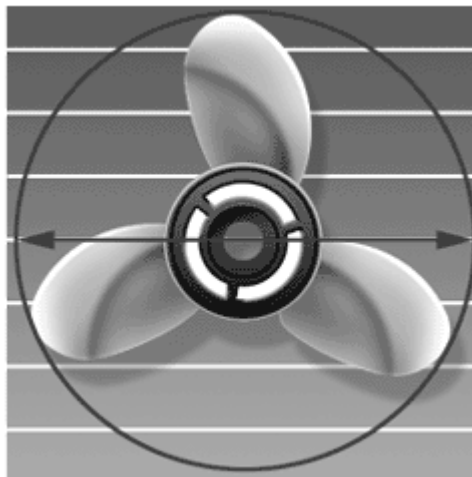


Figure 2.1: Diameter of propeller

Pitch

Pitch is the theoretical distance travel in one revolution of propeller. For example, the propeller move 10 inches in one revolution, thus the nominal pitch of the propeller is 10 inches. It is called nominal pitch because the actual pitch of propeller will be less than the nominal pitch. The difference between nominal and actual pitch is called slip.

Slip is the difference between actual and theoretical travel of the propeller blades through water. A properly matched propeller will actually move forward about 80 to 90 percent of the theoretical pitch. The ratio of pitch to diameter (P/D) is typically falls between 0.5 and 2.5 with an optimal value for most vessels closer to 0.8 to 1.8. Pitch effectively converts torque of the propeller shaft to thrust by deflecting or accelerating the water astern – simple Newton's Second Law.

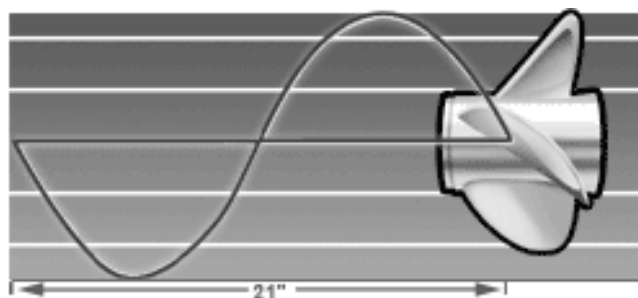


Figure 2.2: An example of propeller with 21 inches pitch

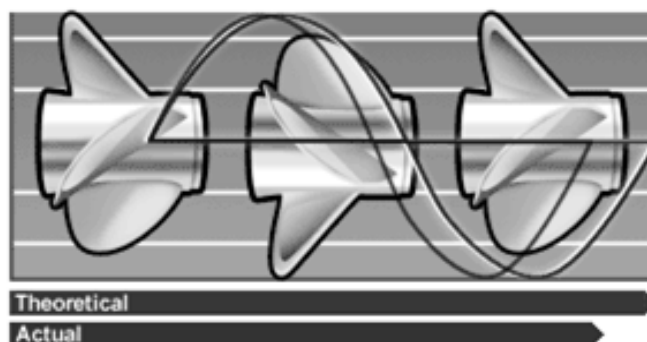


Figure 2.3: Illustration of the slip on propeller

Hub

Solid centre disk that mates with the propeller shaft and blades. Ideally the hub should be as small in diameter as possible to obtain maximum thrust, however there is a tradeoff between size and strength. Too small a hub ultimately will not be strong enough.

Blade

Blades are the twisted fins or foils that protrude from the propeller hub. The shape of the blades and the speed at which they are driven dictates the torque a given propeller can deliver. Blade root is where the blade attached to the hub, and blade tip is the outermost edge of blade at a point furthest from the propeller shaft.

High pressure side of blade is called blade face. This is the side that faces aft (backward) and pushes the vessels in forward motion. The back of the blade is the low pressure side or the suction face of the blade. This is the side that faces upstream or towards the front of the vessel.

Number of blades

The number of blades will critically dictate the performance of a propeller. Basically greater speed, horsepower and load requirements of vessel need propeller with more blades. In design consideration, the number of blades is primarily determined by the need to avoid harmful resonant frequencies of the ship structure and machinery. It also found that both propeller efficiency and optimum propeller diameter increase as blade number decrease.

With increased number of blades the surface area increases which reduces the slip in cruising speeds. Increased number of blades also gives a smoother behavior of the vessel with greater control in turns and in rough waters. Four and five blade propeller are also reducing vibrations and noise due to a better balance and are causing less wear on the transmission system. Adding blades however often decreases top speed with a couple of knots, but this is a trade-off in the propeller selection process. The propeller in this project has three blades.

2.2.2 Type of Propellers

The type of propeller and their characteristics are discussed in table below:

Table 2.1: Type of propeller and their characteristic

Propeller Type	Characteristics
Fixed pitch propellers	Ease of manufacturer Design for single condition Blade root dictates boss length No restriction on blade area or shape Rotational speed varies with power absorbed Relatively for small vessels
Controllable pitch propellers	Can accommodate multiple operating conditions Constant or variable shaft speed operation Increased mechanical complexity Larger hub size
Ducted propellers	Can accommodate fixed and controllable pitch propellers Enhanced thrust at low ship speed Duct form can be either accelerating or decelerating
Azimuthing units	Good directional control of thrust Increase mechanical complexity Can employ either ducted or non-ducted propellers of either fixed or controllable pitch type
Cycloidal propellers	Good directional of thrust Avoids need for rudder on vessel Increase mechanical complexity
Contra-rotating propellers	Enhanced propulsive efficiency in appropriate conditions Increased mechanical complexity

Source: Carlton, J. 2007. Marine Propellers and Propulsion Second Edition.

The propeller used in this project is type fixed-pitch propeller.

2.2.3 Material of Propellers

The materials from which propellers are made today can broadly be classed as members of the bronzes or stainless steels. The once popular of cast iron has now virtually disappeared, even for the production of spare propellers, in favor of materials with better mechanical and cavitation resistant properties. The propeller in this project is made from aluminium alloy.

The properties required in a propeller material will depend to a very large extent on the duty and service conditions of the vessel to which propeller are being fitted. However, the most desirable set of properties which it should possess as follows:

- (i) High corrosion fatigue resistance in water
- (ii) High resistance to cavitation erosion
- (iii) Good resistance to general corrosion
- (iv) High strength to weight ratio
- (v) Good repair characteristics including weldability and freedom from subsequent cracking
- (vi) Good casting characteristics

2.3 PROPELLER PERFORMANCE CHARACTERISTICS

The performance of propellers are mostly depends on the thrust produced. Thrust is a force that driven the propeller forward. Actually the details on how a propeller generates thrust are very complex. A lot of consideration must be made including the wake field, temperature, water density and others. However it still can be elaborated using simplified momentum theory.

Simple momentum theory state that the thrust of a propeller depends on the volume of fluid accelerated per time unit, fluid acceleration and density of medium. The formula based on momentum theory expressed by equation (2.1) below.

$$T = \pi/4 \cdot D^2 \cdot (v + \Delta v/2) \cdot \rho \cdot \Delta v \quad (2.1)$$

Where:

- T Thrust
- D Diameter
- V Velocity of incoming flow
- Δv Additional velocity accelerated by propeller
- ρ Density of fluid (water: $\rho = 1000\text{kg/m}^3$)

Examining this quite simple formula reveals that the thrust, T increases when the diameter, D increases or when the density, ρ of the medium increases. The acceleration, Δv of a propeller depends on the velocity, v , thus it is generally not true that increasing the velocity increases the thrust. But it can be said, that increasing the additional velocity increases the thrust.

The performance characteristics of a marine propeller can be divided into two; open water and behind-hull properties. Open water characteristics relate to the description of the forces and moments acting on the propeller when operating in a uniform fluid stream. Behind-hull properties are performance of propeller in a mixed wake field behind a body, thus more complex and closer to actual performance. However we only discussing open water characteristics since these form basic performance parameter of propellers.

The forces and moments produced by the propeller are expressed in their most fundamental form in terms of a series of non-dimensional characteristics. The terms used to express general performance of propeller are as follows:

$$\text{Thrust coefficient: } K_T = T / \rho n^2 D^4 \quad (2.2)$$

$$\text{Torque coefficient: } K_Q = Q / \rho n^2 D^4 \quad (2.3)$$

$$\text{Advance coefficient: } J = V_a / nD \quad (2.4)$$

Where:

- T Thrust
- Q Torque
- D Diameter
- ρ Density of fluid
- n Rotational speed
- V_a Speed of advance

2.4 DEFINITION OF CFD ANALYSIS AND SOFTWARE USED

2.4.1 Computational Fluid Dynamic (CFD)

Computational Fluid Dynamic (CFD) is a branch of fluid mechanics that uses numerical methods and algorithm to solve and analyze problem that involve fluid flows. Computers are used to perform the millions of calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. Even with high-speed supercomputers only approximate solutions can be achieved in many cases. Ongoing research, however, may yield software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows.

