DESIGN AND FABRICATION OF MARINE BOAT PROPELLER BLADE MOULD FOR INVESTMENT CASTING

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

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2021

DECLARATION

I declare that this Choose an item. entitled "Design And Fabrication Of Marine Boat Propeller Blade Mould For Investment Casting" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : Qalif

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Date : 25 June 2021

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature :

Supervisor Name :

TS. MUHAMMAD SYAFIK BIN JUMALI

Date : 25 June 2021

DEDICATION

Dedicated to

My honourable father, Ismail Bin Abd Rahaman

My precious mother, Limah Bt Sutan

My beloved brothers, Tasriq Bin Ismail,

Araaf Bin Ismail,

My beloved sisters Mujadilah Binti Ismail, Martiana Binti Ismail,

Izani Binti Ismail, Sajida Binti Ismail and Wahaiyu Binti Ismail

Thank you so much

ABSTRACT

The goal of this research is to design the mould for investment casting and investigate how the CATIA V5 software simulates the CAM process of a mould propeller blade by using the machining strategies such as multi-axis sweeping and multi-axis isoparametric by using the same parameter. Then, using a 5-axis milling machine, complete the fabrication. After that, investigate the impact of machining strategies on the surface roughness.The previous method of creating the propeller blade used machining, and the blade had some issues, such as the surface roughness not being smooth and insufficient dimensions. The previous method, which used a mold to create the pattern of the propulsion blade using wax before the investment casting process, was abandoned for this project.The type of material used for the mould is aluminium.

ABSTRAK

Matlamat penyelidikan ini adalah untuk mereka bentuk acuan untuk tuangan pelaburan dan menyiasat bagaimana perisian CATIA V5 mensimulasikan proses CAM bagi bilah kipas acuan dengan menggunakan strategi pemesinan seperti sapuan berbilang paksi dan isoparametrik berbilang paksi dengan menggunakan parameter yang sama. . Kemudian, menggunakan mesin pengilangan 5 paksi, selesaikan fabrikasi. Selepas itu, siasat kesan strategi pemesinan terhadap kekasaran permukaan. Kaedah sebelumnya untuk mencipta bilah kipas menggunakan pemesinan, dan bilah mempunyai beberapa masalah, seperti kekasaran permukaan tidak licin dan dimensi tidak mencukupi. Kaedah sebelumnya, yang menggunakan acuan untuk mencipta corak bilah pendorong menggunakan lilin sebelum proses tuangan pelaburan, telah ditinggalkan untuk projek ini. Jenis bahan yang digunakan untuk acuan ialah aluminium

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform and granting the permission to use the equipments and machines in the laboratory

My utmost appreciation goes to my main supervisor Ts.Muhammad Syafik Bin Jumali and my co-supervisor Ts. Zolkarnain Bin Marjom for all his support, advice and inspiration. His constant patience for guiding and providing priceless insights will forever be remembered. My special thanks go to both supervisors for all the help and support I received from them.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
CNC	-	Computer Numerical Controlled
NAB	-	Nickel-Aluminium-Bronze
MAB	-	Manganese –Aluminium-Bronze
CAM	-	Computer Aided Manufacturing
CAD	-	Computer Aided Design
RPM	-	Revolution Per Minute
3D	-	3-Dimension
V	-	Cutting speed
N	-	Spindle speed
OA	-	Orthogonal array
Ra	-	Surface Roughness

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CHAPTER 1

INTRODUCTION

1.1 Background

The marine boat is one of the vehicles used in the runaway area. This marine boat has various types and uses, such as the purpose of national defence army, cargo ship, transport services for passengers and personal use. It has difference sizes depending on its own use, from small size to large size.

After that, the marine boat has the main part of the propeller blade. The function of this propeller blade is to move the marine boat forwards and backwards. The propeller blade uses rotational movement or rotations on the blade, such as turning the screw. It causes the blade to generate a single power to push the boat when it is twisted. The propeller blade system is not only used transportation in the water, it is also used in other mediums as well as in the air such as aircraft.

This propeller look like a fan, and it has several types of blades in this industry, namely from a 3 propeller to a 4 blade propeller and the size of the blade. Each of these blade has its own distinct advantages, such as the purpose of increasing speed and providing maximum traction as well as smooth navigation. The marine propeller is an important component that can affect the performance of the ship. The choice of material should be the focus of marine propeller manufacturing because it must maintain the durability and be able to survive for an extended period of time. Among the material used are gray cast iron, carbon and low-alloy steels, chromium stainless steel, chromium-nickel stainless steel, manganese bronze, nickel-manganese bronze, nickel-aluminium bronze, Naval brass etc. The common material used to make the blade is Nickel-Aluminium Bronze (NAB) because it has high toughness and erosion-corrosion resistance (Durganeeharika & Babu, 2015)..

1.2 Problem Statement

There are numbers of manufacturing method to produce propeller such as casting, machining and composite layup and has its own advantages. Each process and equipment must be provided to produce blades using casting or layup methods such as moulds, machines, furnaces, etc. CNC machining is the most advanced technology in the blade manufacturing process because it has high throughput potential, accuracy, and repeatability, but it has some issues when machining on small propeller blades because it can cause cracks and insufficient dimensions and takes longer time to complete one blade due to its complex shape and thin. Therefore, this study, will developed an investment casting mould to produce blades to speed up the machining process after the casting process is done. Next, the surface of the mould must be smooth so that the surface of the blade is beautiful and there is no need to do the machining process.

1.3 Research Objective

The objective of this project are:

i. Design mould core and cavity propeller blade for pattern investment casting.
ii. Fabricate and evaluate the difference of machining strategies sweeping and isoparametric on surface mould core and cavity using CATIA V5 software simulation and CNC milling DMU60e.
iii. To investigate the impact of machining strategies on the surface roughness between core and cavity.

1.4 Scope of Research

This study will be limited to this aspect:

i. Design mould core and cavity for propeller blade.

ii. Simulation using CATIA V5 software.

iii. Machining strategies

iv. Fabricate the mould of propeller blade

v. Surface roughness.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, we will cover the process of machining the mold casting for the Propeller Blade. Using 5-Axis CNC Milling and CATIA software to design the mold and generate code for machining. After that, to know the appropriate parameters to obtain a suitable surface for the mold.

2.2 Propeller Blade

The propeller whose name originates from the Latin word "propeller" which mean "to move forwards". As a viable power source for the steam engine, an efficient screw propeller was developed at the beginning of the 19th century. Propellers are revolving duct fans that convert rotational motion into thrust which balances the resistance against move forward at that particular throttle speed. As a result, the engine's revolution are producing a higher propulsion force at a lower rotational speed (Durganeeharika & Babu, 2015). The propeller are produce the propulsion of a ship at lower speeds while also reducing vibration over the tugs while operating at a constant water flow rate (Santhosh Babu & Padmanabhan, 2017). The forward and back surfaces of the air foil-shaped blade create a pressure differential, and a fluid such as air or water accelerates behind the blade (Prasanth, 2018). The most common propulsion on ships is a propeller, which imparts momentum to a fluid and generates a force to act on the ship. Bernoulli's principle and Newton's third law are used to drive a ship. The propeller's thrust is delivered to move the ship through a transmission system that includes a rotating motion created by the main engine crank shaft, intermediate shaft and bearings, stern tube shaft and bearings, and ultimately the propeller itself (Durganeeharika & Babu, 2015). In terms of ship and torpedo performance, the marine propeller is regarded as a vital component. Majority in marine application, propellers manufacturing of Nickel-Aluminium-Bronze (NAB) are employed, because have a good corrosion resistance, high-yield strength, dependability and affordability (Prasanth, 2018).

2.3 Investment Casting

Investment casting is a popular process for producing titanium alloy and super alloy components with a near-net shape and numerous for investment casting, including wax injection, shell mould making, dewaxing, roasting and pouring (Yameng & Zhigang, 2018). According to Dhilawala (2017), they studied that, among the metallurgical arts, investment casting is both one of the oldest and most advanced and the rudiments of the investment casting method were employed by painters and sculptors in ancient Egypt and Mesopotamia to make elaborately designed jewellery, pectorals, and idols.

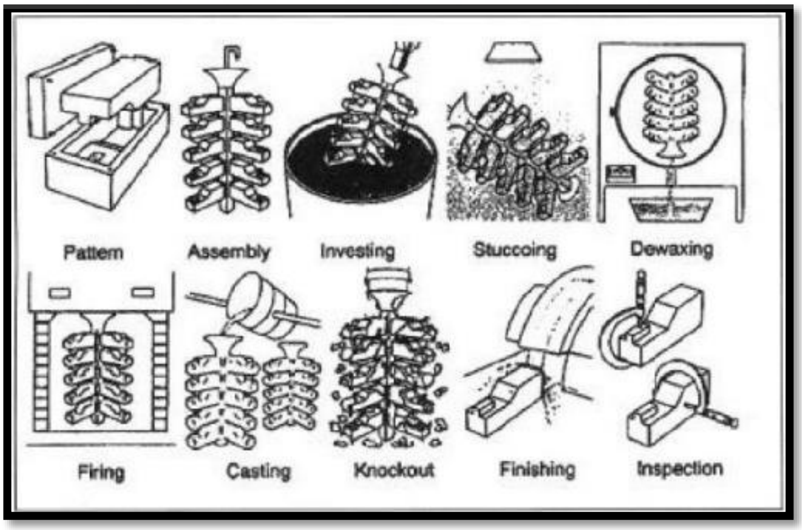


Figure 2.1Progress in Investment Casting (Dhilawala, 2017)

Figure 2.1 shows the progress in investment casting. The investment casting method proved useful for many military components, and it spread into numerous commercial and industrial uses where complex metal part were required throughout the post-war period, however, the technology remained largely unknown.

2.3.1 Shell Mould

In There are numerous processes of investment casting including wax injection, shell mould making, dewaxing, roasting and pouring (Yameng & Zhigang, 2018). Direct pouring into an investment casting shell mould using vacuum induction melting (VIM) because casting trees with a high yield can be manufactured quickly using a shell mound, it is an advantageous production process (Thomas et al., n.d.). According to Yameng & Zhigang (2018), they studied that one of the most important variable in keeping the casting process operating well is the shell's strength performance and with the popularity of investment casting in the aerospace industry, assessing the performance of ceramic shell moulds has become a research priority.

According to Harun et al (2015), they studied that the construction of a very thin ceramic shell mould is difficult because it necessitates many dipping processes in slurries including fine mesh refractory filler and a colloidal binder system. As a result of its origins in colloidal slurry loose particles, ceramic shell mould is extremely brittle and sensitive to breakage. The strength and integrity of the mould are very important factors in ensuring that the metal part has the proper dimensions.

Figure 2.2 Shell Moulding

2.4 CATIA V5

CATIA stands for Computer Aided Three Dimensional Interactive Application. This software is much more than a CAD (Computer Aided Design). In this software is complete set of software that combines with CAD, CAE (Computer-Aided Engineering) and CAM (Computer-Aided Manufacture). According to Zhu (2017), they studied that the CATIA version of V5, which is based on the idea of digital goods and e-commerce integration, can be utilized to create a working environment for the whole digital company development process and the different components of the product development process may be mimicked in this environment, as well as electronic communication between engineers and non-engineers. After that, the whole development process of the product includes concept design, detailed design, engineering analysis, finished product definition and the use and maintenance of manufacturing and finished products in the whole life cycle. Next, CATIA can help management in designing and manufacturing a tool for a compact aircraft, and it offers a complete design capabilities and CATIA will integrate mechanical design, engineering analysis, and simulation processing features like organic to enable users with a tight paperless work environment, reducing design time, improving quality, and lowering manufacturing costs.

2.5 CNC High Speed Machining

High speed machining (HSM) is a promising technology that uses a tiny side and down step in combination with a high spindle speed and feed rate to minimise machining time (Mebrahitom et al., 2016). According to Jain & Bajpai (2020), they studied that C. Salomon originated the concept of HSM, and he is one of the forerunners of HSM. In addition, according to Gupta & Paulo Davim (2020), they studied about J. F. Kahles, M. Field, and S. M. Harvey published the CIRP Keynote Paper 'High Speed Machining Possibilities and Needs' in 1978, which examined the state of high speed machining based on a worldwide survey of CIRP members and others from the industry. After that, they also made an additional report at 1982 CIRP General Assembly which was mainly focused to practical application of high speed machining in the USA.

According to Jain & Bajpai (2020), they studied about HSM is a metal-cutting method that employs a 10 to 15-times quicker cutting speed than conventional machining. In HSM, the cutting speed range is determined by some factors, including the work material, tool material, cutting circumstances, and machine tools. The history of HSM, its benefits, features, and scientific differences from conventional machining and the tooling system, machine tools, and software that is currently available.

Figure 2.3 CNC Milling Machine

2.5.1 5-axis CNC Milling Machine

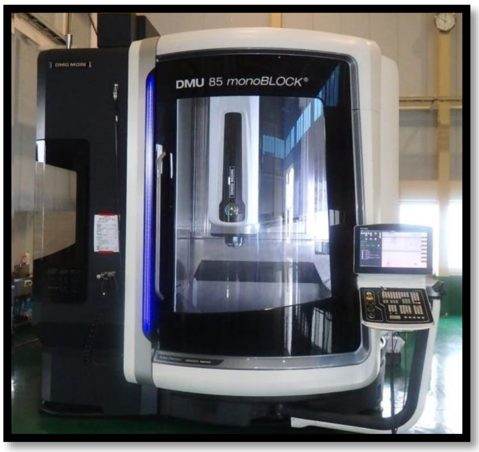


Figure 2.4 5-axis CNC Machine

From this figure its show the 5-axis CNC milling. This machine have five direction of cutting tool can move. From the center machine, the cutting tool can move to Z, X and Y axes as a linear axes. After that, A and B axis as a rotation of table and spindle machine to approach the work piece from any direction. 5-axis machine are more important industrial application for precision manufacturing of complex work pieces, particularly driven by requirements of aerospace and medical engineering industry. The accuracy of 5-axis machine tool depends, among others, mostly on the geometrical position and orientation and component errors of the machine tool axes.

