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

MOHAMMAD LUKMAN NURHAKIM BIN AHMAD DAHAM

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS & TECHNOLOGY) WITH HONOURS

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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 & Technology) with Honours**

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this Choose an item. entitled " **Design And Fabrication of Marine Boat Propeller Hub 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 :

Name : Mohammad Lukman Nurhakim Bin Ahmad Daham

Date : 18 Januari 2022

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 & Technology) with Honours.

Signature	:	....
Supervisor Name	:	Ts. Muhammad Syafik Bin Jumali
Date	:	28 Januari 2022

DEDICATION

Alhamdulillah

Praise to Allah for the strength, guidance and knowledge that was given by Allah for me to complete this study.

&

To my beloved families and housemates for every support that was given to me.

&

To my supervisor, Ts.Muhammad Syafiq Bin Jumali for his guidance and advice in completing this research.Thanks to my project conductor Ts. Zolkarnain Bin Marjom for his knowledge and mentorship in this thesis.

&

To all people who support me throughout my journey.

ABSTRACT

Investment casting has been extensively used to produce significant global industrial processes of the best quality products. Thus, ongoing enhancements in quality of product surface roughness are essential to sustaining a competitive edge in the casting industry. Material, man, method and mold of these components as a process generates effectiveness. To produce and design the good result mold need to be done by good planning, process and proper design with the good machining strategy. This thesis focuses to fabricated mold and how impact the sweeping and isoparametric machining strategy to the surface roughness of investment casting mold by design using CATIA V5 software. Computer program using CATIA V5 software from the technology industry was used to design the mold using two machining strategy with the same machining parameter. By study Sweeping and Isoparametric machining strategies to optimize the marine boat hub blade propeller mold has been well using CNC high speed machining and CATIA V5 software. The optimum parameter of machining is to be found from this research and the result of the surface roughness was prove in this research. The work flow for this study will be following the process flow and the Gantt chart. To produce good surface roughness product the machining parameter of machining strategy must be have a good combination.

ABSTRAK

Pemutus tuangan telah digunakan secara meluas untuk menghasilkan proses perindustrian global yang penting bagi menghasilkan produk berkualiti baik. Oleh itu, peningkatan berterusan dalam kualiti kekasaran permukaan produk adalah penting untuk mengekalkan kelebihan daya saing dalam industri tuangan. Bahan, manusia, kaedah dan acuan komponen ini sebagai proses menjana keberkesanan. Untuk menghasilkan dan mereka bentuk acuan hasil yang baik perlu dilakukan dengan perancangan yang baik, proses dan reka bentuk yang betul dengan strategi pemesinan yang baik. Tesis ini memfokuskan kepada pembuatan acuan dan bagaimana kesan strategi pemesinan seeping dan strategi pemesinan isoparametrik kepada kekasaran permukaan acuan tuangan pelaburan melalui reka bentuk menggunakan perisian CATIA V5. Program komputer menggunakan perisian CATIA V5 dari industri teknologi ini telah digunakan untuk mereka bentuk acuan menggunakan dua strategi pemesinan dengan parameter pemesinan yang sama. Dengan mengkaji strategi pemesinan Sweeping dan Isoparametrik untuk mengoptimumkan acuan bilah kipas hab bot marin telah menggunakan pemesinan berkelajuan tinggi CNC dan perisian CATIA V5 dengan baik. Optimum parameter pemesinan boleh didapati dan hasil kekasaran permukaan telah dibuktikan dalam penyelidikan ini. Aliran tindakan untuk kajian ini akan mengikuti aliran proses dan carta Gantt. Untuk menghasilkan produk kekasaran permukaan yang baik parameter pemesinan strategi pemesinan mestilah mempunyai kombinasi yang baik.

ACKNOWLEDGEMENTS

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

In the Name of Allah, the Most Gracious and Most Merciful. Alhamdulillah, I am thankful to Almighty Allah (Subhanahu Wa Taa'la) who give me the strength and spirit throughout my life letting me to fulfil this research. Thanks for His blessing, guidance and His kindness for granting my wishes.With the deepest gratitude I would like to give a million appreciations to everyone who helped me during the period of my research. Especially to my respectable supervisor Ts Muhammad Syafiq Bin Jumali, I would like to express my sincere honor for his guidance, critics and willingness in giving his helping hand, advices, hospitality, intelligence and knowledge from the beginning of the semester until now through this research. Without his guidance, this research would not have been completed. Not to forget, I would like to express my sincerest gratitude to Ts. Zolkarnain Bin Marjom for helping me all this while. I totally owe them both.