CFD is now recognized to be a part of the computer-aided engineering (CAE) spectrum of tools used extensively today in all industries, and its approach to modeling fluid flow phenomena allows equipment designers and technical analysts to have the power of a virtual wind tunnel on their desktop computer. CFD has become an indispensable part of the aerodynamic and hydrodynamic design process for planes, trains, automobiles, rockets, ships, submarines; and indeed any moving craft or manufacturing process that mankind has devised.

2.4.2 PolyWorks 10.0

PolyWorks version 10.0 is developed by InnovMetric Software Inc. InnovMetric was founded in 1994 and pioneered the market for point cloud inspection and reverse engineering software solutions. InnovMetric is a privately owned company that enjoys an enviable position as the market leader in point cloud processing software in the automotive and aeronautic industries.

PolyWorks is a complete point cloud processing software solution which comprises of two packages; PolyWorks Inspector and PolyWorks Modeler. In this project, PolyWorks Modeler is used because it is a reverse-engineering module that produces highly accurate polygonal models and NURBS surfaces that are exportable to any CAD/CAM/CFD/FEA software for stringent manufacturing applications.

2.4.3 SolidWorks 2008

SolidWorks is developed by Dassault Systèmes SolidWorks Corp that was founded in December 1993 and headquarters at Concord, Massachusetts, USA. In this project, SolidWorks 2008 was use as the platform to analyze the propeller because CosmosFloWorks is the ads-in for SolidWorks. The IGES file from Polyworks needs to be open using SolidWorks before the analysis can start. Other than that, SolidWorks also can check the geometry error at the propeller model and repaired it. If the model had defects like hole, layer and others, no analysis can be made by CosmosFloWorks.

2.4.4 CosmosFloWorks

CosmosFloWorks is the first easy-to-use fluid flow simulation and thermal analysis program that is fully embedded inside SolidWorks. CosmosFloWorks can analyze a wide range of real fluids such as air, water, gasses, plastic melts and other more which makes it ideal for engineers in nearly every industry.

Table 2.2: Some analyze operation by CosmosFloWorks

Type of fluid flow	Operations available
Internal flow	Flow of liquids and gases through valves, regulators and ducts.
External flow	Flow of liquids and gases around solid bodies like flow of air over an airplane or flow of water around a submarine.
Transient flow	Simulate unsteady flow over a short period of time.
Turbulent flow	K-E model to understand turbulence in the flow domain, for example, the flow of gases from an aircraft engine nozzle.
Compressible flow	Analyze gas flows in subsonic, transonic, and supersonic speed zones like flow around an aircraft engine moving at the speed of Mach 1.

Source: CosmosFloWorks Overview, 2008.

2.5 INVENTIONS OF PROPELLER WITH FINS

2.5.1 Introduction

The propeller with fins is a simple but yet effective idea by Ir. Suryo Widodo Adji in enhancing the performance of propeller without any major changes to the engine and gearing system. He is the head lecturer of Marine Engineering Sepuluh Nopember Institute of Technology (ITS) – Surabaya, Indonesia. This propeller is called Adjie Propeller and it had been patented and commercialize.

The propeller with fins is suitable to use with small wood ships for fisherman and fiberglass ships with outboard engine. It can increase the velocity of ship by 15% to 19% faster and also better acceleration. It had been tested using small fisherman wooden ships and the result was very encouraging. The ship can achieve 5 to 6 knots when using propeller with fins and only 4 to 5 knots if using propeller without fins.

This propeller is based on Wageningen B screw series with three blades and blade area ratio of 0.55. It is made from aluminium alloy and comes with three different diameters; 8 inches, 10 inches and 12 inches.

2.5.2 The Dimensions of Fins

There are several conditions must be fill in designation of propeller fins to achieve optimum performance and required goals. Two fins attached to the back side of propeller blade in parallel position and it is called upper and lower fins. The figure 2.4 is the description if propeller with fins from Teknik Sistem Perkapalan, FTK-ITS (2009). It shows us the position of fins and other dimensions of propeller.

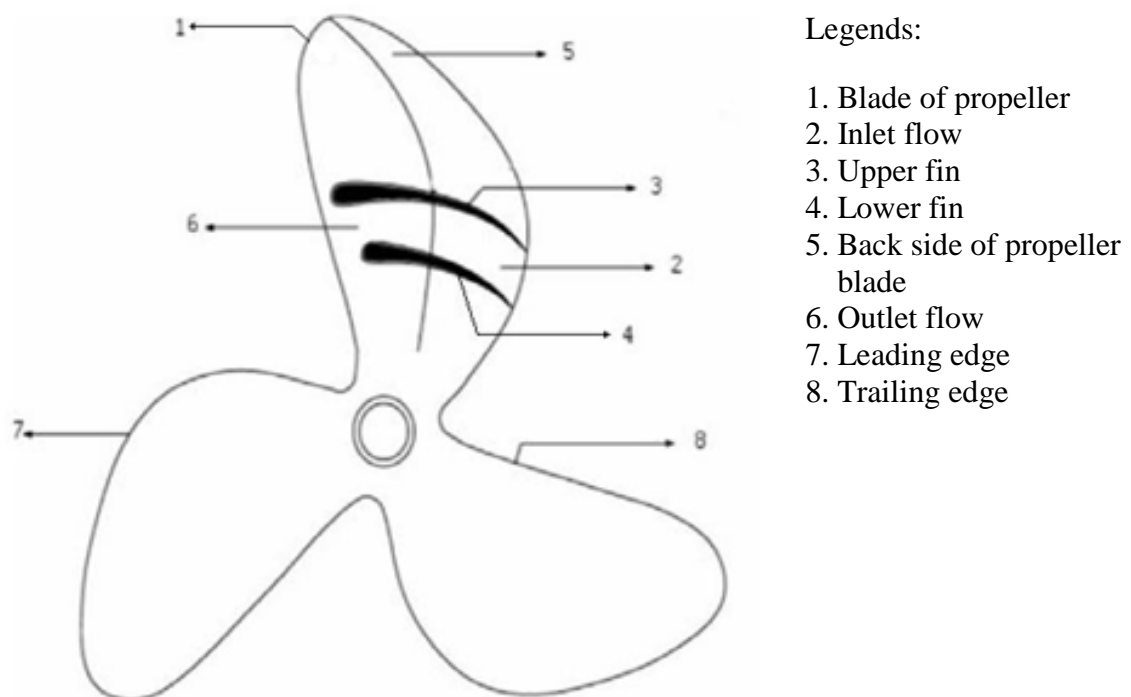


Figure 2.4: Illustration of the propeller dimensions

The shape of fins is actually like an aerofoil where the sharp part is towards the leading edge of propeller. The length of upper fins is longer than lower fins by 40% and maximum height of fins is 14% from overall length of fins. The position of fins is depends on two parameters; the radius of propeller and the ratio of inlet and outlet of flow through the fins. The inlet and outlet is illustrated by number 2 and 6 in the figure above. The fins are positioned from 30% to 80% of the propeller radius. Maximum thickness of fins is situated 60% to 90% of fins length from the trailing edge. There are others dimensions and considerations made in this design but it is protected by the patent law and undisclosed from public.

2.5.3 The Concept of Propeller with Fins

The purpose of the invention of propeller with fins is to maximize the thrust produce by the propeller without any changes on the engine of the boat. With this extra thrust, the boat will cruise faster and have better acceleration.

The concept of this invention is by decreasing the pressure on the back face side of propeller, thus enhancing the pressure difference between the back and front side of propeller compare to conventional propeller. The method used to achieve this objective is by using two fins that is attached on the back face side of the propeller blade. These fins will accelerate the fluid flow velocity and make the flow more uniform, hence increase the lift force act on the blade of propeller.

Law of Bernoulli states that this higher velocity will decrease the pressure on the back side of propeller blade. Then according to blade element theory, higher pressure different will yielded higher thrust. Below is an illustration in explaining the pressure on the blade according to blade element theory.