2.6 Machine Parameter

Machine parameter is the most important in process machining for the good result of surface finish. Three relative motions between the work piece and the cutting tool are necessary for gradual material removal from the work piece in any machining or metal cutting operation. In the machining processes of moulds and dies which require a high surface finish and geometric accuracy (Mebrahitom et al., 2016). After that, there are three parameter needed which is cutting speed, feed rate and depth of cut. The machine parameter is very important because it can affect the machining performance. Surface finish of the machined surface is most important due to its effect on product appearance, function, and reliability (Pattanayak et al., 2016)

Table 2.1 Optimum Parameters For Surface Roughness(Vishnu et al., 2015)

FACTORS	OPTIMUM VALUES
Cutting Speed (rpm)	2487
Feed Rate (mm/min)	1540
Depth of Cut (mm)	1.5
Coolant Flow (lt/min)	4.8

2.6.1 Spindle Speed

The spindle speed is the rotation of the spindle of the machine, measured in revolution per minute (RPM). The speed is determine by working backward from the desired surface speed (sfm or m/min) and incorporating the diameter of work piece or cutter. (Wikipedia). Spindle power should be piecewise linear representation according to spindle speed characteristic, due to the correlation coefficient of power model only has 25.45% without segmented (Feng et al., n.d.). After that, to control the spindle speed has developed to achieve the constant value of cutting speed and consequently provide a solution to control the feed rate in order to maintain the constant value of feed per tooth. The constant value of cutting speed can be achieved only when the spindle speed will continuously change according to the real cutting diameter. (Vavruska, Zeman and Stejskal et al. 2018). The cutting speed V (in. /min.) is generally used to evaluate the spindle speed N (rpm). The formula is: Spindle Speed, N $=\frac{V \div \pi}{D \times 1000}$

Where D is the cutter diameter. The cutting speed range depends upon several parameters such as work material, tool material, cutting conditions and machine tools. However, work material significantly affects the cutting speed. For example, the cutting speed of aluminium is notably higher than the titanium alloy (see Figure 2.4) (Jain & Bajpai, 2020).

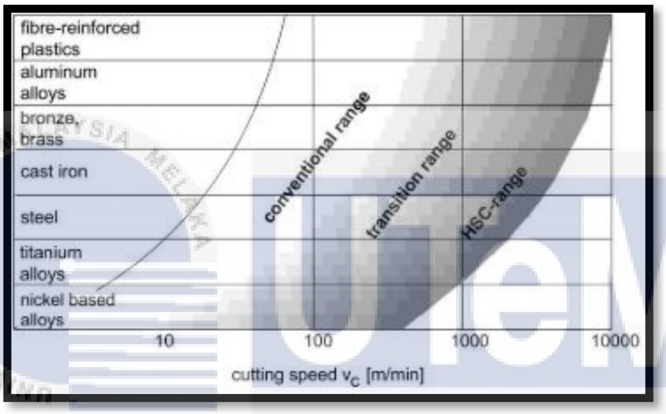


Figure 2.5 Cutting speed range for various materials

2.6.2 Feed Rate

Feed rate is the one of cutting factor, which is used to move the tool against the work piece in order to process the entire surface. Feed rate is the speed at which the cutter is fed so that it advances against the work piece. According to Abdulwahhab (2015), they stated that feed rate refers to the rate at which the cutter moves across the work piece and the rate of feeding is expressed in mm/min. They also study the rate at which the revolving milling cutter advance the work piece in the process and the revolving is known to remain stationary while feeding the work piece through the worktable. And then, there is three ways to convey feed which are feed per tooth, feed per revolution and feed per unit of time. The formula for feed rate can be calculated using the following equation:

$$FR = RPM \times T \times CL$$

Where,

- FR is the calculated feed rate in inches or mm per minute.
- RPM is the calculated speed for the cutter.
- T is number of teeth on the cutter.
- CL is the chip or feed per tooth.

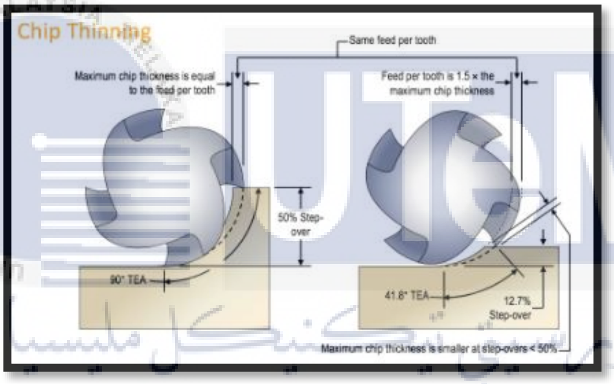


Figure 2.6 Feed per tooth

2.6.3 Depth of Cut

In the milling process, depth of cut is the total amount of cutting to remove the material in the machining process using a cutting tool. It depends on the type of tool and work material. According to Abdulwahhab (2015), they stated that it is the thickness of the material that has been removed by one pair of cutters during the procedure. They also studied when a cutter mills from one end of the work piece to the other pair of cutter. In other word, it's the distance between the work piece's original surfaces measured in millimetres. The total amount depth of cut can determine the time of the machining process. If using the higher value, the time of process machining become faster. The selection of the cutting depth must be guided by the type of material and if using high cutting force and cutting on hard material, it will cause vibration, rough surface and tool wears.

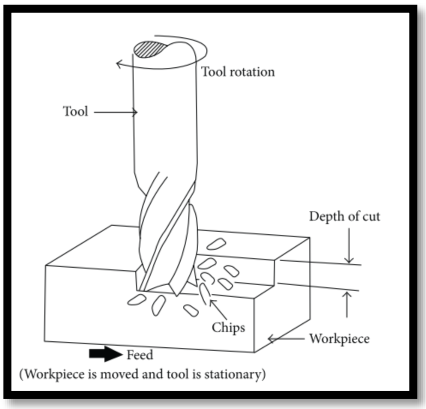


Figure 2.7 Cutting tool on work piece

2.7 Surface Roughness

Surface roughness is the roughness reading that measured on the work piece surface using the surface roughness tester to check the reading on the work piece. The readings taken can determine whether the surface work piece is rough or smooth. The higher value indicate a rough surface and the lower value are smooth surface. According to Abdulwahhab (2015), they studied that surface roughness is the most important factor in determining product quality. After that, surface roughness is formed through a complex, dynamic, and process-dependent mechanism. In CNC milling operation, several factor influence the final surface roughness, including controllable parameters spindle speed, feed rate, and depth of cut and uncontrollable element which is tool geometry and material properties of both tool and work piece. There are more than to measure surface and interpret the data in today's world, but the roughness measurement is the most common measurement of the mark created by tool, or the surface texture (Sahay & Ghosh, 2018).

According to Wu & Yin (2018), they studied that surface roughness has a large impact on mould processing quality and surface roughness refers to the treatment of minor pitch and micro-peak micro-valley geometry errors on the surface. According to Sahay & Ghosh (2018), they studied about the most contact-based measurement tool are traces done 90º to "lay" with a conical diamond stylus and the radius of the stylus tip is in the range of 2-10 μm. In a skidded measurement tool as shown in figure 2.7.

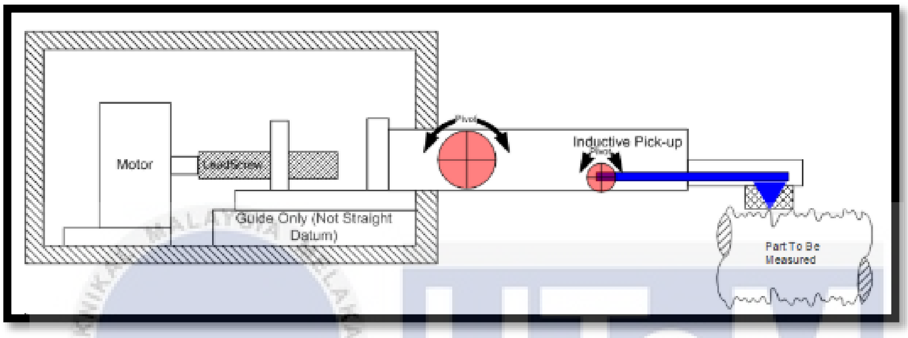


Figure 2.8 Skidded Measurement too

2.8 Machining Strategies

Machining strategies are important to determine the cutting method for the cutting tool while performing the machining process. This is because it aims to achieve higher productivity and good surface quality. The objective of the study presented was to analyse the parameter and cutting method that are appropriated for machining the mould casting propeller blade to achieve a smooth surface. For this studied, the commonly used is Taguchi method. The function of Taguchi is to determine the optimal parameter setting for the CNC milling procedure and Taguchi design was used to determine the signal to noise ratio, as well as the cutting parameter (Anwar et al., 2015). According to Pattanayak et al (2016), they studied that Dr Genichi Taguchi is a Japanese quality management expert who developed the Taguchi method. After that, the technique investigates the notion of a quadratic quality loss function and employs a signal-to-noise (S/N) ratio as a statistical measure of performance. Mostly, the orthogonal array is commonly employed because it allows for the performance of a small number of tests.

2.9 Summary

From this chapter, I can conclude that researchers evaluate various machining parameters to obtain the best surface readings in terms of high speed to low speed to determine the best machining parameters. This is because, to get a quality surface, we have to ensure that the parameters used are appropriate. This can reduce damage and time when performing the machining process on the surface of the investment casting mould for the propeller blade. There are machining techniques commonly used as machining matrices. A large number of studies have been conducted at three points during the cutting process, which is surface roughness, cutting parameter, and machining strategies.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The simulation used to develop the CAM process for moulding propeller blade will be the focus of this chapter. Besides that, the design of the propeller blade used the previous design. For this study, will design the mould to know the ability of the machine and the tool. After that, the shape of the surface mould is examined in order to determine machining capability. From the existing design 3D core and cavity of blade propeller, it applied to create a CAM program to do the fabrication on machine CNC milling for manufacturing operations. Finally, the parameter CAM simulation and the CAM strategies are used to determine the optimum surface roughness of the surface core and cavity blade propeller.