Finally, I am particularly grateful for the support gave by my housemates in this semester. I recognize that this research would not have been possible without their support. In advance, I wish to apologize for all other unnamed who helped me in various ways to finish my research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

FR	-	The calculated feed rate in inches per minute or mm per minute
RPM	-	Revolution per minute
T	-	The number of teeth on cutter
CL	-	Feed per tooth
CNC	-	Computer Numerical Control
CAD	-	Computer Aided Design
CAM	-	Computer Aided Manufacturing
Al	-	Aluminium
Cu	-	Copper
HSM	-	High speed machining
BUE	-	Burr free edge and eliminate built up edge
HPM	-	High performance machining
HSC	-	High speed cutting
CSS	-	Constant surface speed

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

An understanding by examining and using current literature in order to build up study is one of the tasks necessary for conducting a thesis study. It is a tool for expanding our knowledge based on research, information, and focusing on research issues and bringing clarity. In the meantime, previous study knowledge can improve the methodology and make the results more contextual. It is important to create a theoretical framework, in order to comparison our findings with others and a body of knowledge, using a simple procedure to research the literature in our field of concern and to review these studies. In the first chapter, project introduction was explained which include the project background, problem statement, objective and work scope.

A boat is a kind of transportation that comes in a variety of shapes and sizes, but it is typically smaller than a ship, which is differentiated by its bigger size, shape, cargo or passenger capacity, or ability to transport boats. Boats can be categorized into several main types which is motorboats, propelled by mechanical means, such as engines. A boat propeller is a mechanical device with radial blades set at a pitch to produce a helical spiral that performs an action similar to Archimedes' screw when rotated. It acts on a working fluid, such as water or air, to convert rotational power into linear thrust (Propeller | Britannica, n.d.). By developing a pressure difference between the two surfaces, the blades' rotating motion is transformed into thrust. The ship moves in the opposite direction as a given mass of working fluid accelerates in one direction. The majority of marine propellers are screw propellers with helical blades (Marine Investigation Report M00L0039, 2000).

A boat's propulsion system is one of the most critical components of any seagoing boat. The engine is regarded to be the boat's heart, as it generates huge push to propel the ship across the oceans. It is made up of numerous key components that work together to successfully power massive boat. The propeller hub is one such component that is critical in providing the necessary support to drive the boat. Due to some researcher study about the manufacturing process of propeller hub, the research will focus on design and fabrication of marine boat propeller hub mould for investment casting.

1.2 Problem Statement

Hub are made from numbers of manufacturing methods such as, casting, machining and composite layup. Numbers of process and equipment have to be setup or prepare to produce hub using casting or layup methods such as mold, machine, furnace, 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 part which is at the area that blade connected because it can cause error dimensions and takes longer time to complete the part due to its complex shape. This is why the mold for investment casting will be produce. Therefore, this study, will developed an investment casting mould to produce propeller hub blade to speed up the process of the casting process. Lastly, the surface finish must be good and no need to secondary process.

1.3 Research Objective

The objective of this project:

i. To fabricate the propeller hub blade mold for investment casting.

ii. To study Sweeping and Isoparametric machining strategies to optimize surface roughness for the marine boat hub blade propeller mold under condition of constant parameter.

1.4 Scope of Research

The scope of this research are as follows:

i. Fabricate and design propeller hub blade mold for investment casting.

ii. Sweeping and Isoparametric machining strategies.

iii. Mold surface roughness.

iv. Simulation using CATIA V5 software.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 will be some discussion about the research background related to the project. This chapter also discusses the journals as references and examples from other sources linked to the project. Firstly, will go over the process of machining the Propeller Hub Blade mould casting. To design the mould and generate machining code, we used 5-axis CNC milling and CATIA software. Afterwards, now need know the right settings to get a good mould surface.