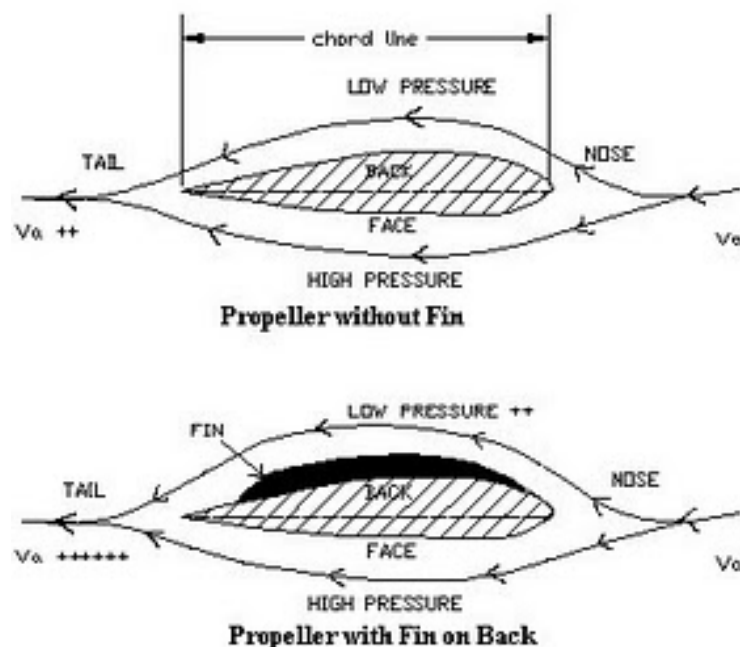


Figure 2.5: Illustrations of the pressure act on the surface of blade

Source: <http://marinoos.blogspot.com> (2007)

The first illustration show us the pressure exerted on the surface of blade without fins. When arrive on the leading edge, the fluid flow with velocity of V_a divide into two surface, back and front side of propeller blades. The back side has higher velocity and thus the pressure become lower. The front side has lower velocity and thus the pressure is higher. Lift force created towards the back side of the propeller.

The second illustration show us the pressure exerted on the surface of blade when the fins attached by assuming same inlet flow velocity, V_a . Note that the velocity flows on the front side remain same as before. However on the back side where the fins attached, the flow become higher compare to the propeller without fins. Water at leading edge has wider path and gradually the path become narrower towards the trailing edge. Higher pressure difference on blade will increase the lift force on the blade as well as the thrust produce. Also the velocity of flow after it had passed the propeller is higher compare to propeller without fins.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will explain the overall methodology involve in this project. Before the project start, good understandings in propulsions of propeller are essential. The basic parts and nomenclature of propeller in terms of propulsion performance had been discussed in the literature review chapter. In addition, understanding the software used is primary importance to make sure better analysis operation and furthermore increase the accuracy of the result.

Generally this project involves 3D modeling, analysis and comparing the result of analysis.

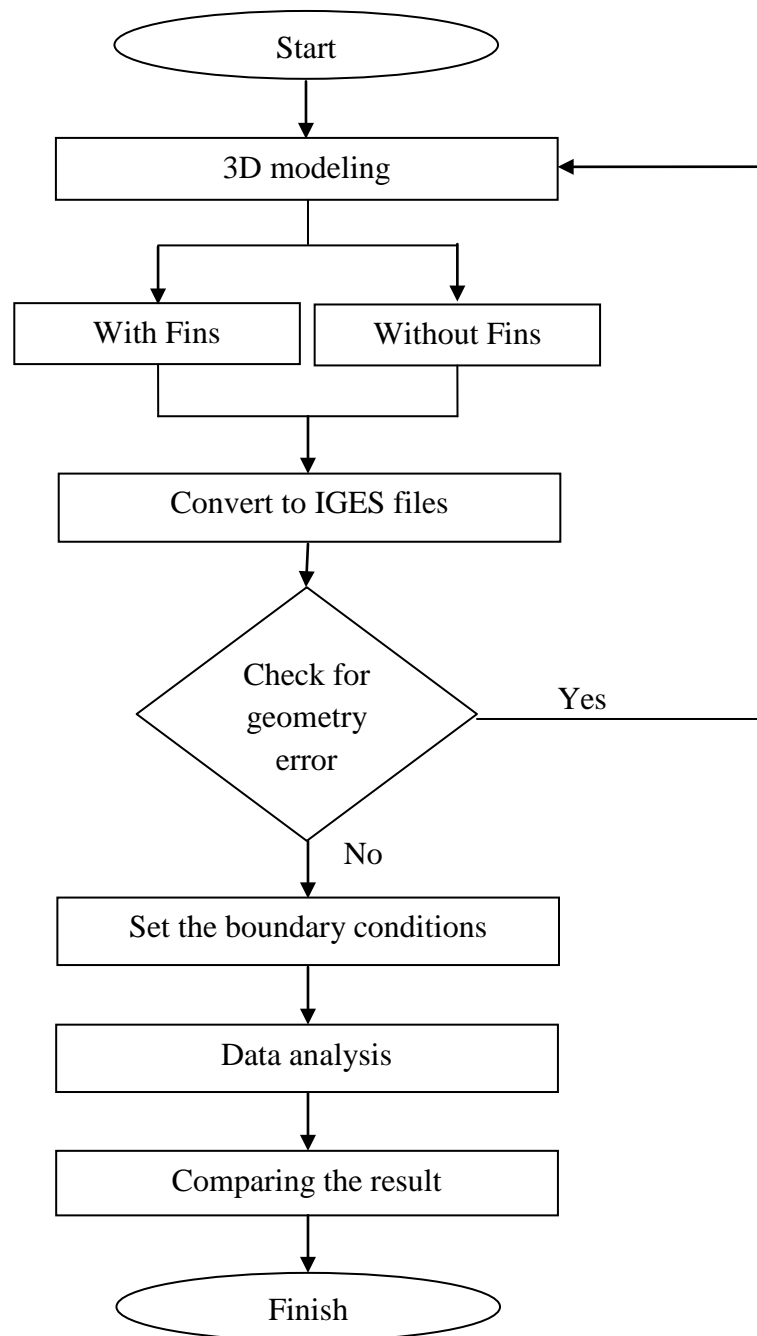


Figure 3.1: Flowchart of the project

3.2 3D MODELING

The supervisor had prepared the 3D model of the propeller using 3D scanner before the project can start. In this step, software named PolyWorks version 10.0 had been used. Using PolyWorks, the 3D model are repaired, reconstructed and edited to fulfill the objectives of this project. The model must be repaired because there are a lot of defects on the surface like holes, layer and rough surface due to the sensitiveness of 3D scanner. If the surface did not repaired, the model can still converted to iges (.IGES) format but cannot analyze using CosmosFloWorks.

3.2.1 Hole Filling

Figure below is an example a hole on the surface of propeller:

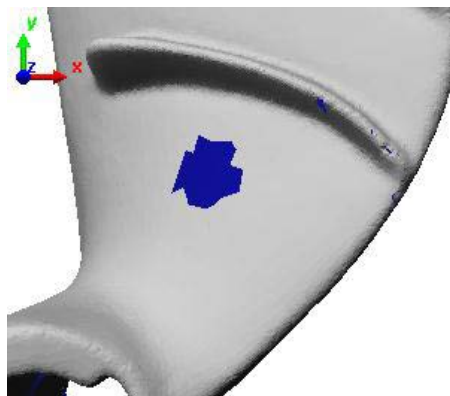


Figure 3.2: A sample of hole on the surface of propeller model

PolyWorks offers a tool for filling holes interactively. This tool automatically detects hole boundaries on the model and offers an interactive mode for selecting the boundaries of the holes to clean and/or fill.

To invoke the operation, select the Click & Fill Holes item [*Model > Triangles (Advanced)*], or press the “Fill holes in one mouse click” button in the Advanced Triangle Creation and Editing section of the Polygonal Edition toolbar.

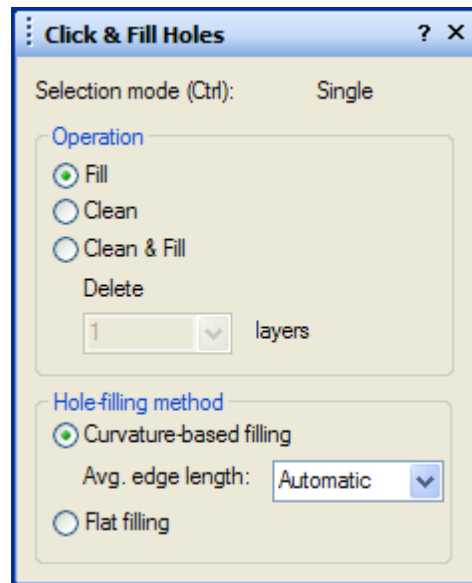


Figure 3.3: Dialog box for 'Click & Fill Holes' process

The hole will automatically fill:

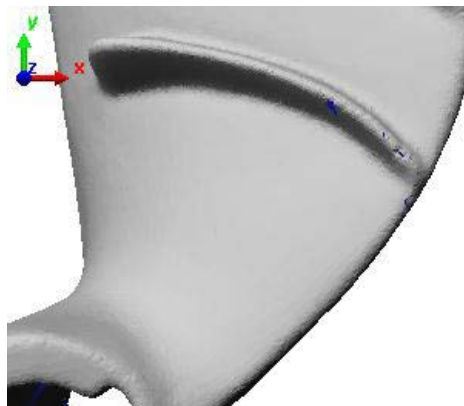


Figure 3.4: Surface of propeller after the hole was filled

3.2.2 Mesh Reconstruction

Other than filling the hole, PolyWorks also provides a tool for automatically reconstructing selected areas of a model with a smooth surface following the local geometry of the part. Area of interest is selected, then select the Reconstruct item [*Model > Triangles (Advanced)*], or press the corresponding “Reconstruct Mesh” button in the Advanced Triangle Creation and Editing section of the Polygonal Edition toolbar. This area will automatically be constructed.