3.2 PSM Flow Chart

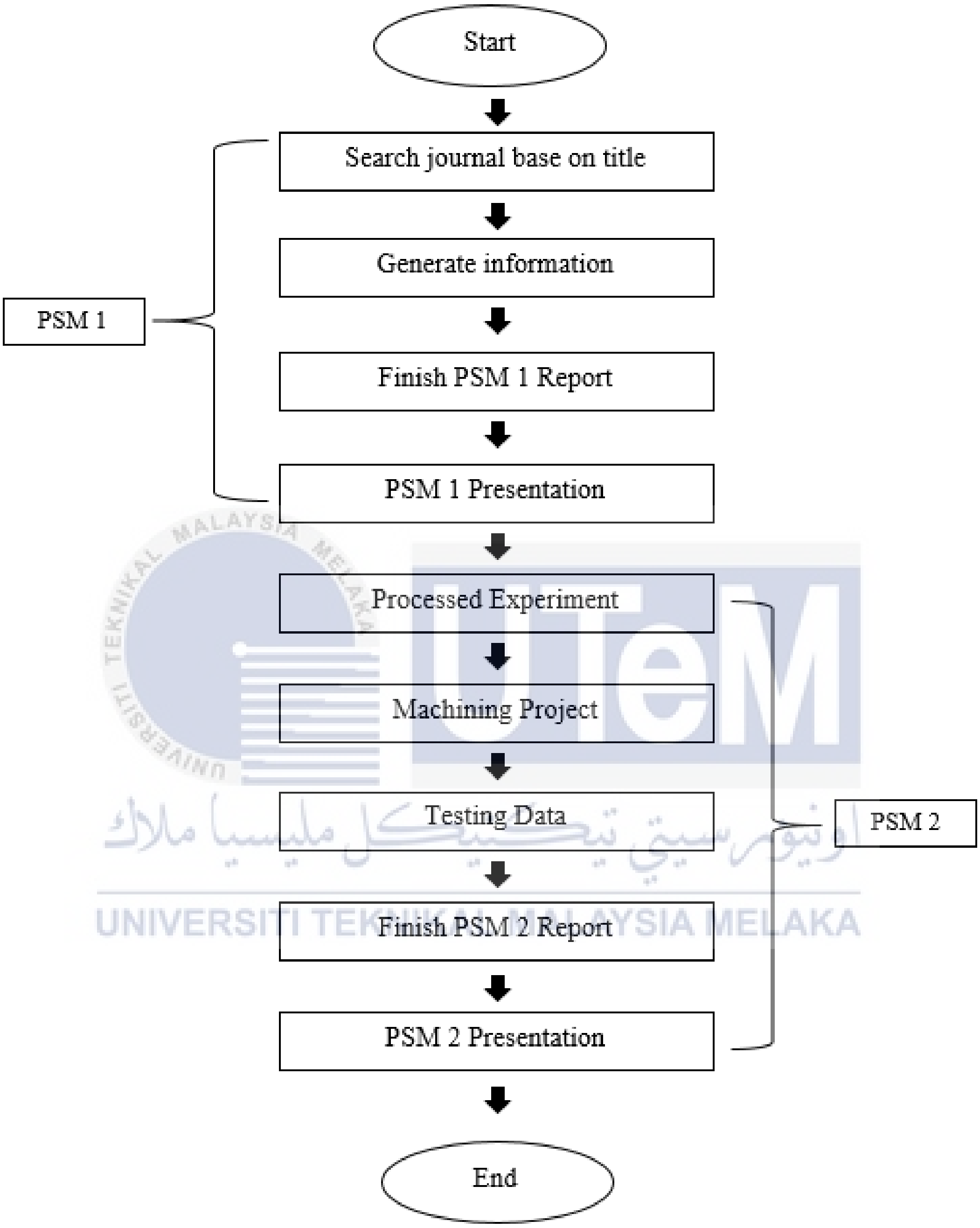


Figure 3.1 PSM Flow Chart

3.3 Project Flow Chart

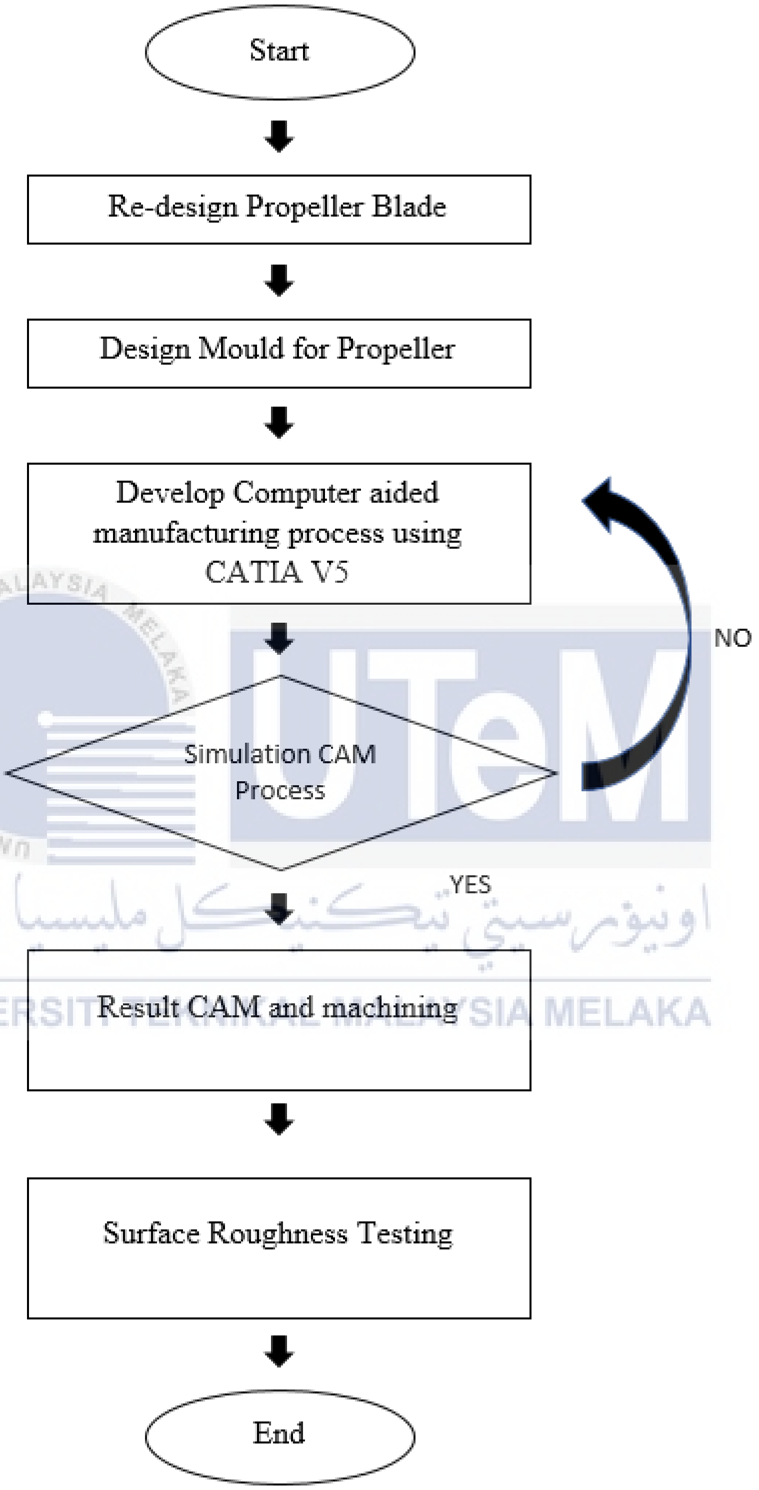


Figure 3.2 Project Flow Chart

3.4 Design of Propeller Blade

Figure 3.3 Previous Prototype Propeller Blade

The figure 3.3 show that the previous 3D prototype of propeller blade. From this prototype, re-designed the propeller blade using the CATIA V5 software. Besides that, the dimensions and shape of the blade will follow the previous project. After that, there is a change in the dimension at the base of the propeller blade for the next process which is machining process for assembly part. The redesigned propeller blade is depicted in Figure 3.4.

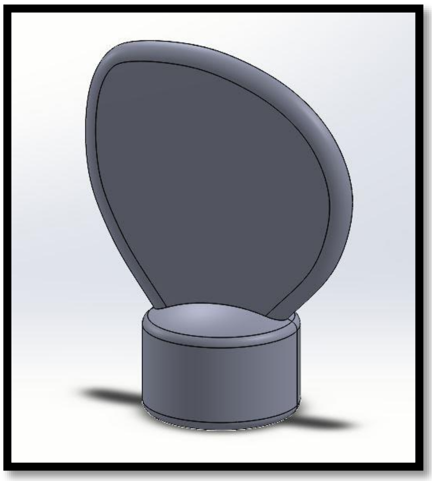


Figure 3.4 Design of Propeller Blade

3.5 Mould Design

Moulding manufacturing is used to create complex part that the machining process cannot. The moulding process is divided into two part the core and the cavity. The core and cavity are critical component in the moulding process because they are used to create the shape's pattern. Used the solidwork software to create the core and cavity designs, as well as the 3D models for the core and cavity, respectively. The design of the core and cavity must follow the geometry of the part. The geometry of the surface core and cavity design can be machining.

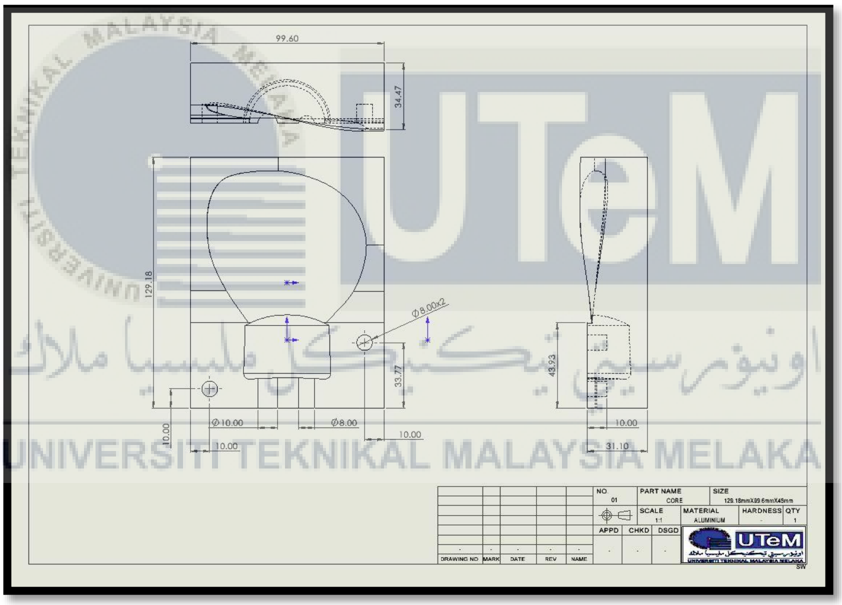


Figure 3.5 Design Mould Core for Propeller Blade

The figure 3.5 show that 3D models and dimension of the blade mould. The part of this mould is the core for the top side of blade. The size of the core is 129.10mm X 99.60mm X 34.47mm. The design of the surface core has a curve shape of the mould. The hole at the corner of the core is for the dowel pin. The purpose is to align the core and cavity when the mould in assembly process. The size of hole and dowel is diameter 8mmx20mm.

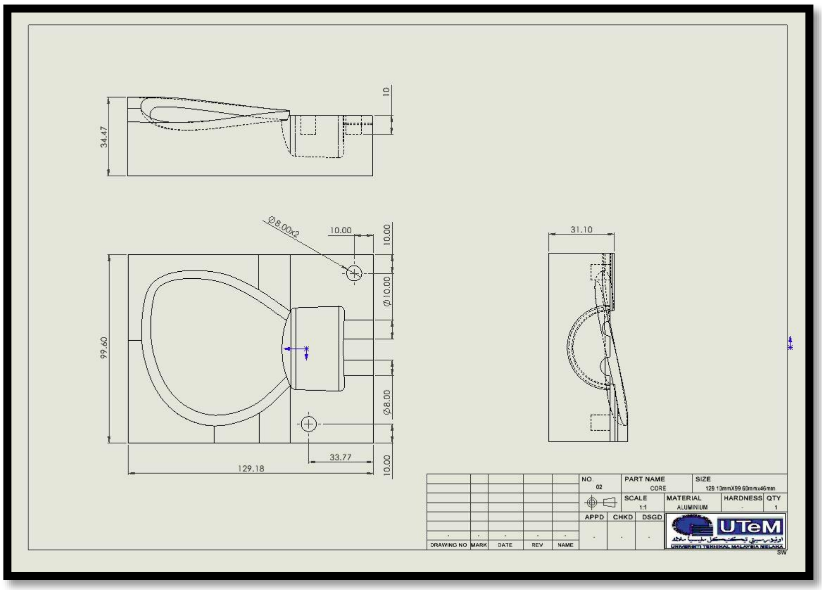


Figure 3.6 Design Mould Cavity for Propeller Blade

The figure 3.5 show that 3D models and dimension of the blade mould. The drawing show that, the part of this mould is cavity for the bottom side of blade. The size of the core is 129.10mm X 99.60mm X 34.47mm. The difficult design of this cavity has a curve shape on the surface mould. The hole at the corner of the core is for the dowel pin. The purpose is to align the core and cavity when the mould in assembly process before inject wax into the mould. The size hole of dowel is diameter 8mm x 10mm.

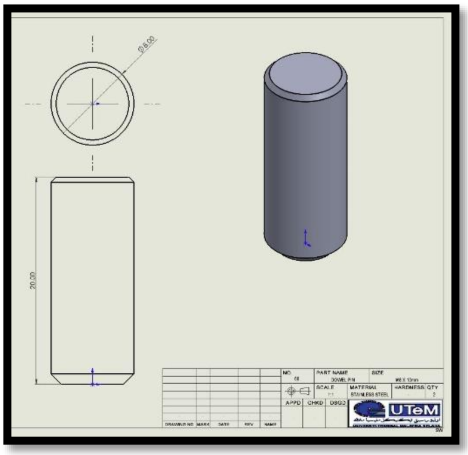


Figure 3.7 Dowel Pin

Figure 3.7 show the dimension of dowel pin. Dowel pin are cylindrical tools designed to secure into machinery by fastening difference workpieces together. They are effective when aligning the part during assembly process. The material selection for this dowel pin is stainless steel. Stainless steel is a strong, corrosion-resistant alloy with excellent resistant to heat. The type of dowel pin are precision dowel pin. This dowel pin are effective in interference fit applications. The dowel pin is specially designed based on hole size, tolerance and ductility. The size that used is M8 x 20mm

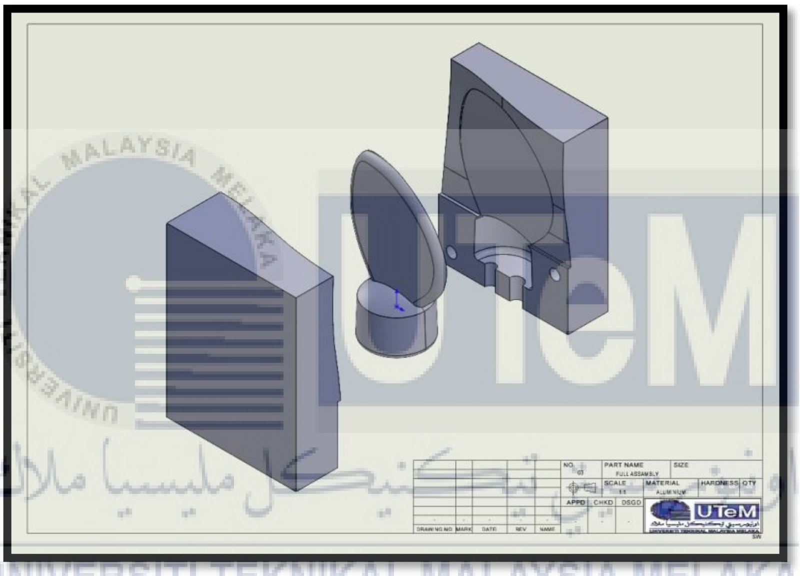


Figure 3.8 Full Assembly Mould

Figure 3.8 show that the full assembly mould for propeller blade. The purpose of this assembly view is to show the step by step how to assemble the mould properly without have any problem. This drawing can show the procedure of adding wax into the mould is completed, this drawing may display the geometry of the finished propeller balde.

3.6 CAM Process

Computer aided manufacturing is the method to develop the machining strategy using CATIA V5 software. CAM is the software that tells a machine how to make a product by generating tool paths. To use CATIA V5 software, need to convert the format to file such as STEP, IGES or STL. This file format only can open directly by CATIA V5 software from other software.

3.6.1 Preparation Stock and Axis System

The stock dimension for the CAD (computer aided design) mould must bigger than actual part size. The stock must be create and the origin of the coordinate of axis system (x, y, and z) must select the correct direction of the edge corner stock. The Y-axis refer to vertical direction on the top mould stock surface and the X-axis refers to the horizontal direction and parallel with side edge of stock. After finish create the stock, need to save at the file location of this project. The detail stock and origin axis system are shown on figure 3.9 for core and figure 3.10 for cavity.

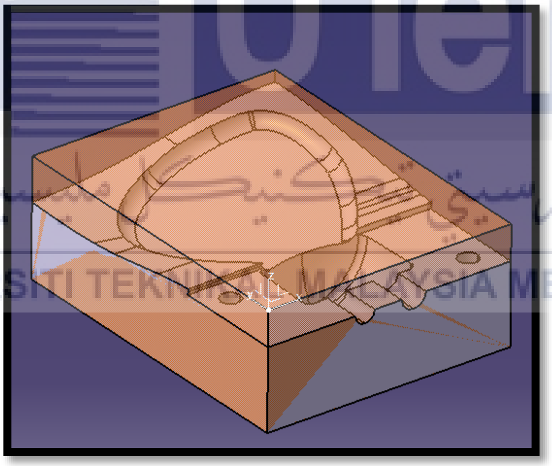


Figure 3.9 CAD Cavity with Stock and Origin Axis System

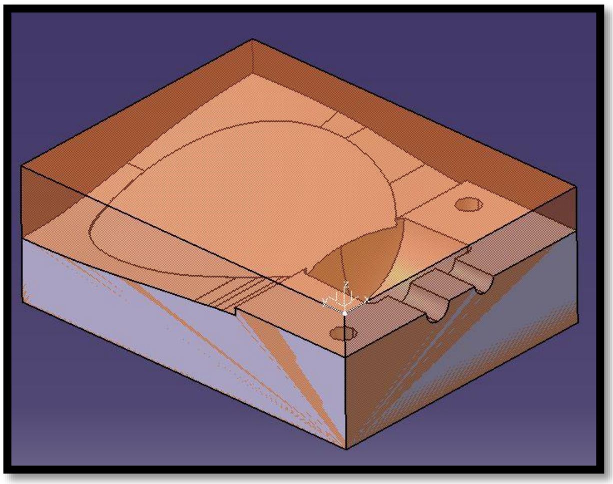


Figure 3.10 CAD Core with Stock and Origin Axis System

3.6.2 Plane System Preparation

In this step, create a plane system with three plane which is approach, home and retract. The objective of these three planes is to allow the tool to travel with a strting point at the edge of the home plane. The distanced between three plane are difference which is starting from the plane axis to approach plane 30mm, approach to retract plane 30mm and from plane axis to home plane 100mm. This plane system are important for the tool movement because to ensure the tool travel safely. From the figure 3.11 shown, the plane system has made respestively with CAD part.