2.2 Boat Propeller Hub

The tail boat's flanged end is bolted to the hub. The propeller blades are attached to the propeller crank disc, which is linked to the hub's pitch setting mechanism. The pressure inside the hub is greater than the pressure outside, preventing water from leaking into the hub. A push-pull rod runs from the hub mechanism forward to the gearbox or shaftline on small controllable pitch propellers. Because of its simplicity and well-proven functionality, such a solution is recommended. The servo cylinder is built into the hub of larger propellers. (*Propeller Hub (of CP Propeller)*, n.d.).

2.3 Materials Used for Marine Propellers Hub

The propeller is an important component of the ship. In choosing a propeller, stability, life, and cost are all important considerations. Traditionally, propellers have been produced using steels, aluminium, and cast iron, but recently, a few researchers have changed to the use of alloys for propellers, such as Al alloys, Cu alloys, and others. As the entire world of materials has shifted its focus to composites due to their advantages of low cost, high life, and stiffness in recent decades, marine research has shifted its focus and begun to adopt composite material for various parts of the ship, such as the drive shaft, hull, and propeller (Vardhan et al., 2019). In fabricate this mold, aluminum is selected material because it has low density, is non-toxic, has a high thermal conductivity, has excellent corrosion resistance and can be easily cast, machined and formed. It is also non-magnetic and non-sparking. It is the second most malleable metal and the sixth most ductile. Based on the charecteristic that are suitable with this mold in fabricate by machining process, alumnium 6061 are selected.

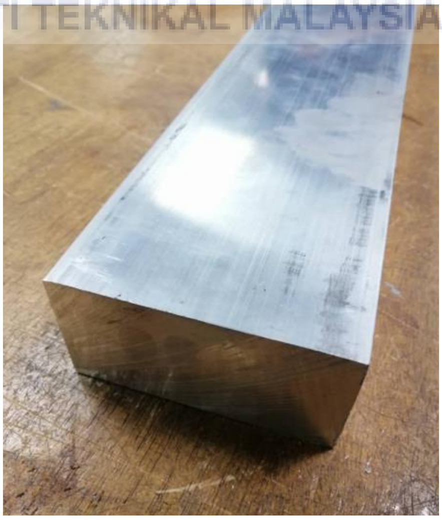


Figure 2.1: AA6061- Aluminium Block Bar

2.4 Manufacturing Process of Marine Propeller Hub

A propeller is the most common type of vessel propulsion that perceives torque from a shaft drive transmitted from an engine. In turn, reaction pressure is created on the propeller blades to bring the vessel into motion (Korsmik et al., 2019). The manufacturing technique of maritime propellers has stayed essentially constant over the past half century, and they are currently created in the same way. It's also one of the most crucial steps in the production of a marine propeller. Furthermore, sand casting technology is a method that can produce a wide range of components in the manufacturing industry, but it has issues with finish and tolerance. Pattern making, constructing the mould chamber, metal pouring, and finishing are the next major phases. Machining is another method used in the production process. This approach is suitable for precision and accuracy of marine propellers when using a 5-axis CNC machine, although cutting parameters and machining performance must be considered. By using CNC machine it can fabricate the mold for investment casting process.

2.5 Investment Casting

Investment casting, which dates back thousands of years, is a manufacturing process in which molten metal is poured into an expendable ceramic mould. A wax pattern - a disposable component in the shape of the required item - is used to create the mould. The pattern is encased in a ceramic slurry that solidifies into the mould, or "invested." Because the wax pattern is melted out of the mould after it has been made, investment casting is commonly referred to as "lost-wax casting." When compared to other casting techniques, lox-wax processes are one-to-one (one pattern makes one item), which increases production time and costs. Parts with complex geometries and detailed details can be manufactured because the mould is destroyed throughout the process.