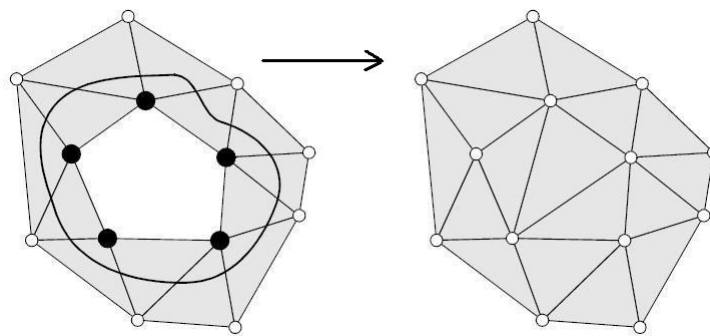


Figure 3.5: Illustration of reconstruction operation

3.2.3 Editing Model

The models of propeller are divided into two:

- (i) Propeller with fins
- (ii) Propeller without fin

The default 3D model of propeller has two fins. Thus to achieve these goals, the model is edited to eliminate fins as well as maintaining its original geometry. This step needs to be done carefully because any defects even a very small hole or layer can disturb the surface produced. For example, steps taken to eliminate one fin is summarize like below:

- (i) Select the fin as well as the surface around the fin.

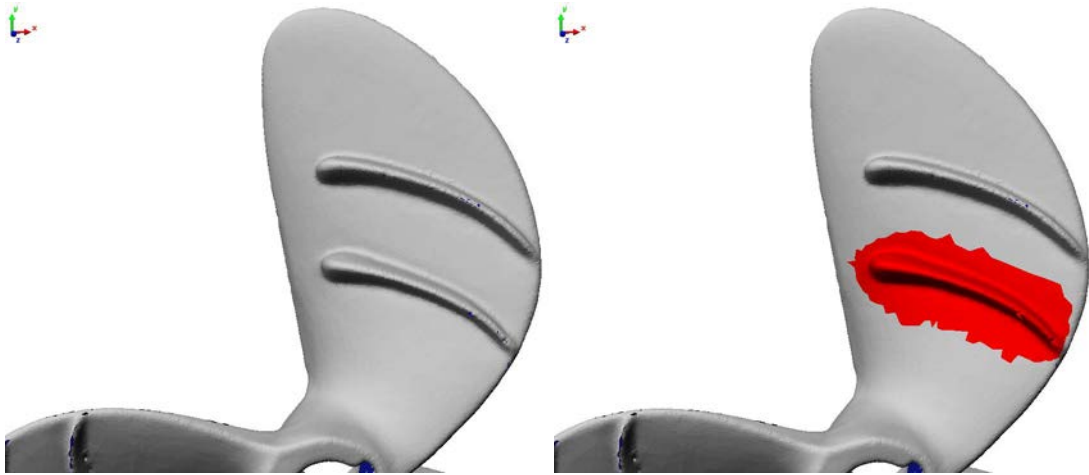


Figure 3.6: The area with red color was the selected area for this operation

(ii) Then delete the fin.



Figure 3.7: Surface of propeller after the area of interest is deleted

The result was a hole. At this time, we cannot use ‘Click & Fill Holes’ option yet because there are many particles of surfaces that is not fully deleted. If these particles did not eliminate, it will cause geometry errors. From closer view and different angle, we can see these particles better:

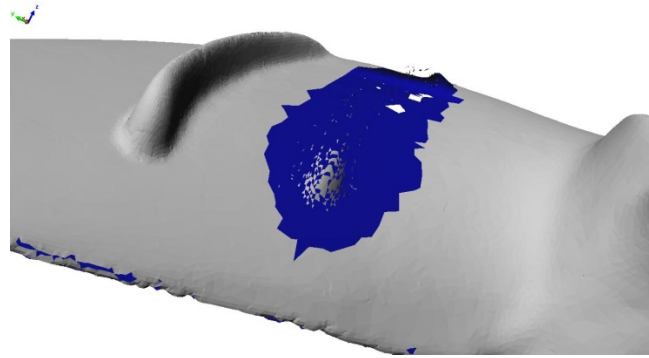


Figure 3.8: Picture of particles on the surface of propeller from closer and different view

These steps are repeated until the desired model did not have any defects or particles before proceed to create curve network.

3.2.4 Creating Curve Network

A curve network is built from a set of magnetized curves. Each magnetized point forms a node in a curve network. The curve must continues, belong to only one polygonal model and cannot be associated to more than two patches. Invalid patches will result in holes in the curve network.

PolyWorks offers automatic surfacing capabilities. The algorithm analyzes the curvature of the polygonal surface and tracks the natural lines of curvature, and automatically lays down a network of curves on selected triangles of a polygonal model. We need to select the Create Automatically from Model item [*Edit > Curve Network*], or press the corresponding button in the Curve Network Creation section of the Main Objects tool-box.

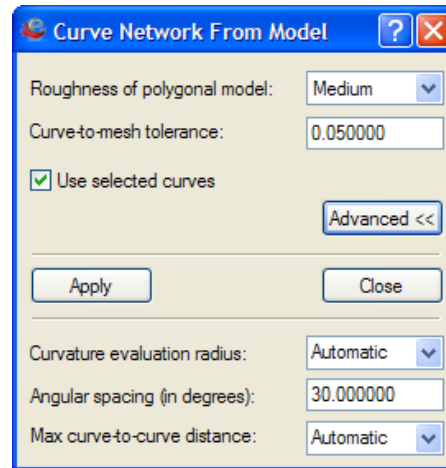


Figure 3.9: Dialog box for ‘Curve Network From Model’

This dialog box offering several items that control the creation of the automatic Curve Network:

(i) Roughness of polygonal model:

A combo box that guide the algorithm by qualifying the roughness of the surface of the polygonal model subjectively as low, medium, or high. This parameter is used when the Curvature evaluation radius parameter in the Advanced section of the dialog box, is set to Automatic.

(ii) Curve-to-mesh tolerance

A text box that defines a tolerance between the created curves and the polygonal mesh.

(iii) Use selected curves

A check box that, when enabled, specifies that selected Curves will be magnetized and networked to automatic curves.

3.2.5 Creating NURBS Surfaces

To invoke this operation, select the Curve Network objects and then select the Fit NURBS Surfaces item [*Edit > Curve Network*], or press the corresponding button in the Curve Network Editing section of the Main Objects toolbar.

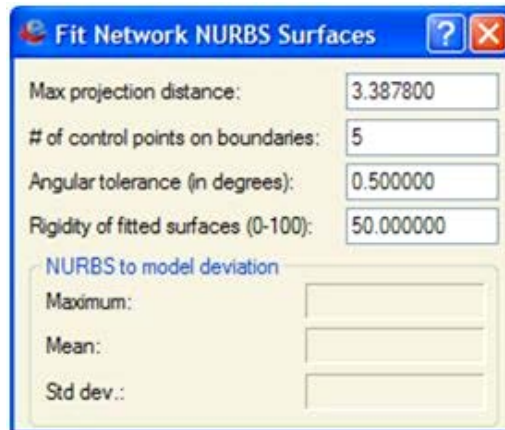


Figure 3.10: Dialog box for ‘Fit Networks NURBS Surfaces’

This dialog box offering several items that control the creation of the automatic Curve Network such as:

- (i) Max projection distance

Boundary control points within this distance are projected onto the polygonal mesh.

- (ii) # of control points on boundaries

Defines the number of control points for the boundary curves that make up each NURBS surface. The default value is 5. It is not recommended to use a value smaller than this.