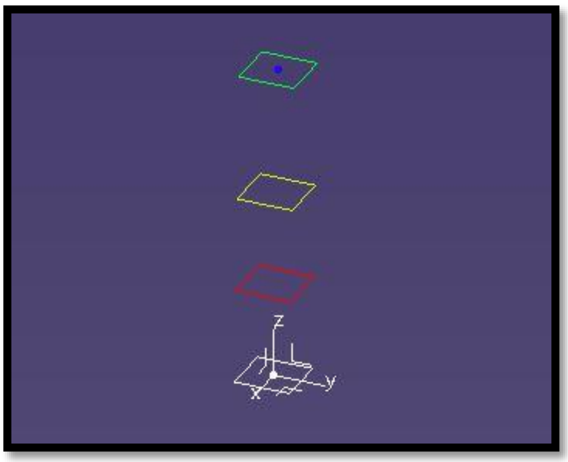


Figure 3.11 Plane System

3.6.2.1 Part Assembly at Product

In this part assembly, the two part was prepare need to import in the CATIA V5 software for the assembly process. After the two part have been imported, the plane system and the stock axis system must be in sync using the coincidence command. After that, please ensure that both axis system are pointing in the same direction. Figure 3.12 and figure 3.13 show that, the assembly of stock part and plane system for part core and cavity.

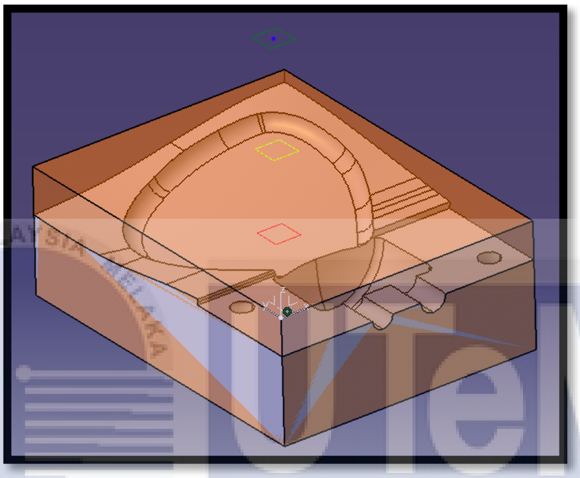


Figure 3.12 Assembly CAD part with Plane System

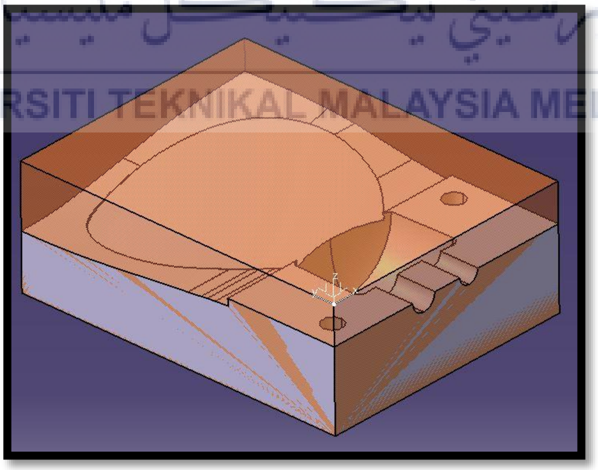
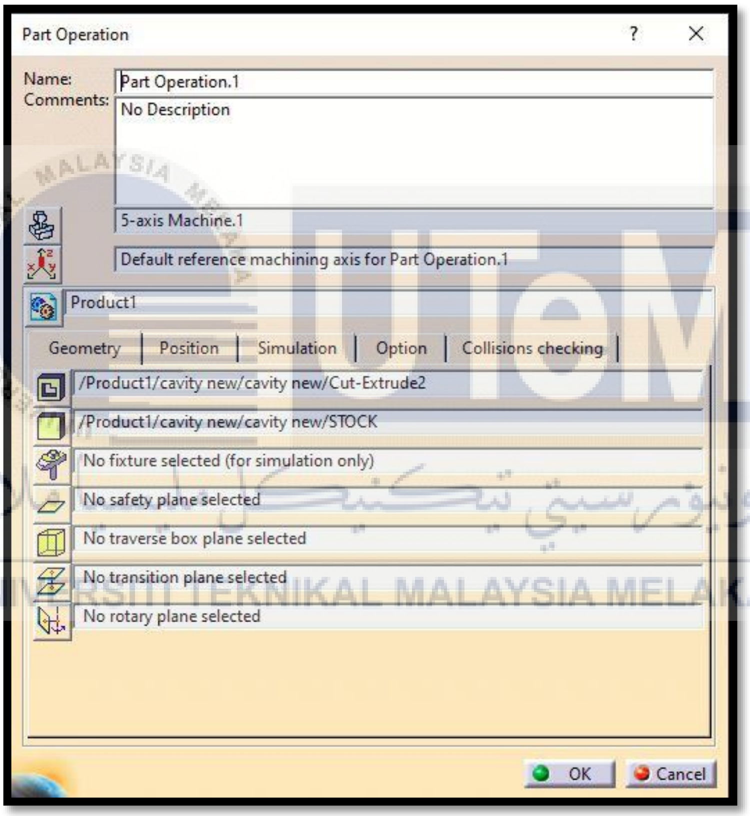


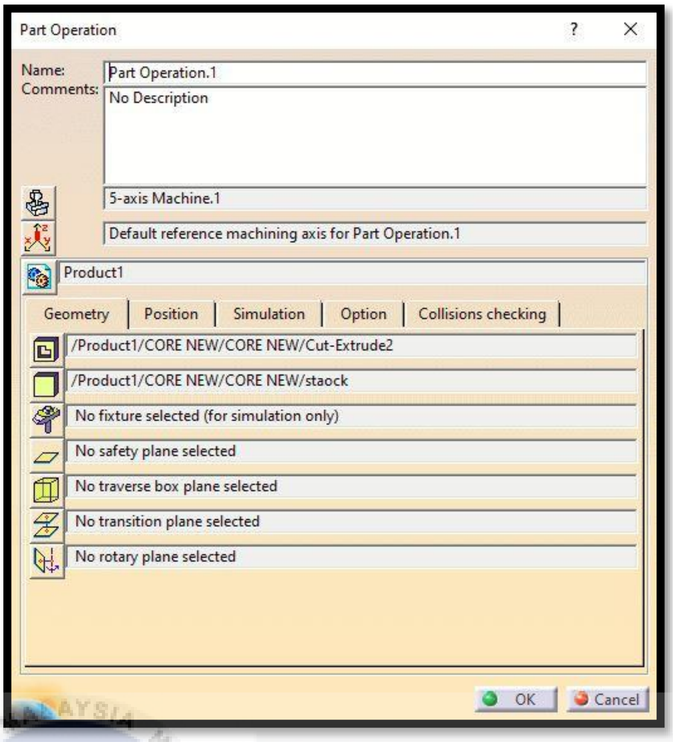
Figure 3.13 Assembly CAD part with Plane System

3.6.3 CAM Machining

After finish the assembly preparation, it will go thru the advanced machining workbench for the machining operation. At the machining workbench, need to determine all the part operation needed such as type of machine is 5-axis machine, select work piece coordinate (WPC) at the part, select the stock of mould and select the mould. In this project have two part need to do the preparation which is core and cavity. The purpose for this operation for prepared the CAM program.



a)



b)

Figure 3.14 a) Part Operation of Cavity b) Part Operation of Core

3.6.4 Tool Selection

Tool selection must be made first regarding the process needed for the mould. The tool selecting base on the facing process, roughing process, profile countering process, sweeping process, isoparametric process, Multi-axis Flank countering, drilling and reamer. The selection cutting tool must be compatible with the shape of mould.

Table 3.1 Detail Dimension of Selected Cutting Tool

Cavity		
Tool	Dimension	Operation involved
End Mill 20mm(ø)- 4 Flute	Db = 20mm D = 20mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing 1

End Mill 12mm(ø) - 4 Flute	Db = 12mm D = 12mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing 2
End Mill 10mm(ø) - 4 Flute	Db = 10mm D = 10mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing 3 Profile contouring
Ball Mill 10mm(ø) - 2 Flute	Db = 10mm D = 10mm Rc = 5mm Lc = 50mm L = 100mm l = 60mm	Sweeping 1 Sweeping 2 Isoparametric Profile contouring
Ball Mill 8mm(ø) - 2 Flute	Db = 8mm D = 8mm Rc = 4mm Lc = 20mm L = 100mm l = 50mm	Profile contouring
Ball Mill 6mm(ø) - 2 Flute	Db = 6mm D = 6mm Rc = 3mm Lc = 30mm L = 100mm l = 50mm	Isoparametric
Drill 7.5mm(ø)	Db = 7.5mm A = 20deg Lc = 50mm L = 100mm l = 60mm	Drilling
Reamer 8mm(ø)	Db = 8mm D = 8mm Lc = 50mm L = 100mm l = 60mm	Reaming
Core		

End Mill 20mm(ø) - 4 Flute	Db = 20mm D = 20mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing 1 Profile contouring
End Mill 12mm(ø) - 4 Flute	Db = 12mm D = 12mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing 2
End Mill 10mm(ø) - 4 Flute	Db = 10mm D = 10mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing 3 Profile contouring
End Mill 4mm(ø) - 2 Flute	Db = 4mm D = 4mm Rc = 0mm Lc = 15mm L = 50mm l = 20mm	Multi-Axis Flank Contouring
Ball Mill 10mm(ø) - 2 Flute	Db = 10mm D = 10mm Rc = 5mm Lc = 50mm L = 100mm l = 60mm	Profile contouring
Ball Mill 8mm(ø) - 2 Flute	Db = 8mm D = 8mm Rc = 4mm Lc = 20mm L = 100mm l = 50mm	Profile contouring
Ball Mill 6mm(ø) - 2 Flute	Db = 6mm D = 6mm Rc = 3mm Lc = 30mm L = 100mm l = 50mm	Isoparametric sweeping

3.6.5 CAM Machining Strategies Selection

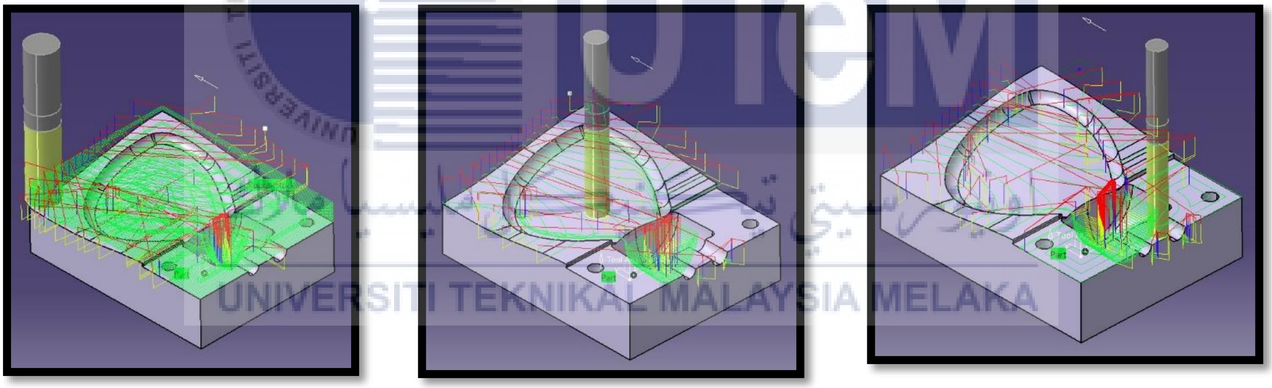
After completing the cutting tool setup, part operation, and assembly part, continue to make the machining strategies of mould cavity and core for propeller blade. Figure 3.15 show that, the tree of machining strategies used for mould core and cavity. The selection of machining strategies depend on geometry design of mould. In this machining strategies have process roughing, profile contouring, multi-axis sweeping, multi-axis isoparametric, multi-axis flank contouring, drilling and reaming. The tool path machining strategies is very important because it can affect the surface roughness of mould and cycle time machining. The example of tool path is one way, zig-zag, and helical.

a) b)

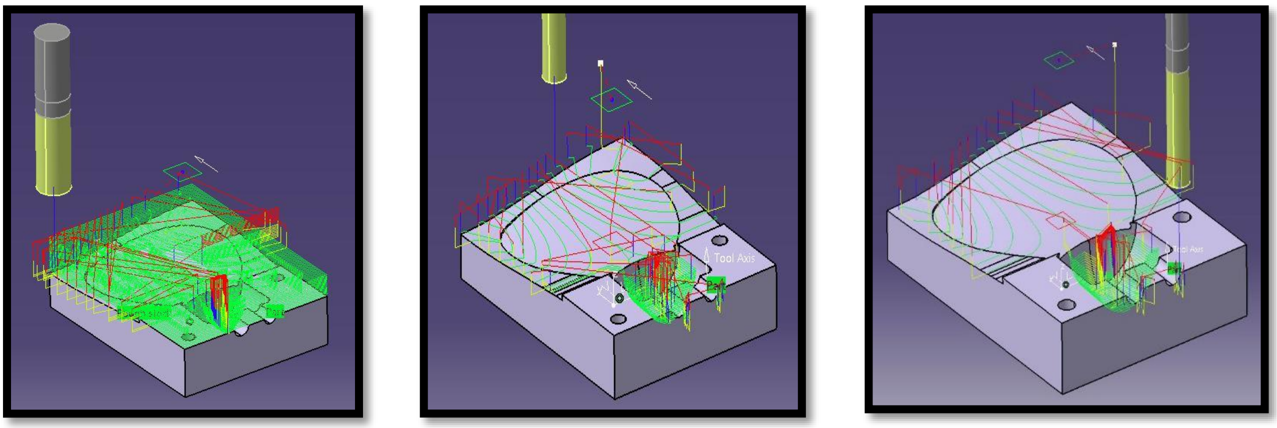
Figure 3.15 a) Tree Machining Strategies of Cavity b) Tree Machining Strategies of Core