Most metals can be used in investment casting, but aluminium alloys, bronze alloys, magnesium alloys, cast iron, stainless steel, and tool steel are the most frequent. This method is useful for casting metals that cannot be moulded in plaster or metal because to their high melting temperatures. Parts with complex geometry, such as turbine blades or weapon components, are often manufactured through investment casting. Parts for the automobile, aircraft, and military industries are among the high-temperature uses (*Investment Casting*, n.d.). Investment casting requires the use of a metal die, wax, ceramic slurry, furnace, molten metal, and any machines needed for sandblasting, cutting, or grinding. In this process, the mold are fabricated to produce the first step of the process which is wax pattern with good surface finish and dimension from the mold created. The process steps include the following below and figure 2.2:

i. Pattern creation - Wax designs are injection moulded into a metal die and created as a single piece. Cores can be utilized to create any internal pattern characteristics. To produce a tree-like assembly, several of these patterns are attached to a central wax gating system (sprue, runners, and risers). The gating system creates pathways for the molten metal to pass through on its way to the mould cavity.

ii. Mold creation - This "pattern tree" is immersed in a slurry of small ceramic particles, then covered with coarser particles and cured to produce a ceramic shell around the patterns and gating system. This technique is repeated until the shell is thick enough to survive contact with molten metal. The wax is then melted out of the shell in an oven, leaving a hollow ceramic shell that works as a one-piece mould, hence the name "lost wax" casting.

iii. Pouring - The mould is preheated to around 1000°C (1832°F) in a furnace, and molten metal is poured from a ladle into the mold's gating system, filling the mould cavity. Pouring is usually done by hand using gravity, however alternative methods such as vacuum or pressure are also utilized.

iv. Cooling - The molten metal is allowed to cool and solidify into the shape of the final casting after the mould has been filled. The length of time it takes for the component to cool is determined by the thickness of the part, the thickness of the mould, and the material employed

v. Casting removal - The mould can be shattered and the casting removed after the molten metal has cooled. Water jets are commonly used to break the ceramic mould, although there are various additional options. The parts are detached from the gating system by sawing or cold breaking once they have been removed (using liquid nitrogen).

vi. Finishing - To smooth the portion at the gates, finishing processes such as grinding or sandblasting are frequently utilized. In some cases, heat treatment is utilized to harden the finished product.

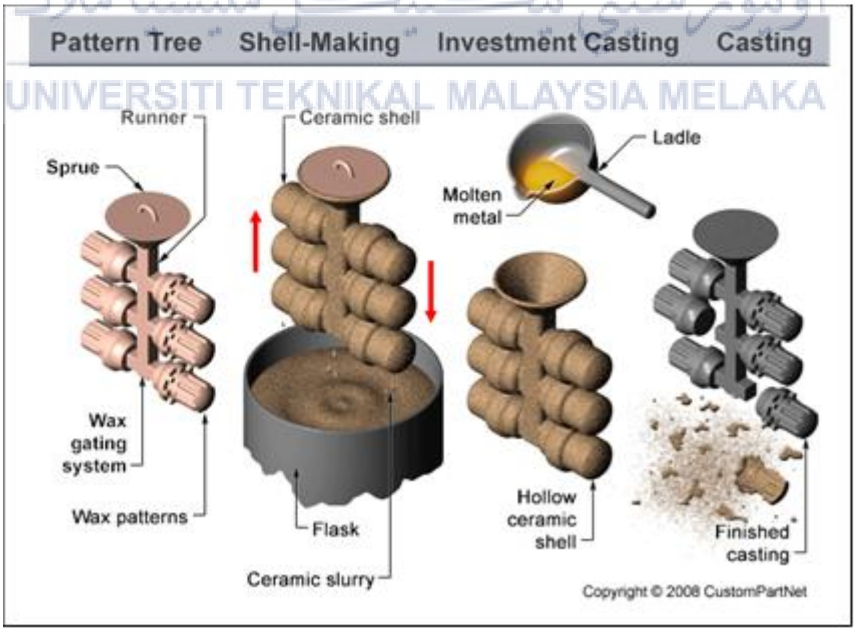


Figure 2.2 : Progress in Investment Casting (*Investment Casting*, n.d.)

2.6 CNC Milling Machine

The CAD-generated construction data is translated into milling strips for CAM processing before being put into the milling machine. Milling machines are classified as 3-axis, 4-axis, or 5-axis, depending on the number of axes. In each of the three spatial directions, a 3-axis device has degrees of movement. Thus As, the mill path points are unique. The X –, Y –, and Z – values define the shape. As a result, the computational effort is minimal. All 3-axis devices. In the dentistry field, the milled component can be rotated by 180 degrees while being processed on the inside and the outside of a crown or a capping, for example. The advantages of these milling devices are short milling time and simplified control via the three axis. Using the three axes, you can save time and simplify control. As a result, milling machines like this are usually less expensive than traditional milling machines. Those with four or five axis. In a 5-axis milling machine, in addition to the three spatial dimensions and the moveable tension bridge (4th axis), the milling spindle can also be rotated (5th axis). Milling of complex geometries with subsections is now possible (Yau et al., 2016).