3.3 CONVERT NURBS SURFACES TO IGES FILE

To automatically convert NURBS surfaces to IGES file, click *File > Export Objects > Curve Network NURBS Surfaces to IGES*. We can choose six different units of IGES; milimeter, centimeter, feet, inch, meter and micron. These IGES file then opened using SolidWorks and SolidWorks will request us to save the model as SolidWorks file (.sldprt). We have to accept this request because CosmosFloWorks cannot analyze IGES file. According to objectives of the project, there are two types of 3D model. The snapshots of these models in SolidWorks file format are shown below:

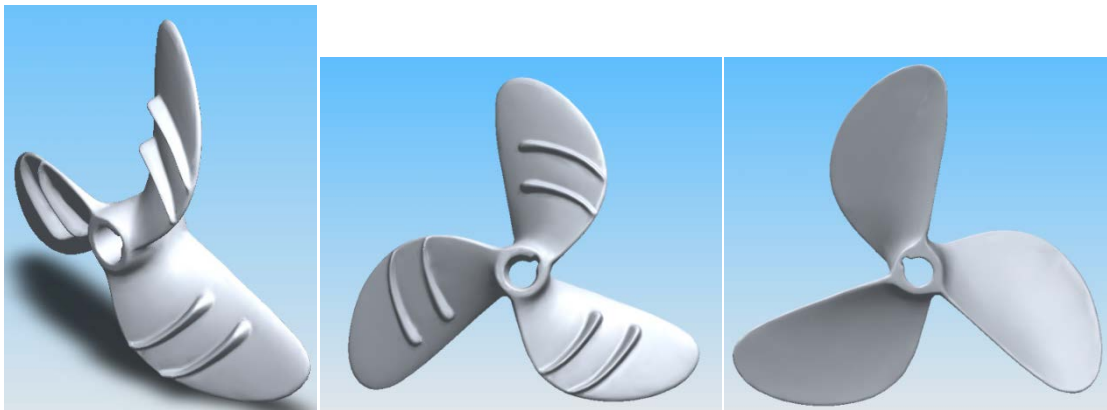


Figure 3.11: Isometric, front and rear view of propeller with two fins

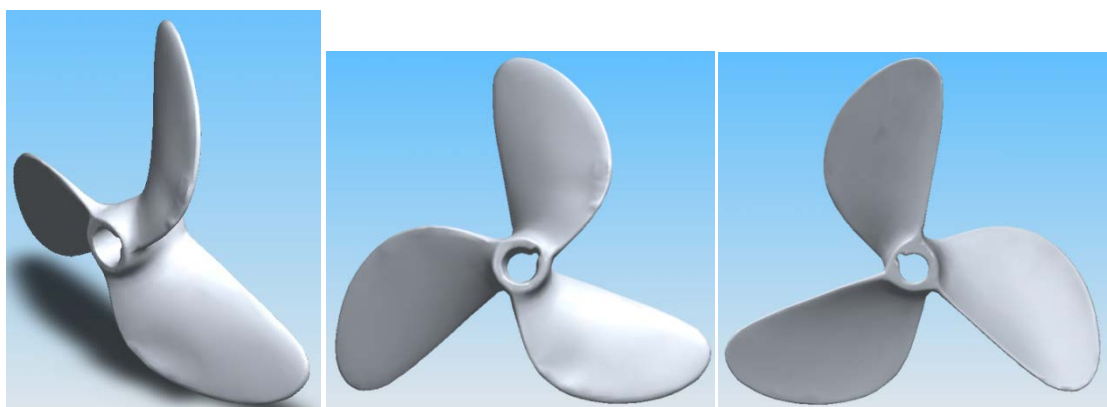


Figure 3.12: Isometric, front rear view of propeller without fins

3.4 CHECK FOR GEOMETRY ERROR

In SolidWorks, we must use 'Import Diagnostics' option to analyze, repair and heal the faulty faces and gapes between faces. This step is really important to make sure the model of propeller did not have any geometry errors. CosmosFloWorks cannot be executed if there are any small error like faulty faces and gapes between edges of surface.

Under 'Evaluate' section, choose 'Import Diagnostics' and right click at the list of faulty faces, then click 'Repair Face'. The same instruction for 'Gaps between faces' or just click 'Attempt to Heal All' for automatic repair operation for all faulty faces and gapes. The example of dialog box shown below:



Figure 3.13: Dialog box for 'Import Diagnostics'

However not all geometry error can be heal and repair by SolidWorks. If this happen, we have to recheck the 3D modeling process that we had done to the propeller. Another process of 3D modeling including mesh reconstruction, polygonal editing, creating curve network and NURBS surfacing need to be done again. This process is repeated until 3D model without geometry error and ready for analysis operation produced.

3.5 SET THE BOUNDARY CONDITIONS

After all the geometry error repaired, then we are ready for analysis operation using CosmosFloWorks. In the General Settings box, we can set analysis type, rotation analysis, fluids, wall conditions and initial and ambient conditions.

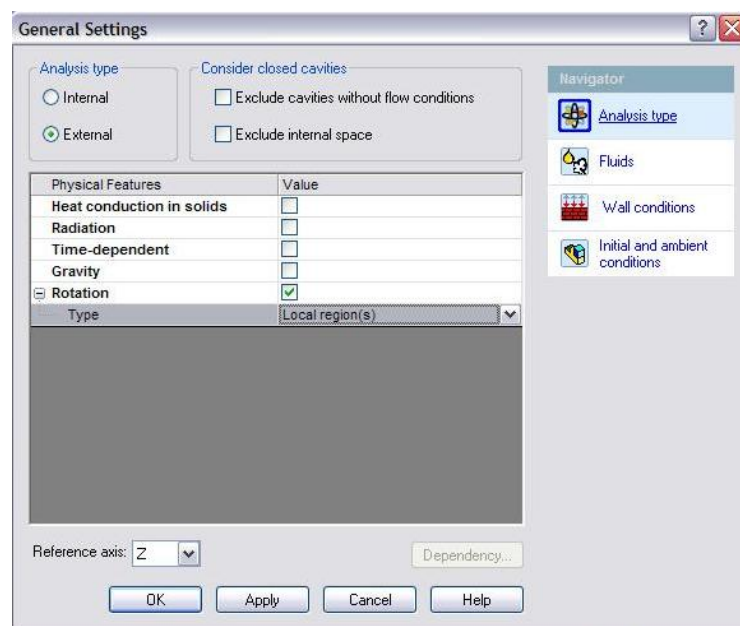


Figure 3.14: Dialog box for ‘General Settings’ in choosing the type of analysis and rotation

3.5.1 Analysis Type

There are two types of analysis under CosmosFloWorks; internal and external. For this project, we use external analysis because flow analysis concerns flows not bounded by outer solid surfaces, but only by the computational domain boundaries. In this case the solid model is fully surrounded by the flow.

3.5.2 Rotation Type

There are also two types of rotation; local region(s) and global rotating. Local region is the best rotation type for this project. Through local region rotation, we can specify the local rotating reference frame(s). This allows us to analyze the fluid flow through rotating components of the model. In order to specify the local Rotating region we need to create a component representing it.

The fluid flow within the rotating region is calculated in the rotating region's local reference frame. Flow field parameters are transferred from adjacent flow regions to the rotating region's boundary as boundary conditions. The flow field must be axially symmetric at the rotating region's boundary and the rotating regions not intersect with each other. The reference axis was axis-Z.

3.5.3 Fluids

In fluids section, we choose water as the project fluids. Note that wall conditions, initial and ambient conditions are set to default.

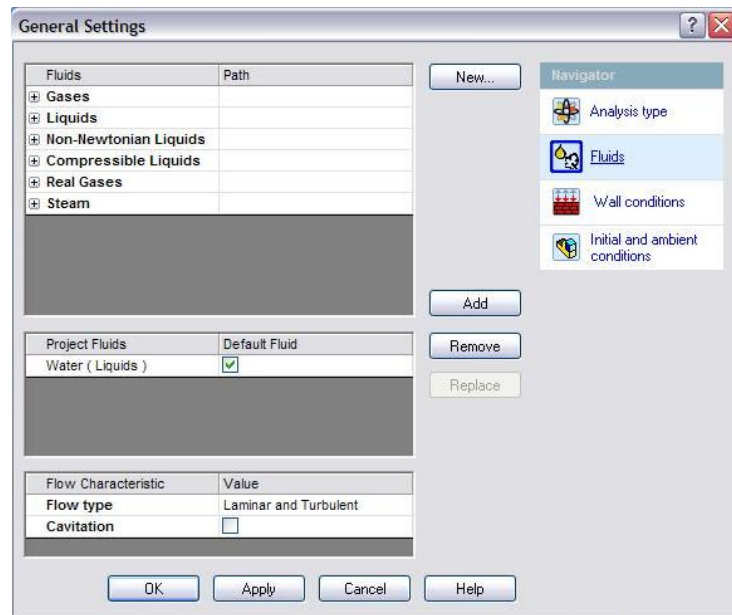


Figure 3.15: Dialog box for ‘General Settings’ in choosing the project fluids

3.5.4 Creating Rotating Region

Creating rotating region was one of the trickiest parts in this project. First, another simple cylinder shape of polygonal model designed like below:

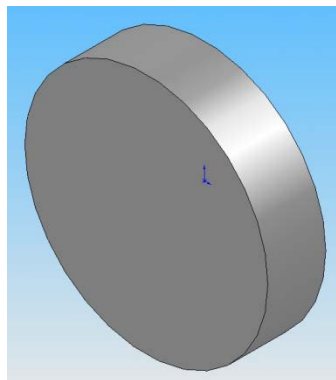


Figure 3.16: Simple cylinder shape of polygonal model as the rotating region

The propeller must fit and enclose in this cylinder model, thus they have same diameter. Their diameter is 217 mm. Also we have to make sure the axis of revolution for cylinder model must coincide with the rotation axis.