3.6.5.1 Roughing Process

The first process machining is roughing process. Roughing process used to remove the bulk material and roughly shape the mould towards the finished form with left 1mm for finishing. Parameter for roughing process used is fixed, which is the offset on part set 0.5mm before the cutting tool removed material. The machining tolerance is set 0.01mm. After that, maximum cut depth is 1mm. And than, for the spindle speed and feed rate, used 6000 rpm and 1500 rpm. The micro setting is set to optimize retract to avoid tool path collisions with ignored safety plane. For this process have three process roughing which is roughing one, roughing two and roughing three. It used the same parameter but the differend cutting tool which is diameter 20, diameter 12 and diameter 10. The figure 3.16 shown simulation result of roughing process.



a) b) c)

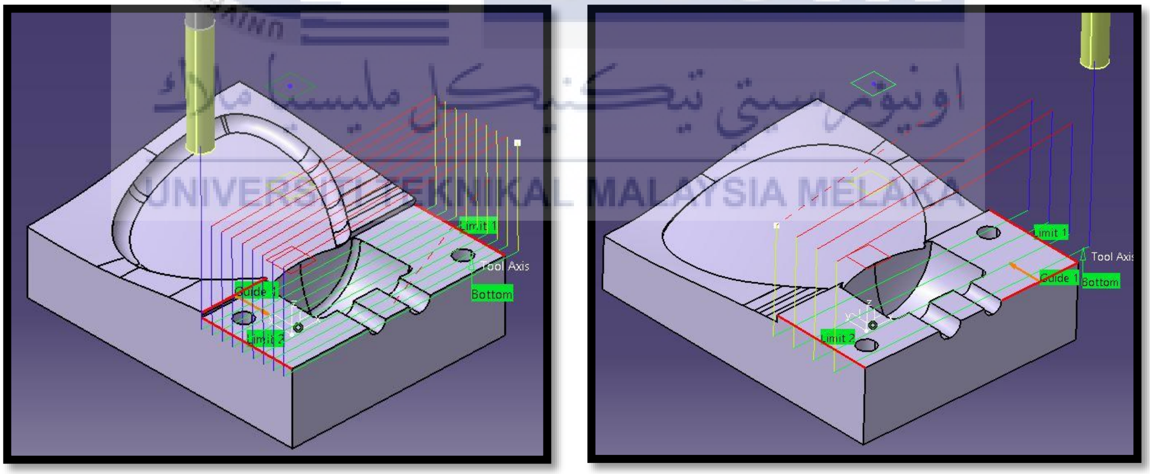


d) e) f)

Figure 3.16 a) and d) Roughing one for Diameter 20, b) and e) Roughing two for Diameter 12, c) and f) Roughing Three for Diameter 10

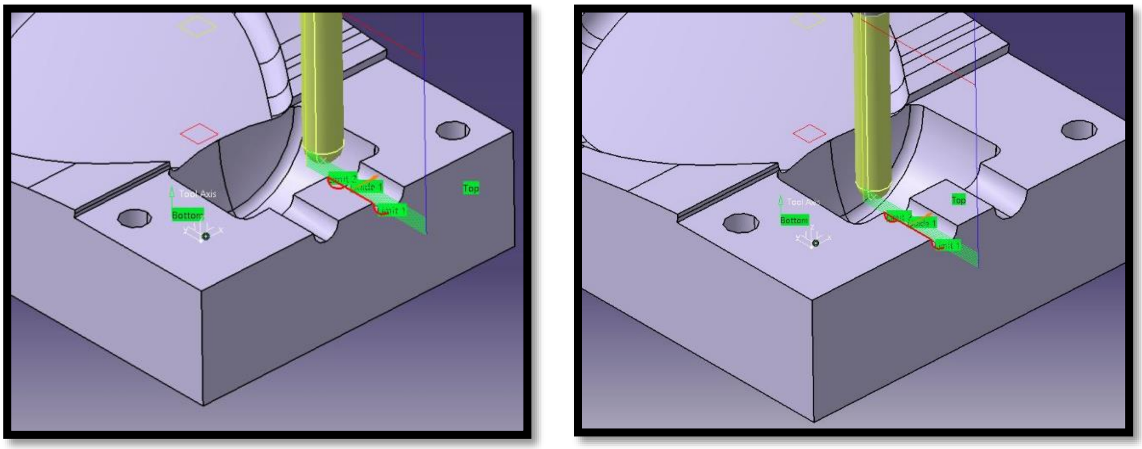
3.6.5.2 Profile Contouring Process

After roughing process are done, continue used profile contouring process to clear the flat area after process roughing. The machining tolerance is set 0.01mm. After that, maximum cut depth is 0.5mm. And than, for the spindle speed and feed rate, used 7000 rpm and 1500 rpm. The tool path style for this process is ‘one way’. Cutting tool used for this process is end mill diameter 10 mm. The figure 3.17 shown the tool path of profile contouring area at mould core and cavity. After that, there have another area using the profile contouring process which is at the sprue core and cavity. For the sprue, there have two size which is 8 mm and 10 mm. The cutting tool is ball mill diameteer 8 mm and 10 mm. The parameter are same used for sprue. The figure 3.18 and figure 3.19 shown the tool path of profile contouring for sprue core and cavity.



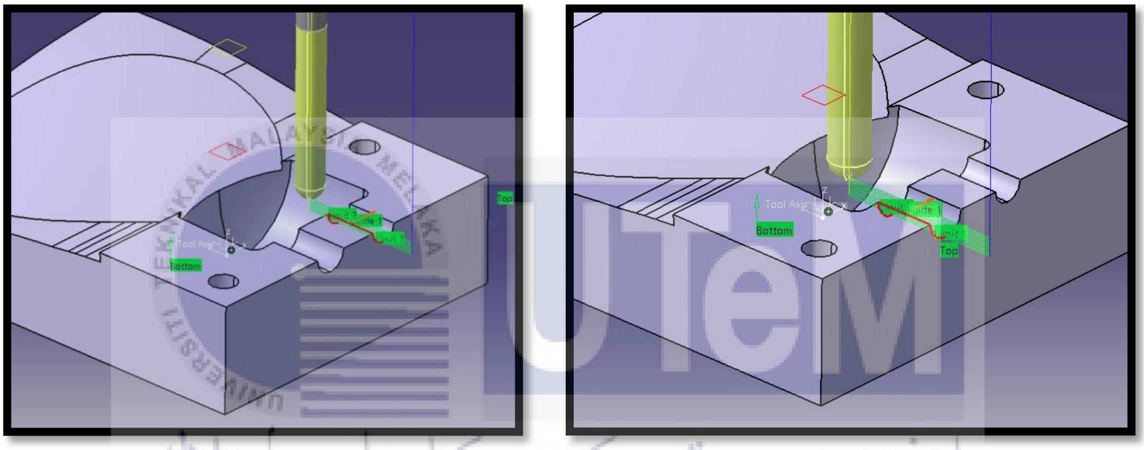
a) b)

Figure 3.17 a) Profile Contouring for Cavity b) Profile Contouring for Core



a) b)

Figure 3.18 a) Profile contouring Ball Mill Diameter 10 b) Profile contouring Ball Mill Diameter 8

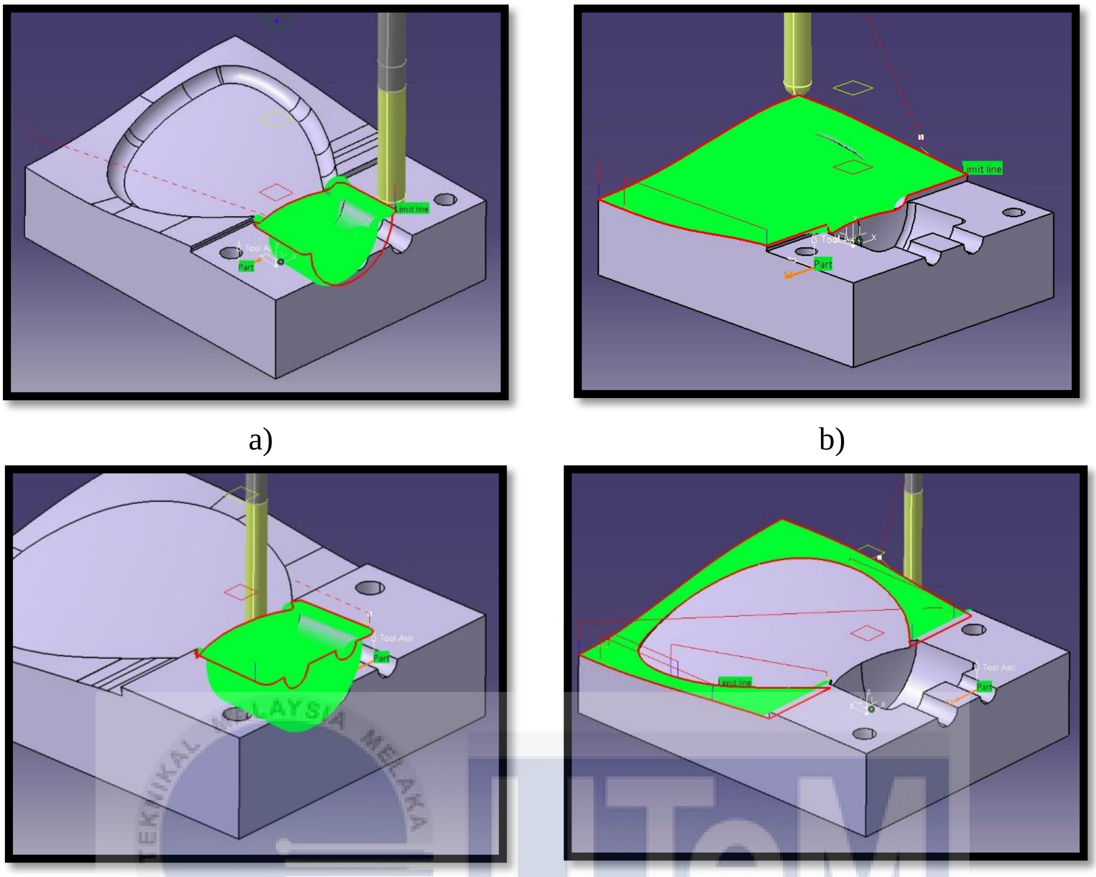


a) b)

Figure 3.19 a) Profile contouring Ball Mill Diameter 8 b) Profile contouring Ball Mill Diameter 10

3.6.5.3 Multi-Axis Sweeping Process

From figure 3.20 shown the sweeping process for two area at the cavity and two area at the core. This process basically used at the difficult area such as for this mould at curve area. The sweeping process used at each part of mould for finishing process. The machining strategies setup used for part of mould are same. The tool path style for this process is zig-zag. It because can reduce the movement tool path during machining and machining time. After that, the scallop height for each sweeping process used 0.01 mm that give the best surface finish. Lastly, the maximum cut depth is 1 mm and machining tolerance is 0.01 mm.



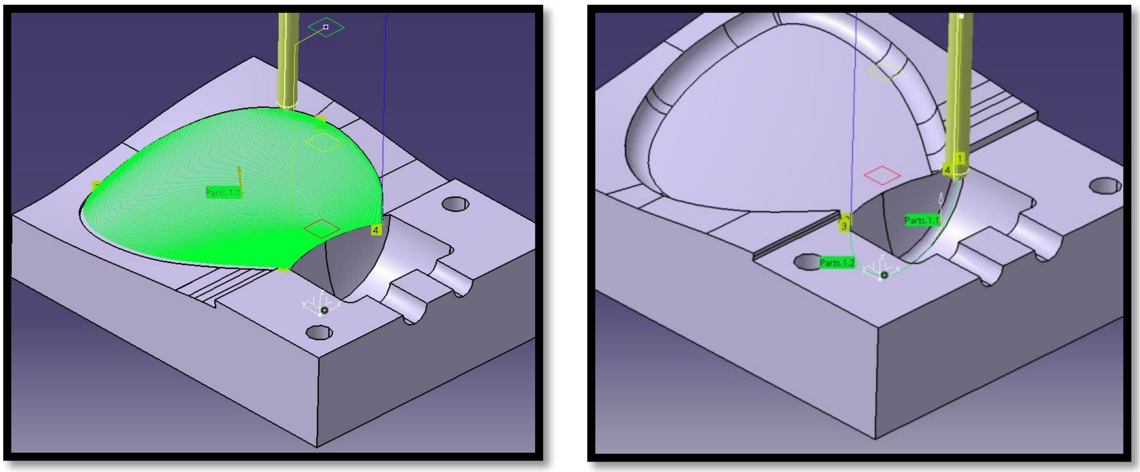
a) b) c) d)

Figure 3.20 a) and b) Sweeping Process for Cavity c) and d) Sweeping Process for Core

3.6.5.4 Multi-Axis Isoparametric Process

Isoparametric process is an operation which allows to select strips of faces and machine along their isoparametrics. Isoparametric command used to solve the problem on five-axis face cutting. The isoparametric cannot examine the component for collisions, but the movement tool path may be specified by selecting the add corner to part and the body portion that has to be machined. A scallop height 0.01 mm was the key factors to make sure that the five axis program runs successfully in this command. The isoparametric also set as finishing process. This process is utilized to manufacture the curve surface and corner radius, as shown in figure 3.21. The setting machine parameter are fixed which the machining tolerance is set 0.01mm. After that, for the spindle speed and feed rate, used 8000 rpm and

1500 rpm. The tool path style for this process is zig-zag. Cutting tool used for this process is ball mill diameter 6 mm.