Figure 2.3 : CNC Milling Machine (Yau et al., 2016)

2.7 CNC High Speed Machining

high-speed machining (HSM) is an innovative and rapidly evolving machining method that is used to produce complicated parts with high productivity, increased quality, long-term durability, and low cost. HSM was originally designed to process aluminium and alloy-based missile and aviation components. Hard metals, difficult-to-cut materials, complicated 3D geometry, and micro/nano-features can now be machined with great accuracy and precision because to ongoing breakthroughs in the field of HSM. Furthermore, the available modern machine tool can cut burr-free edges and eliminate the creation of built-up edges (BUE), resulting in an exceptional surface finish. HSM can be defined as a metal cutting technique, which utilizes cutting speed 10–15 times higher than the conventional machining. Researchers used several parameters to define HSM and classified it with different terms such as high cut- ting speed machining, high-speed and feed rate machining, high spindle speed machining, and high-performance machining (HPM). The cutting speed range in HSM 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 aluminum is notably higher than the titanium alloy. Therefore, the condition of HSM differs for different materials. Figure 2.3 demonstrates the range of cutting speed for different work materials. It can be found from the figure that the range of cutting speed such as conventional and high-speed cutting (HSC) differs for different materials. There is an intermediate region between conventional and HSC zone which is known as transition range (*High-Speed Machining - Google Buku*, n.d.).

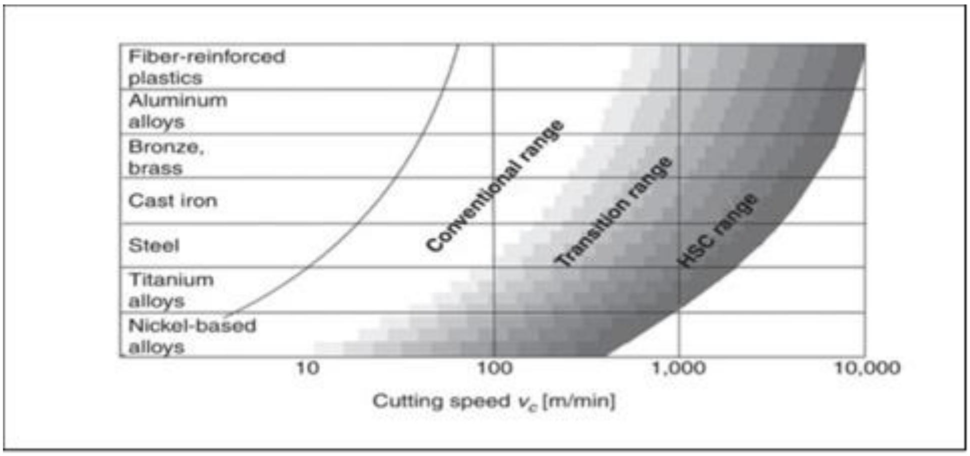


Figure 2.4 : Cutting speed range for various materials (*High-Speed Machining - Google Buku*, n.d.)

2.8 Machine Parameter

During machining, the machining parameter that has the greatest impact on the final surface quality is the machining parameter. In addition, in a metal cutting operation, three relative motions connect the workpiece and the cutting tool. As a result, the cutting parameter should be set to a reasonable value for efficient material removal. Cutting speed, feed rate, and depth of cut are three process parameters. Machining performance is also influenced by process parameters. The application of cutting-edge machine learning to assist with design decisions can result in a variety of advantages, including faster decision-making, preservation of user expertise, cost savings in man hours, and increased computing speed and accuracy (Romeo et al., 2020).