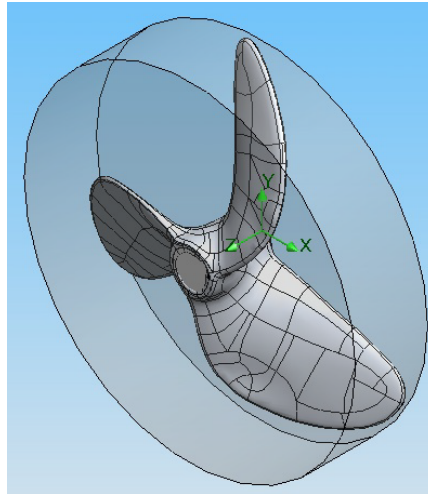


Figure 3.17: Arrangement of circle and propeller model from isometric view

The reason why this circle shape model made is because it will become the basis of the rotating region. The center of this circle will become the center of rotation, so we have to make sure that the center of the circle must coincide with the center of propeller. Before we can set it as the rotating region, it must disabled in the component control. At the toolbar, select *FloWorks* > *Component Control* > *Click the Circle model* > *Disable* > *Ok*. The purpose of this step is to set this region as the rotating fluid region and did not involve in the analysis.

Then to set this circle model as the rotating region, right click 'Rotating Regions' in the Cosmos FloWorks Analysis tree and select 'Insert Rotating Region' then select this circle model.



Figure 3.18: Dialog box for 'Rotating Region'

Note that in this dialog box, we can set the rotational speed of propeller and the direction of rotation. The direction of rotation is simply the annotation of the rotational speed value. For example if the rotation value was 400 rad/s, the propeller will rotate 400 rad/s clockwise. Thus the propeller will rotate counter-clockwise if the value of rotation was -400 rad/s. In this project, the propeller had clockwise rotation.

3.5.5 Set the Computational Domain

All the components involve must positioned in the computational domain area.

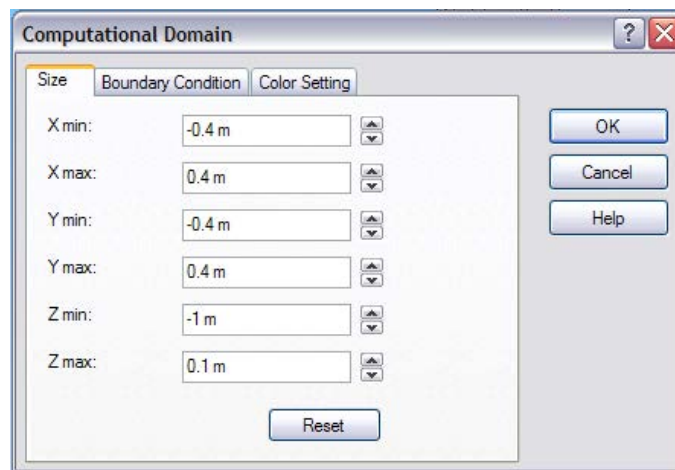


Figure 3.19: Dialog box for 'Computational Domain'

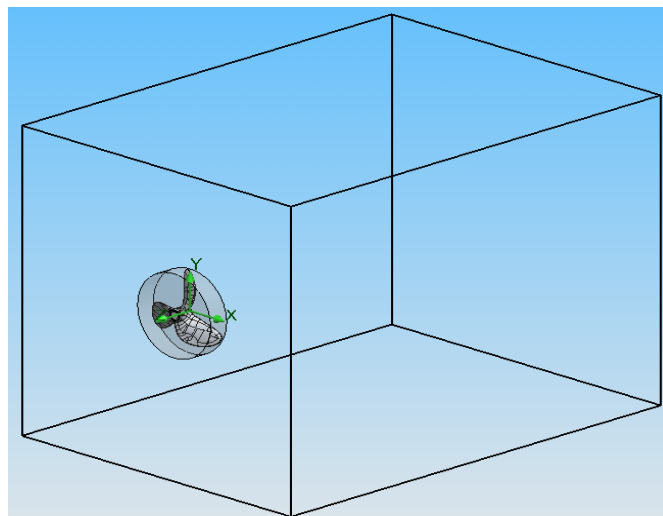


Figure 3.20: Isometric view of computational domain area

3.5.6 Set the Calculation Operations

Right click input data at the FloWorks analysis tree and select Calculation Control Operations. Minimum refinement number is set to 0 and maximum iteration is set to 2000. Clear the maximum calculation time, maximum travels, and goal convergence check box

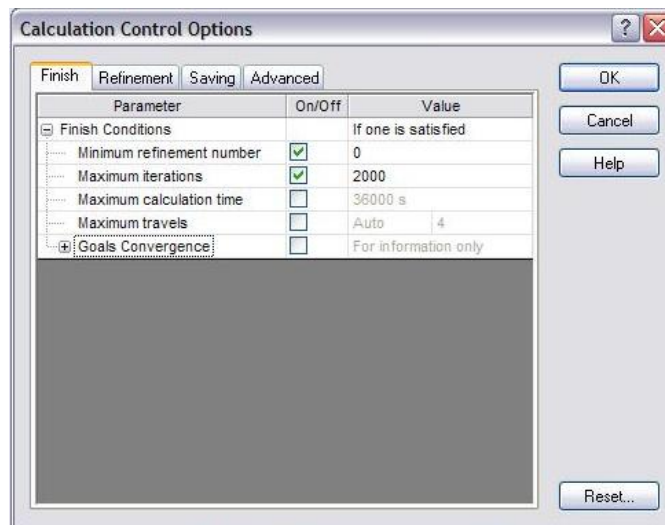


Figure 3.21: Snapshot of ‘Calculation Control Options’ dialog box

3.5.7 Set the Force Engineering Goal

At the FloWorks analysis tree, right click at Goal and select Insert Global Goals. Then tick Z – component of force and Z – component of torque to measure force/thrust and torque of propeller.

3.6 DATA ANALYSIS

After all the boundary conditions has been set, we can proceed to the most important part of the project; data analysis. To start the analysis, select Run and set the Run dialog as shown in Figure 3.22 below. Make sure to click the New Calculation and Solver tab before proceed.

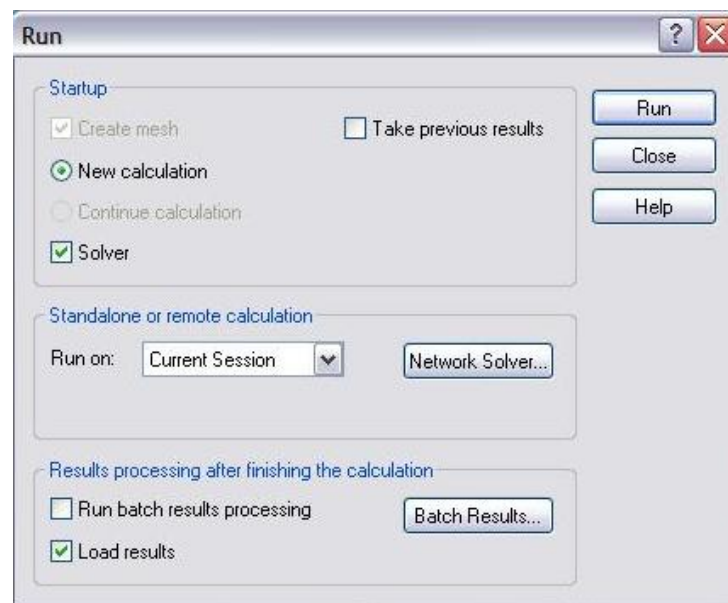


Figure 3.22: The dialog box to start the analysis by CosmosFloWorks

There are many ways to represent the result of analysis using CosmosFloWorks 2008. However, the suitable result presentations are cut plots, surface plots, flow trajectories and animations.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will explain the result from the analysis. The value of thrust and torque is used to compare the performance between propellers. These values are obtained by simply set the Z-component of force as the thrust and Z-component of torque as the torque from Global Goal options in CosmosFloWorks 2008.

Options had been made while using CosmosFloWorks 2008 including the environment conditions and slippage of propeller. In actual condition, the actual value of pitch is less than the nominal pitch because of the slippage. However in CosmosFloWorks 2008, the slip value is not considered in analysis process because there are no options for slippages deficiency. Also we neglect the effect of hull's shape to the flow of fluid. We assume that the fluid is in static condition before the propeller accelerates them.

The propeller with fins is used for small wooden fisherman ships and fiberglass ships with outboard engine. The velocity of the small wooden fisherman ship would achieve 5 knots when using this propeller and only around 4 knots if using the propeller without fins. Thus for this project, we assume the velocity of ships is from 3 knots to 7 knots. By assuming there are no slips occur, the velocity is converted to rotational speed to use in the analysis process.

4.2 THRUST AND TORQUE VALUE FROM STANDARD SERIES DATA

The propeller without fins is based on Wageningen B3.55 model. B3 means it is B model with 3 blades while 55 means it has blade area ratio of 0.55. Using the standard series data of Wageningen B from Appendix B and manipulation of the formulas 2.2 to 2.4, we can predict the value of thrust and torque of this propeller. Note that we assume the propeller did not have slips and the pitch value is 0.23 meter.