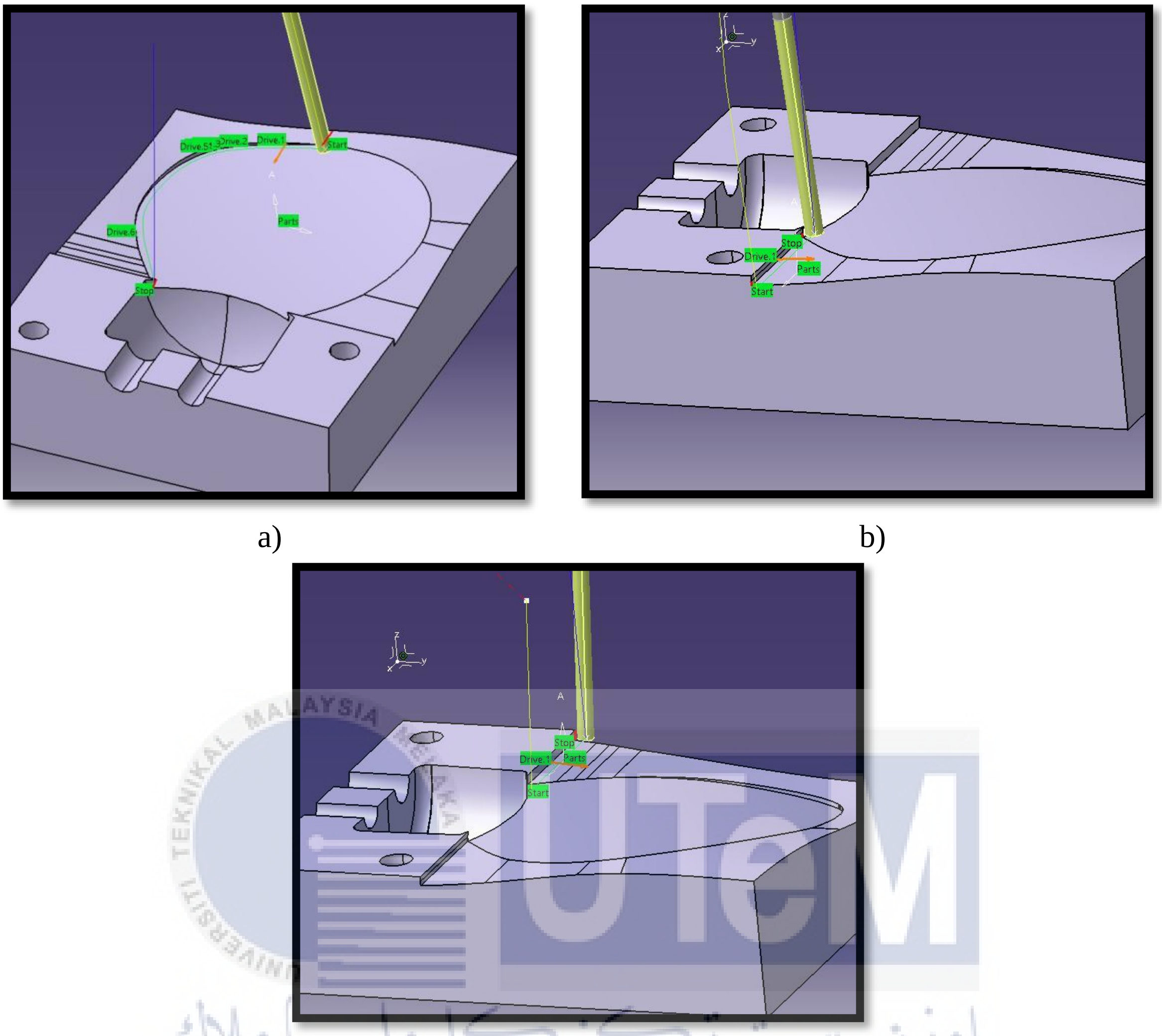


a) b)

Figure 3.21 a) Isoparametric Process on surface mould core propeller blade b) Isoparametric process for corner radius

3.6.5.5 Multi-Axis Flank Contouring

Multi-axis flank contouring is an extra process used to form the mould. This process will apply at the core. This area requires modification since, after the isoparametric process, the edge of the surface leaves an excess of radius. After that, used multi-axis flank contouring to machine the area to clear the radius and get the sharp edge. In this process need to used the setting 5-axis parameter because the geometri of area is curve. The tool path style for this process is zig-zag. This is important thing for 5-axis need to change which is the tool axis guidance. The tool axis guidance used is tanto fan. From the figure 3.22 shown that the area will used multi-axis contouring for do the modification.



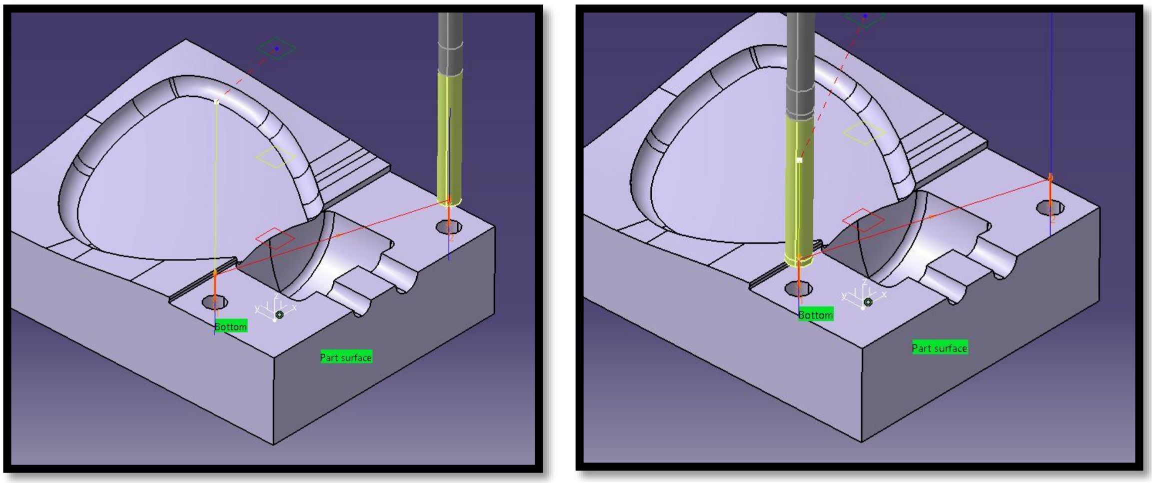
a) b)

c)

Figure 3.22 a) Multi-Axis Flank Contouring one b) Multi-Axis Flank Contouring two c) Multi-Axis Flank Contouring three

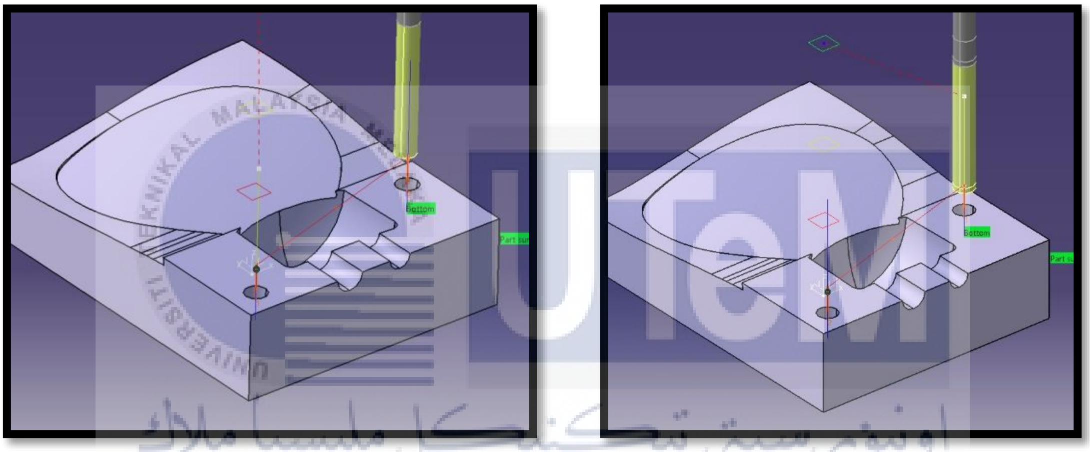
3.6.5.6 Drilling and Reaming

Drilling and reaming is the last process used. This is the process for making a hole for a dowel pin. The hole is diameter 8 mmand depth 10 mm. To make a hole for dowel pin, need to do the drilling first using cutting tool drill diameter 7.5 mm. After process drilling is complete, use a reamer to continue reaming to get the real saiz, which is a diameter of 8 mm. The figure 3.23 and figure 3.24 shown the process drilling and reaming for two hole at core and cavity.



a) b)

Figure 3.23 a) Process Drilling of Cavity b) Process Reaming of Cavity



a) b)

Figure 3.24 a) Process Drilling of Core b) Process Reaming of Core

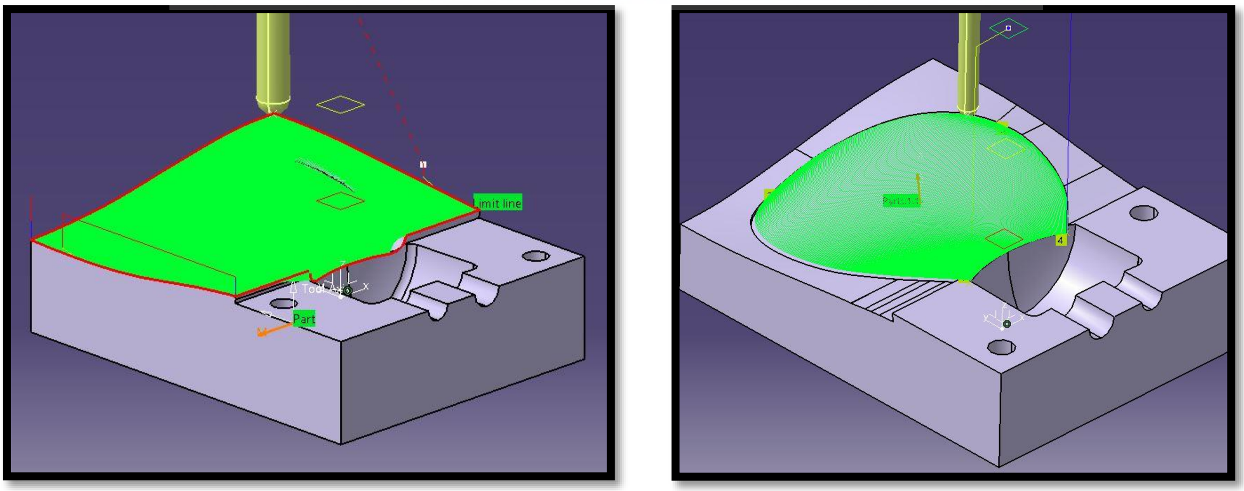
3.6.6 Machining Strategies for Main Area

There are two machining strategies that involved for this study which is Multi-axis Sweeping and Multi-axis Isoparametric. This strategies was used at the surface of blade on mould core and cavity. The machining parameter are same for two machining strategies, as shown in table 3.2 below. There are three important thing machining parameter was involved im this strategies which is cutting speed, feed rate, and depth of cut. These three element may have an impact on the surface roughness of a machined surface. Beside that, machining tolarance also give more impact to the result of surface roughness the less value of machining tolarance is the best influence outcome of surface roughness.

Table 3.2 Machining Parameter of Multi-axis Sweeping and Multi-axis Isoparametric

Parameter \ Strategies	Multi-axis Sweeping	Multi-axis Isoparametric
Machine feed rate (mm/min)	1500	1200
Spindle Speed (rpm)	8000	8000
Cutting Tool	Ball Mill D10	Ball Mill D6
Total Time (min)	72.23	12.12
Machining Time (min)	72.16	12.2
Machining Tolerance (mm)	0.01	0.01
Retract Feed Rate (mm/min)	1200	1200
Approach Feed Rate (mm/min)	3000	3000
Tool Path Style	Zig-Zag	Zig-Zig
Stepover Mode	Constant	Scallop Height
Max. Distance Between Path (mm)	0.01	0.01

From figure 3.25 shown that the simulation in catia v5 for machining strategies multi-axis sweeping and multi-axis isoparametric was apply at surface mould core and cavity. This figure shown the tool path movement for two strategies. This area need to study the surface roughness, which one the better startegies after machining operation done.



a) b)

Figure 3.25 a) Multi-Axis Sweeping for Cavity b) Multi-Axis Isoparametric for Core

3.6.7 Machining Operation

3.6.7.1 Squaring Material

Before moving into the process CNC, the raw material must run into the process squaring. This ia typical process would involved flipping a block around in order to face off all six sides. There are six setup required, as well as a fair amount of measuring, which will keep tied to the machine during the entire process.

The first step is set the raw material on parallels in the vise. If the side to be clamped are not parallel, take a few minute to parallel it. Used the largest cutting tool and step down in small increments to avoid any cutter deflection. The depth of cut for squaring is 0.5 mm. Process squaring using the machine milling conventional at “Makmal Teknologi Pemesinan 1”

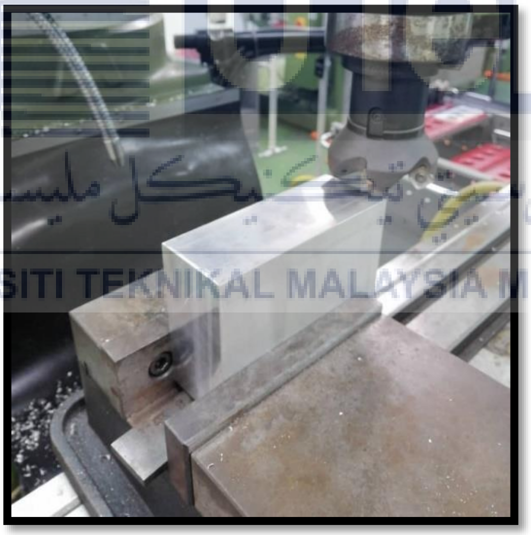


Figure 3.26 Squaring Process

Figure 3.27 Milling Machine FullMark FM-16VS

3.6.7.2 CNC Milling DMU 60 eVo

The project will be carried out using the DMU 60 eVo Linear, as shown in figure 3.24 below. The data produced by the CAM programme, CATIA V5, will be sent into the machine control. When the setup is complete, the machine will begin the process machining using the NC code provided.