Exp No.	Spindle speed (rpm)	Feed Rate (mm/min)	Axial depth of cut (mm)	Radial depth of cut (mm)	Surface Roughness (Ra) (µm)	Predicted values (Ra) (µm)	Percentage deviation φ_i
1	1500	150	25	2	1.12	1.09	2.82
2	2500	150	25	2	0.95	0.91	4.61
3	2500	300	25	1	1.17	1.07	8.47
4	1500	300	15	2	1.27	1.45	-13.91
5	1500	150	15	2	1.1	1.11	-0.93
6	2000	200	20	2.5	1.21	1.14	5.74
7	1500	150	15	1	1.08	1.01	6.77
8	2000	200	20	1.5	1.2	1.06	11.56
9	1500	150	25	1	1.04	0.99	5.09
10	3000	200	20	1.5	0.61	0.92	-50.44
11	2000	500	20	1.5	1.31	1.51	-14.96
12	2500	300	25	2	1.26	1.18	6.28
13	2000	100	20	1.5	0.58	0.81	-40.43
14	2500	300	15	1	1.13	1.09	3.32
15	2000	200	30	1.5	1.16	1.04	9.94
16	2000	200	20	0.5	0.92	0.91	1.18
17	2000	200	20	1.5	1.17	1.06	9.29
18	2500	150	15	2	1.05	0.92	11.96
19	2500	150	15	1	0.84	0.84	0.19
20	2000	200	20	1.5	1.18	1.06	10.06
21	1000	200	20	1.5	1.28	1.36	-6.31
22	2500	300	15	2	1.22	1.2	1.27
23	1500	300	25	2	1.29	1.42	-9.94
24	2000	200	10	1.5	1.12	1.09	2.65
25	2000	200	20	1.5	1.19	1.06	10.81
26	1500	300	15	1	1.26	1.31	-4.13
27	1500	300	25	1	1.24	1.29	-3.73
28	2500	150	25	1	0.75	0.82	-9.58
29	2000	200	20	1.5	1.13	1.06	6.08
30	2000	200	20	1.5	1.15	1.06	7.71

Figure 2.5 : Recommended CNC machine parameter (Romeo et al., 2020)

Cutting Speed $Vc = \dfrac{\pi \times D \times n}{1{,}000}$

Spindle Speed $n = Vc \div \pi \div D \times 1{,}000$

Feed $Vf = n \times fz \times Z$

Feed per Tooth $fz = \dfrac{Vf}{n \times Z}$

Vc = Cutting Speed (m/min)

π = 3.14 [The Circular Constant]

D = Diameter (mm)

n = Spindle Speed (min^{-1})

Vf = Feed (mm/min)

fz = Feed per Tooth (mm/tooth)

Z = Number of Flutes

Figure 2.6 : Calculation for Cutting Speed, Spindle Speed and Feed

(*Calculation for Cutting Speed, Spindle Speed and Feed | NS TOOL CO.,LTD.*, n.d.)

2.8.1 Depth of Cut

The depth of cut is generally selected very cautiously in multi-axis machining of thin-walled workpieces such as a blade, especially at the semi-finishing and finishing stages, to alleviate the workpiece deflection throughout the machining. Furthermore, the depth of cut is frequently designed to be constant for both semi-finishing and finishing (Yan et al., 2018). In the case of the milling process, specific variations in cut intensity must be carefully evaluated to ensure the system's performance. Due to the uneven shape of work pieces, the imprecision of identifying work pieces on the gadget, and machining flaws from prior cutting, the depth of reduction is difficult to control. Furthermore, even if all parameters are accurately accounted for prior to the last machining, the cutter's position should always be consistent with the change in work piece shape, particularly when machining a high-end component (Gaja, 2011). Depth of cut is determined according to the required stock removal, shape of workpiece, power and rigidity of the machine and tool rigidity. Depth of cut also changing depth of cut doesn't effect tool life greatly and small depths of cut result in friction when cutting the hardened layer of a workpiece. Thus, tool life is shortened. Lastly, when cutting uncut surfaces or cast iron surfaces, the depth of cut needs to be increased as much as the machine power allows in order to avoid cutting impure hard layers with the tip of cutting edge to prevent chipping and abnormal wear (*Effects of Cutting Conditions for Turning | MITSUBISHI MATERIALS CORPORATION*, n.d.).