The first step to find the thrust and torque value is by calculating the advance coefficient, J . This value is inserted in the diagram from reference 2 and based on the pitch ratio, we can find the value of thrust coefficient, K_T and torque coefficient, K_Q . These values then inserted into equations 2.2 and 2.3 to find the thrust and torque value. Pitch ratio is the propeller pitch divide by the diameter. The table below shows us the value of thrust and torque of propeller from standard series data.

Table 4.1: Thrust and torque value from standard series data

Velocity, Knots	Thrust, N	Torque, Nm
3	373.20	13.51
4	663.46	24.02
5	1036.66	37.53
6	1492.79	54.04
7	2031.85	73.55

4.3 THRUST AND TORQUE VALUE FROM ANALYSIS

4.3.1 Propeller Thrust

Table 4.2 below is the comparison between the value of thrust from Standard Series Data and the analysis of propeller without fins. Theoretically, the value of thrust from Standard Series data should same as the value of thrust from propeller without fin. It is observe that the value of thrust from Standard Series Data is higher than the thrust value from propeller without fins around 4.3%. It is less than 5%, thus the value of thrust from analysis is valid for this project.

Table 4.2: Comparison of thrust from Standard Series Data
against propeller without fins

Velocity, Knots	Thrust from Standard Series data, N	Thrust for propeller without fins, N	Percent error, %
3	373.2	357.6	4.4
4	663.5	640.8	3.6
5	1036.7	991.4	4.6
6	1492.8	1433.7	4.1
7	2031.9	1940.9	4.7
		Average	4.3

Thrust is the force produced at a given speed when propeller rotates. Based on equation 2.2, the thrust increase as the rotational speed increase. From the analysis, it is observed that uniform slopes are produce where the values of thrust for all propellers increase gradually. Based on figure 4.1, the thrust is almost identical for both propellers at lower velocity from 3 to 4 knots. Their differences then increase from 4 knots to 7 knots. Overall, the propeller with fins is better than the propeller without fins in terms of thrust.

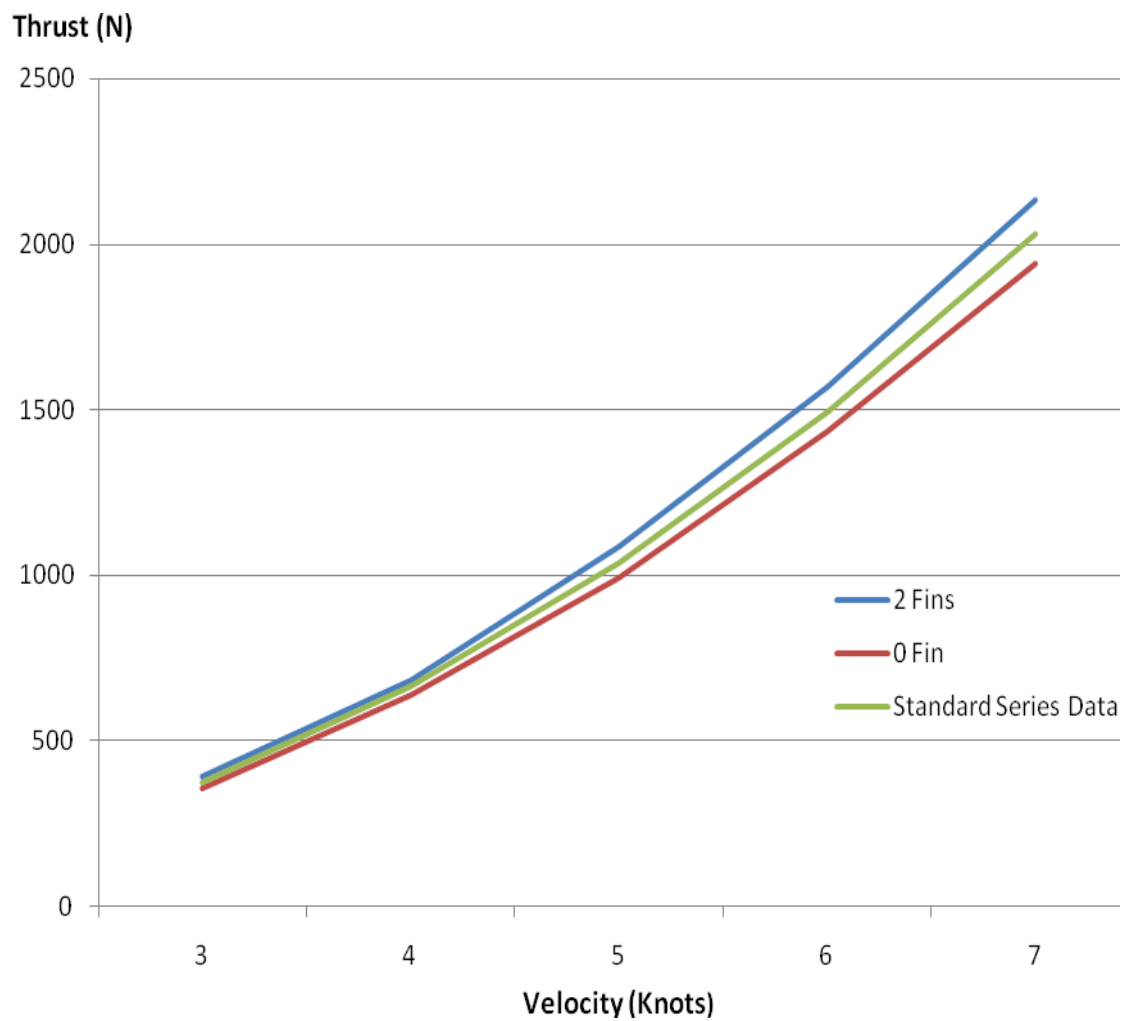


Figure 4.1: Graph of thrust versus rotational speed

According to Dr Widodo Adji (2009), the propeller with fins can make the boat faster for about 15% to 19% compare to boat with propeller without fins. Table below shows us the percent increase of the thrust value when the propeller attached with fins. Based on table 4.3, the percent increase of thrust are not uniform because their range is from 6.76% to 9.8%. The lowest increase of thrust value is at 4 knots with only 6.76%, while the highest is at 3 and 7 knots with 9.8% increase. The average of increase is around 9.1%.

Table 4.3: Comparison of thrust value from propeller with and without fins

Velocity, Knots	Thrust for propeller without fins, N	Thrust for propeller with fins, N	Percent increase, %
3	357.6	392.6	9.8
4	640.8	684.1	6.8
5	991.4	1083.6	9.3
6	1433.7	1569.4	9.5
7	1940.9	2131.7	9.8
		Average	9.1

4.3.2 Propeller Torque

Same steps are used for the torque value. The value of torque from Standard Series Data and the analysis of propeller without fins are included in the table below. Same as thrust, the torque value from Standard Series Data is higher than torque of propeller without fins. The percent errors between the torque value from analysis of propeller without fins and Standard Series Data are also lower than 5%. Their average is approximately 2.6%

Table 4.4: Comparison of torque from Standard Series Data against propeller without fins

Velocity, Knots	Torque from Standard Series Data, N	Torque for propeller without fins, N	Percent error, %
3	13.5	13.2	2.4
4	24.0	23.6	3.1
5	37.5	36.5	2.1
6	54.0	52.8	2.8
7	73.5	72.3	2.4
Average			2.6

The power provided by the engine is must be used to rotate the shaft connected between the engine and the propeller. Shaft horsepower is converted to a rotary force or moment applied to the propeller. This rotary force necessary to turn the shaft is simply torque.

Figure 4.2 shows us the graph of torque versus rotational speed. We can see that this graph is almost similar to the graph of thrust versus rotational speed. Although their value was almost same at slower velocity, propeller without fins has a slight higher torque as the velocity increase. Overall, their trend is almost same and did not have any rapid changes. However the average torque produces by the propeller with fins are better than other propeller.