Figure 3.28 DMU 60 eVo

Before starting the machining, check and examine the machine oil and coolant. Remove any loose or unused tools and equipment from the work area. If necessary, check the machine's air supply pressure. Before turning on the machine and control interface switch, turn on the main switch at the rear of the machine.

Check the tools in the tool carousel as listed in the CNC program tool list. If the cutting not in list, load or install the tool needed. Measure the tool length and record the necessary information about the mounted tools. This is required for the sensor system to work properly.

Load the CNC program code generated by catia V5 software into a USB thumb drive as seen in figure 3.26. Because it offers a variety of programmes such as milling, hole drilling and reaming, it may also be used to create machining programmes.

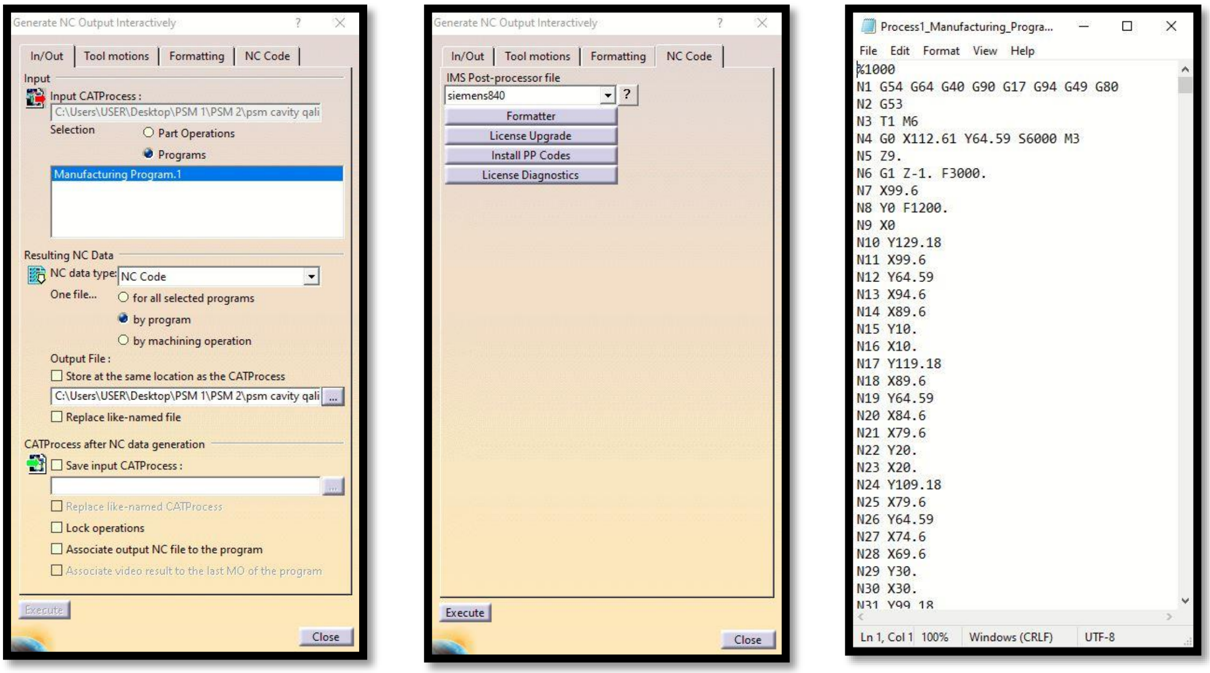


Figure 3.29 Step to generate the NC code applicable to the Siemens840, the post Processor used in the CNC machine

The last step is, find the programme at USB thumb drive, and than import the programme into the machine controller. After that, call the programme to run the simulation on the machine controller for final inspection the tool path movement. After finish the simulation, load the work piece at the vise. Next, locate the datum at work piece X,Y, Z, B and C zero. Call the programme and start the process machining.

3.7 Surface Roughness Testing

The surface roughness testing will be measured using a Surface Roughness Tester, Mitutoyo SJ-400, as shown in figure 3.27. It is a diamond-tipped stylus with a 90-degree angle that is used. As shown in figure 3.28, the machined workpiece is put on the top of the testing table, and the stylus is passed over the surface to detect changes in surface roughness.

Figure 3.30 Surface Roughness Tester, Mitutoyo SJ-400

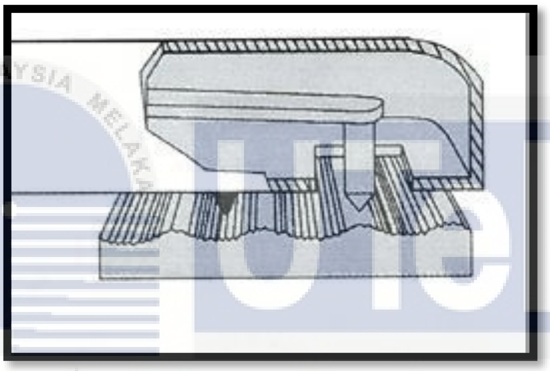


Figure 3.31 Stylus surface

3.7.1 Surface Roughness Testing Preparation

The procedure for surface roughness testing are as listed below:

i. Connect AC adapter and drive unit from the body of the machine to the plug.

ii. Turn on the main plug and the machine.

iii. Calibrate SJ-400.

iv. Place the mould on the test table

v. After setup the mould, bring the stylus close and slowy onto the surface required and make sure the surface are flat to get the reading.

vi. Once the stylus touch the surface, slowly lower the stylus more until the indicator in the tester interface in the green column.

vii. Once green, start the testing by pressing START/STOP.

viii. Take the photo of result.

ix. Repeat step iv until viii 10 times, every two moulds

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter is focuses the value of surface roughness on the surface mould core and cavity at the area surface blade after process machining by using the machining strategies multi-axis sweeping and multi-axis isoparametric and result after machining. The data of the result were taken from surface roughness testing analysis and machining process observation.

4.2 Surface Roughness

The surface roughness testing only do on surface blade for mould core and cavity. The both area needed for surface roughness testing to determine which strategies is better surface between the two strategies. For do the surface roughness testing, the surface for testing need the flat surface. Each specimen will do 10 surface roughness testing and the average will being computed. The final result will being compared between by using difference strategies which is multi-axis sweeping and multi-axis isoparametric and the same parameter.

Table 4.1 Surface Roughness (μm) Result Table

testing	Machining Strategies	
	Cavity Multi-Axis Sweeping	Core Multi-Axis Isoparametric
1	0.547	1.391
2	0.798	1.395
3	0.686	1.383
4	0.661	1.406
5	0.782	1.385
6	0.754	1.325
7	0.753	1.243
8	0.752	1.284
9	0.765	1.269
10	0.805	1.27
Average	0.7303	1.3351

In Table 4.1 shown that the result of surface roughness testing for two mould which is core and cavity. This result comes from the flat area on the surface of the mould as shown in figure 4.1 below. This testing must be carried out in a flat area. From this table, the value average Ra for strategies multi-axis sweeping lowest value compared strategies multi-axis isoparametric. The value shown that surface roughness for sweeping more smooth. The sweeping surface seems smoother and has no cutter mark impact to the visual look as compared to isoparametric. The figure 4.2 shown that the difference of mould core and cavity surface after process machining.

Based on figure 4.3 below, there are some effect or overcut in area surface at core while machining. This effect happen because, it used a cutting tool type ball mill. The cutting method for ball mill is from the tool's centre even the cutting tool is already offset the counter.

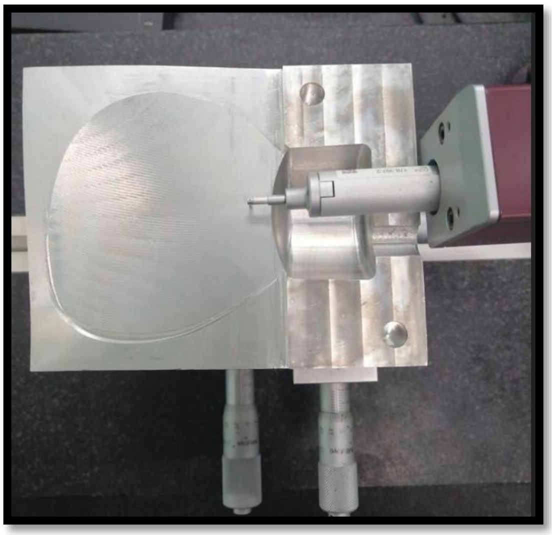


Figure 4.1 Area for Surface Roughness Testing

Figure 4.2 Mould Core and Cavity

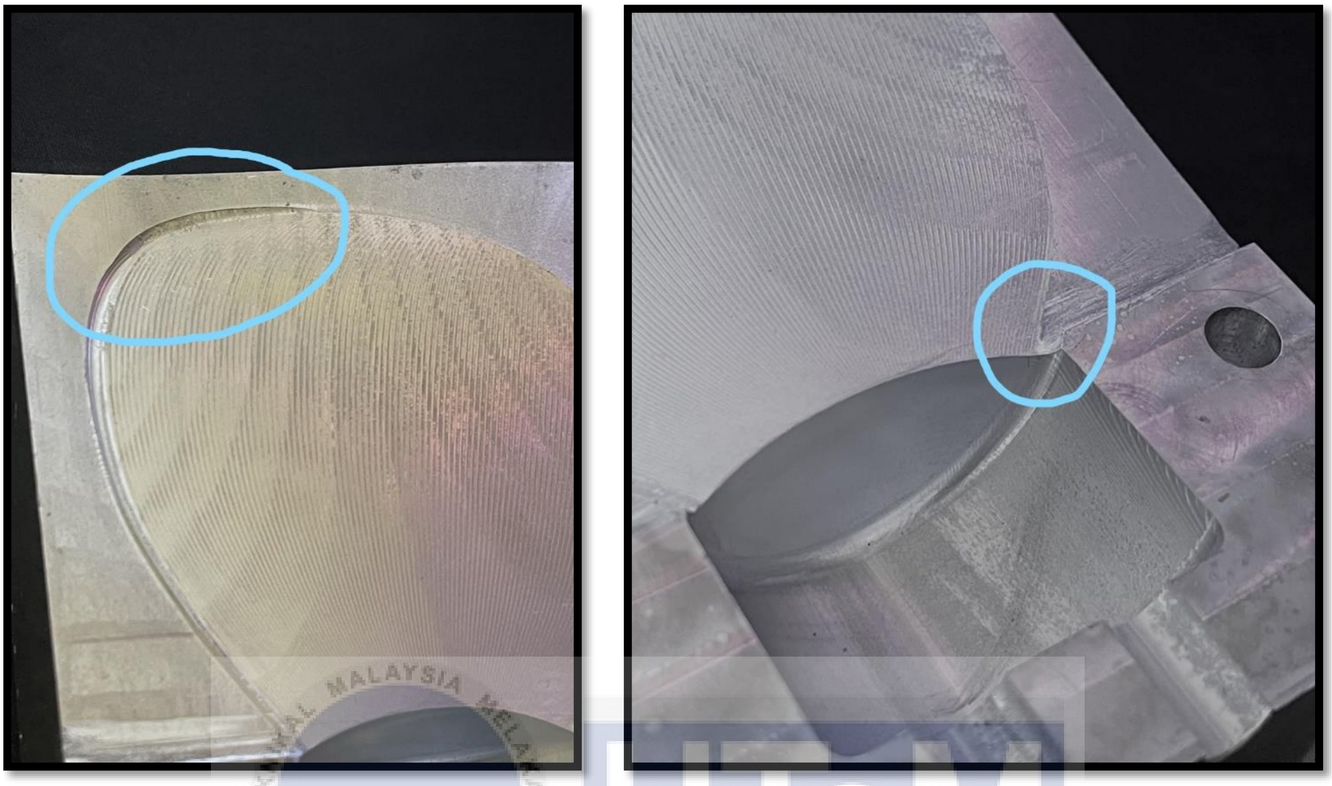


Figure 4.3 Overcut Area at Mould Core

4.3 Core and Cavity

The machining operation for cavity is using the DMU 60 eVo for milling operation. Some adjustments have been made to the initial concept in order to make it easier to handle, less time consuming, and more machining capable. The list of parameter in Table 3.2 was advised by the expert to ensure the smooth operation of the machining process. There are two processes carried out in machining which process roughing and process finishing.

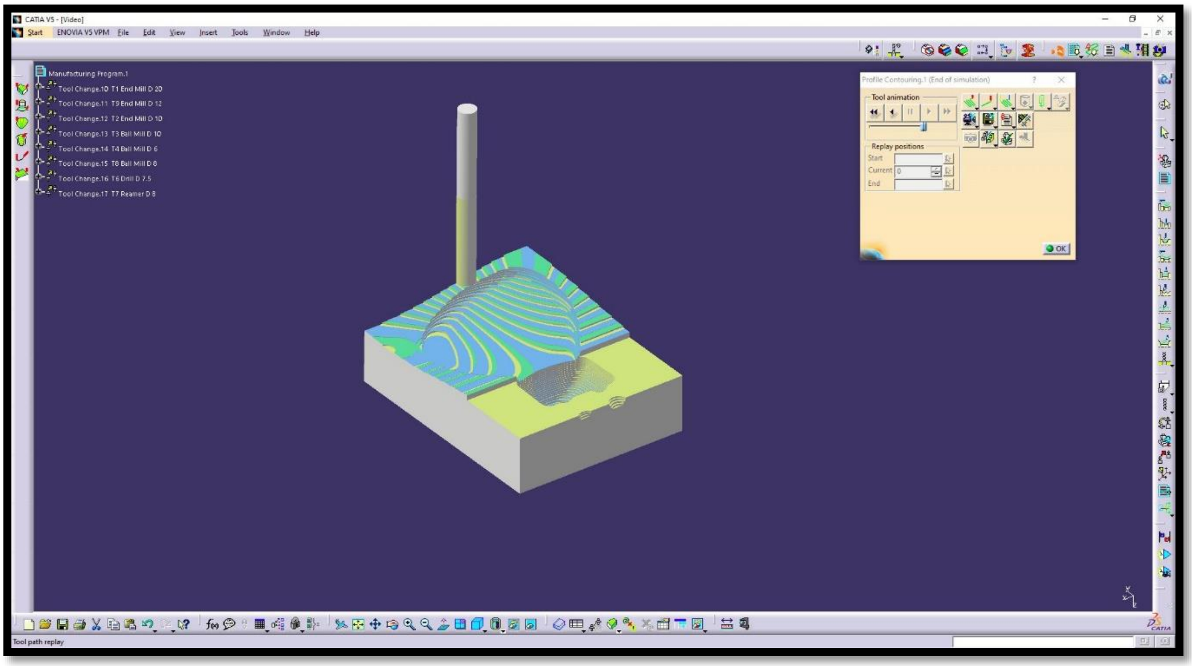


Figure 4.4 The Simulation Result Cavity For Roughing

Figure 4.5 Machining Operation Cavity for Roughing

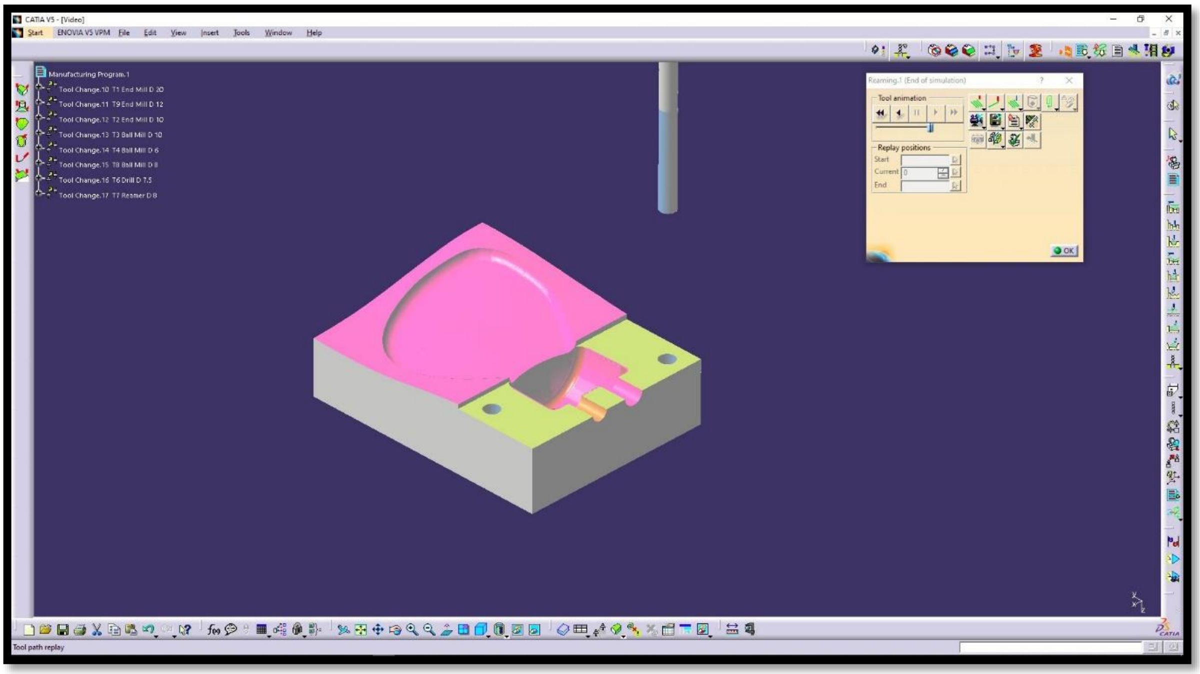


Figure 4.6 The Simulation Result Cavity For Finishing

Figure 4.7 Machining Operation Cavity for Finishing

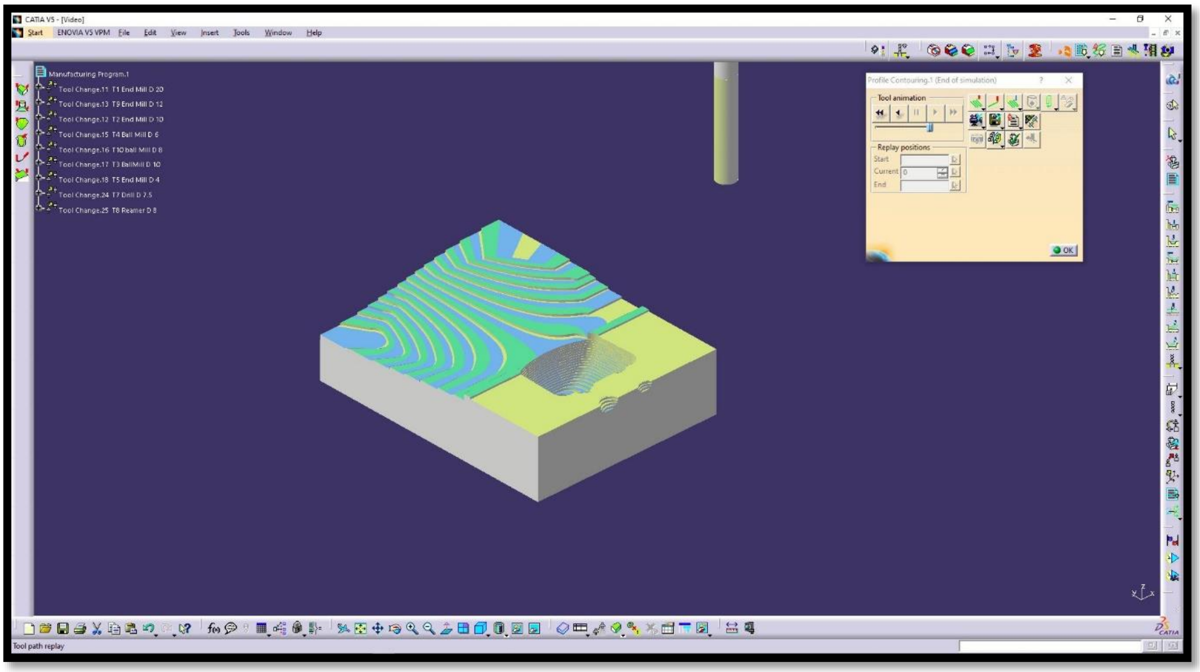


Figure 4.8 The Simulation Result Core For Roughing

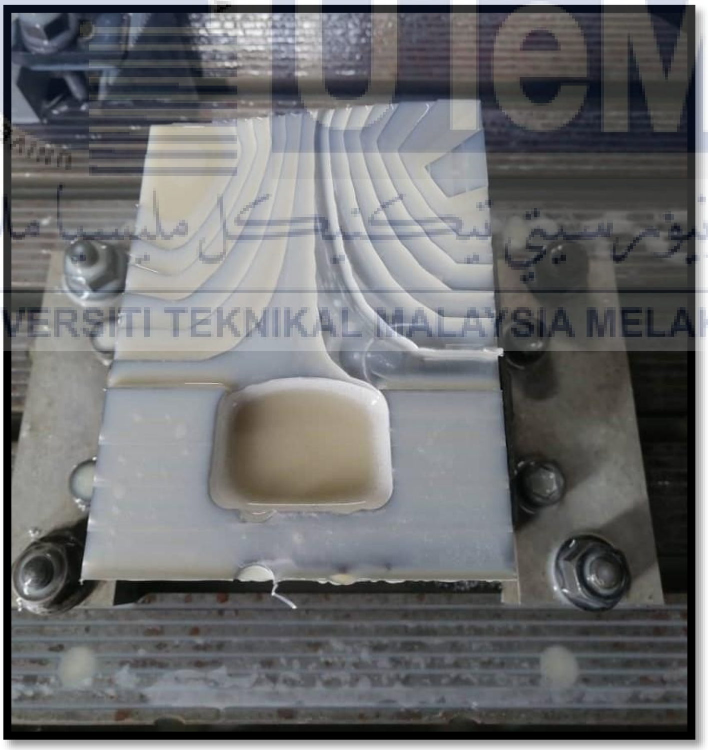


Figure 4.9 Machining Operation Core for Roughing

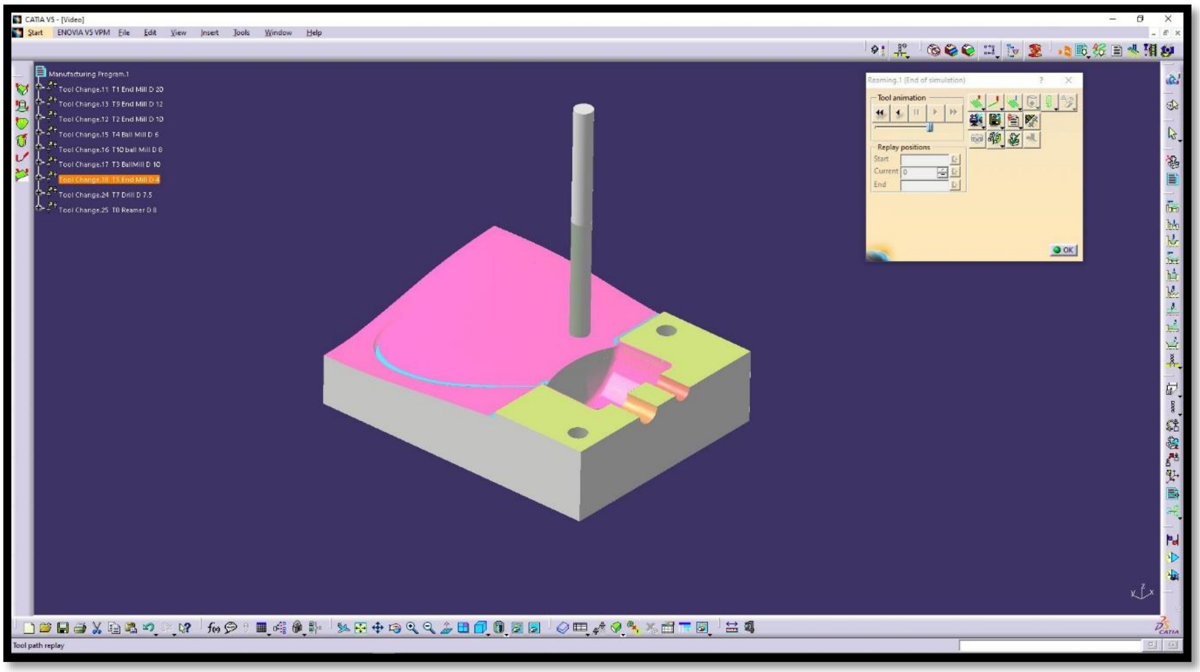


Figure 4.10 The Simulation Result Core For Finishing

Figure 4.11 Machining Operation Core for Finishing

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As a conclusion from this study, can design and produce the mould of propeller blade for investment casting succesfully. And than, can produce the CAM by using the machining strategies from CATIA V5 software to fabricate the mold until finish.

After that, design and fabrication a mould of propeller blade for the first process investment casting which is to do the pattern using the wax. Able to modelling the core and cavity by using the solidwork software. After that, import the 3D modelling into the CATIA V5 software. Before importing the 3D modelling from SolidWorks, the type of file needs to be saved as STEP. Next, create machining simulation for core and cavity using suitable machining strategies.

Furthermore, able to used machining strategies Multi-axis Sweeping and Multi-axis Isoparametric. This machining strategies will be used on the curve surface of the mould core and cavity. After the simulation was completed, generate the NC code for do the machining operation using DMU 60 eVo. The machining parameter used are same for two main machining strategies, because to evaluate the difference of machining strategies sweeping and isoparametric on surface mould core and cavity using CATIA V5 software simulation and CNC milling DMU60e. Indirectly, was able to use a CNC high speed machining DMU 60 eVo to make a mould propeller blade.

The result showed that Multi-axis sweeping machining strategies provide good surface roughness than Multi-axis isoparametric machining strategies. Because the value Ra of Multi-axis sweeping is lower than Multi-axis isoparametric which is for Multi-axis sweeping 0.7303 µm and 1.3351 µm for Multi-axis isoparametric. Instead of looking at the surface from a visual perspective, may also determine which surface is the best.

5.2 Recommendation

Thera are a few recommendation provided to extend understanding of fundamentals in machining, as well as to enhance the machining process in order to gain a greater surface roughness and gether more knowladge about cutting strategies with difference condition used while machining. The recommendation for this project, in future when used the machining strategies multi-axis isoparametric, the scallop height value need to reduce to get the smooth surface. Normally, after the machining process to manufacture the mould, the mould must go through a polishing process to get the smooth surface at core and cavity before the mould is injected. For the next planned project, after machining the mould must go through the process polishing to get the good surface and get the better finish product.

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APPENDICES

APPENDIX A Gantt Chart for BDP 1.

Gantt chart for PSM 1																	
No	Task project	Plan/Actual	Week														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Registration of PSM title	Plan														
		Actual														
2	Briefing of PSM and project explanation by supervisor	Plan														
		Actual														
3	Drafting and writing of Chapter 2 Literature Review	Plan														
		Actual														
4	Writing of Chapter 1	Plan														
		Actual														
5	Submission of Chapter 1	Plan														
		Actual														
6	Draft and writing of Chapter 3	Plan														
		Actual														
7	Submission of Chapter 3	Plan														
		Actual														
8	Submission of report to supervisor and panels	Plan														
		Actual														
9	Preparation slide and presentation PSM 1	Plan														
		Actual														

APPENDIX B Gantt Chart for BDP 2.

Gantt chart for PSM 1																	
No	**Task project**	**Plan/Actual**	**Week**														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Briefing	Plan															
		Actual															
2	Briefing of PSM 2 and project explanation by supervisor	Plan															
		Actual															
3	Design Part propeller blade and mould	Plan															
		Actual															
4	Generate NC code using CATIA V5 for core and cavity	Plan															
		Actual															
5	Squaring the material	Plan															
		Actual															
6	Running CNC milling 5-Axia DMU 60eVo	Plan															
		Actual															
7	Surface Roughness Testing	Plan															
		Actual															
8	Submission of eLogbook and report to supervisor and	Plan															
		Actual															
9	Preparation slide and presentation PSM 1	Plan															
		Actual															

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **DESIGN AND FABRICATION OF MARINE BOAT PROPELLER BLADE MOULD FOR INVESTMENT CASTING**

SESI PENGAJIAN: **2020/21 Semester 1**

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