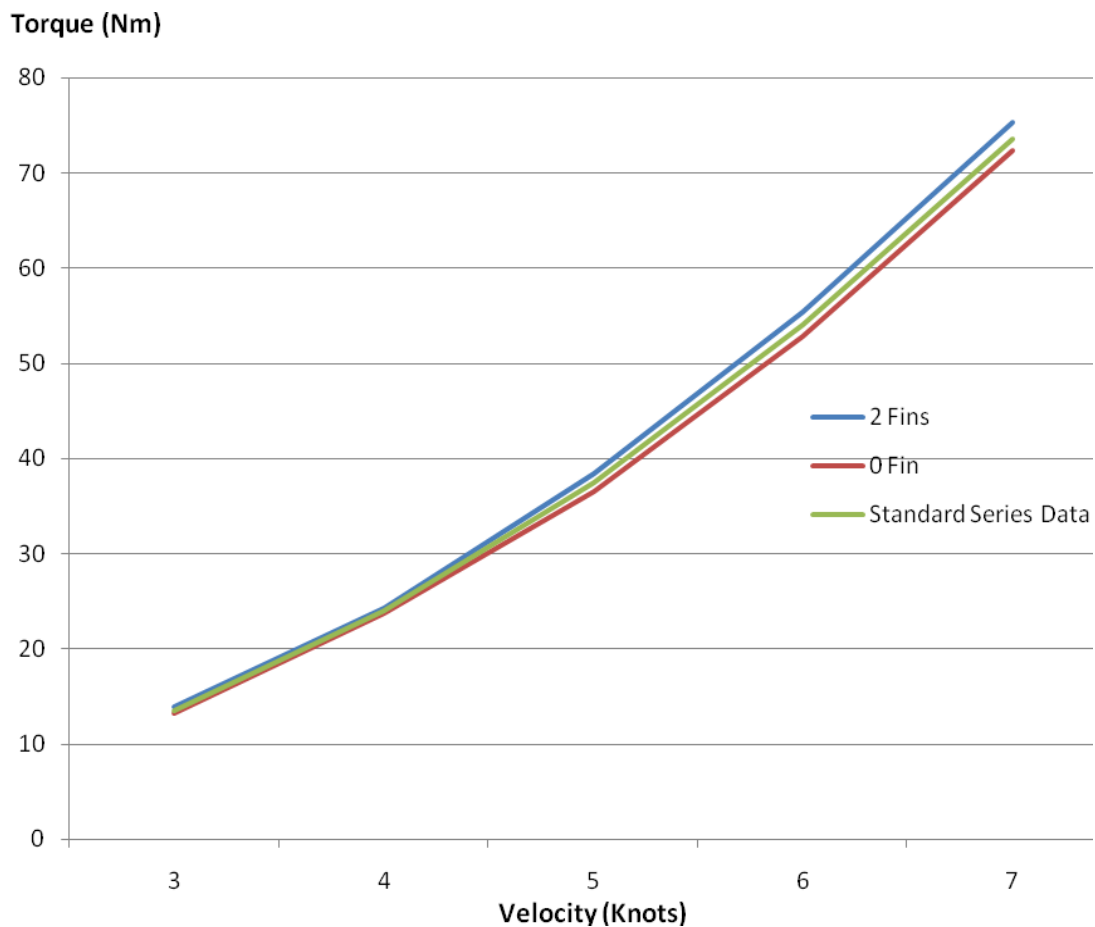


Figure 4.2: Graph of torque versus rotational speed

Table 4.5 shows us the percent increase value of torque between the propellers. Their trend is almost same as the table 4.3 because the percent increase value is not uniform. At 4 knots, the fins only increase 2.63% of the torque value. The percent increase is highest at 3 knots because the propeller with fins produces 5.1% higher value of torque compare to the propeller without fins at the same velocity.

Table 4.5: Comparison of torque value from propeller with and without fins

Velocity, Knots	Torque for propeller without fins, N	Torque for propeller with fins, N	Percent increase, %
3	13.2	13.8	5.1
4	23.6	24.3	2.6
5	36.5	38.3	4.9
6	52.8	55.4	5.0
7	72.3	75.3	4.2
		Average	4.4

4.4 ANALYSIS ON FLOW TRAJECTORIES

As previously discussed in Chapter 2, the increase of thrust can be explained by using blade element theory. It states that the thrust produce by the propeller are depends on the lift force act on the blade of propeller. These lift force is generated by the pressure difference between the back and front side of propeller. The back side is the side of propeller that faces the incoming fluid flow. It has higher velocity than the front side and hence the pressure here is lower. The difference of pressure between them dictate the lift force where higher pressure different will increase the lift force produced.

Through analysis by CosmosFloWorks 2008, we can clearly observe the difference of flow velocity at the back side of blade propeller between the propeller with and without fins while the front side remains same. The figure 4.3 and 4.4 is a flow trajectories view from CosmosFloWorks 2008 at 5 knots on the back side of propeller blade.

As we can see, the fluid flows from the inlet area near leading edge to the outlet area and the velocity increase through the surface of blade. The color tone bar shows that maximum velocity of flow on the surface of the propeller with fins is 11.4 m/s while the maximum velocity for propeller without fins is 10.6 m/s. Other than higher velocity, fins also make the flow lines close to each other. While the flow lines for propeller without fins spread to wider area.

These faster flows will create higher pressure difference between the surfaces of the propeller blades and increase the thrust produce. Thus it is proved that the fins increase the performance of propeller in terms of thrust by manipulating the fluid flow on blade of propeller without any changes to the gear systems or engine.

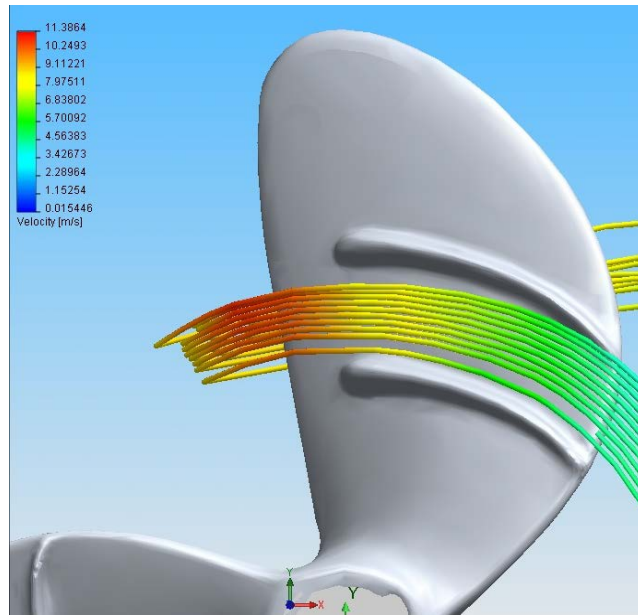


Figure 4.3: Flow trajectories at the back side of propeller with fins

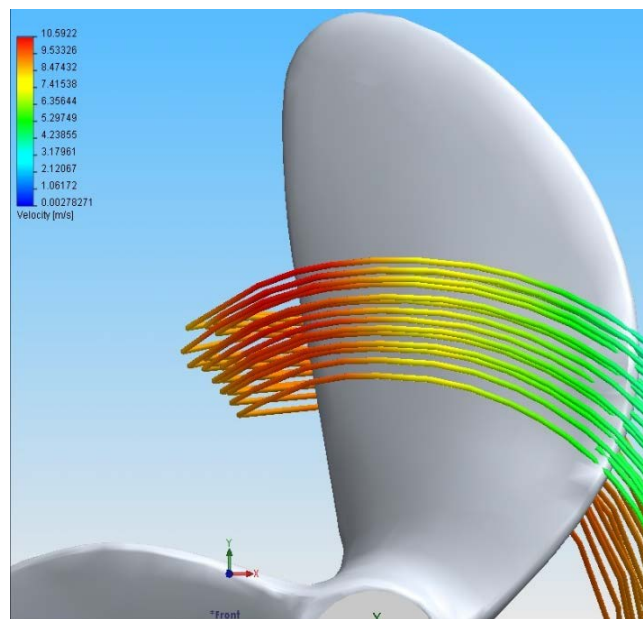


Figure 4.4: Flow trajectories at the back side of propeller without fins

CHAPTER 5

CONCLUSIONS

5.1 INTRODUCTION

This analysis addressed the effect of fins to the performance of propeller in terms of thrust and torque. This chapter summarizes the important finding from the analysis carried out in this project. It is also includes some suggestions for the further work.

5.2 CONCLUSIONS

We can assume that the value of thrust and torque from the analysis using CosmosFloWorks is valid and acceptable because their difference from Standard Series Data of Wageningen B series propeller is less than 5%. The thrust value of propeller from Standard Series Data is higher than propeller without fins with average of 4.3% error and 2.6% error for the torque value.

As the conclusion, the propeller with fins is better than propeller without fins because they produce higher value of thrust and torque. However, the percent increases are less than 10%, where the average increase of thrust value is 9.1% and 4.4% for torque. Higher value of thrust will increase the speed and acceleration of boat without any changes to the engine and gear system.

5.3 RECOMMENDATIONS

The objective of this project to predict the performance of propeller is achieved, but it need further study using better software. Although it is more complex and need computer with high performance, FLUENT is the better software to analysis the performance of propeller compare to CosmosFloWorks. It is because FLUENT consider will more parameter and closer to actual condition. For further research, the experimental works under controlled laboratory conditions is important to determine the validation of the result from the software analysis. Other parameters like slippage, boat shape and engine capacity should be considered in the calculations. Also the scope of performance is widening to include vibrations, sound and cavitations.

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APPENDIX A **Standard Series Data for Wageningen B3.55**