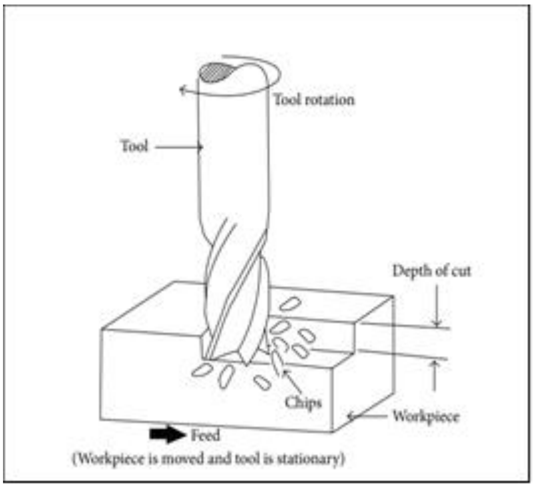


Figure 2.7 : Tool engagement on workpiece material (Nurhaniza et al., 2016)

Cutting depth (mm)	Spindle speed (r/min)	Cutting speed (m/min)	Chip load (mm/tooth)	MRR (mm^3/min)
0.4	2070	65	0.05	621.0
0.6	1750	55	0.05	787.5
1.0	1430	45	0.05	1072.5
1.2	1270	40	0.05	1143.0
1.5	1110	35	0.05	1248.8

Figure 2.8 : Parameter of depth of cut

(Ma et al., n.d.)

2.8.2 Spindle Speed

The spindle speed is the machine's spindle's rotating frequency, measured in revolutions per minute (RPM). Working backward from the required surface speed (sfm or m/min) and including the diameter yields the ideal speed (of workpiece or cutter). Excessive spindle speed can result in premature tool wear, breakage, and tool chatter, all of which can result in potentially dangerous situations. Using the proper spindle speed for the material and equipment will greatly improve tool life and surface finish quality. In most cases, the cutting speed for a given machining operation will remain constant. As a result, the spindle speed will be consistent. On a lathe or screw machine, however, activities such as facing, forming, parting off, and recessing require the machining of a constantly changing diameter. In an ideal world, this would entail altering the spindle speed as the cut progresses across the workpiece's face, resulting in a constant surface speed (CSS). CSS-effecting mechanical arrangements have existed for ages, but they have never been widely used in machine tool control. The principle of CSS was largely overlooked in the pre-CNC era. Special care was taken to obtain it for unusual work that required it. Spindle speed N (rpm) is usually determined by the cutting speed V (in./min.) that is:

$$N = \frac{V}{\pi D} \times 100$$

Where D is that the cutter diameter. The material being machined (steel, brass, alloy steel, plastic, wood) the fabric cutter is made of (carbon steel, hot-paintings steel, carbide, ceramics) and, as a result, the low-budget lifetime of the cutter (the price to regrind or purchase new compared to the wide variety of components produced) are all factors affecting the calculation of slicing pace (Chang, 2015).

Table 11.1 Recommended Cutting Speeds

(a) Recommended by Kalpakjian and Schmid (2010)

Workpiece Material	Cutting Speed (m/s) HSS	Cutting Speed (m/s) Carbide Inserts
Aluminum alloys	1.5–6	10 +
Magnesium alloys	3–5	12 +
Copper alloys	0.3–1.5	1.5–7
Steels	0.1–0.7	0.5–4
Stainless steels	0.2–1	1–2
High-temp alloys	0.05–0.1	0.2–0.3
Titanium alloys	0.1–1	0.5–2
Cast irons	0.2–0.6	0.5–2

(b) Recommended by Krar et al. (2010)

Workpiece Material	Cutting Speed (m/min) HSS	Cutting Speed (m/min) Carbide Inserts
Machine steel	21–30	45–75
Tool steel	18–20	40–60
Cast iron	15–25	40–60
Bronze	20–35	60–120
Aluminum	150–300	300–600

Figure 2.9 : Recommended Cutting Speed

(Chang, 2015)

2.8.3 Feed Rate

Feed rate is the velocity at which the cutter is fed, that is, advanced against the workpiece. The Feed rate is the linear speed of the tool as it travels along the part contour. A cutting tool is designed to cut a certain amount of material in each revolution, and the insert's chip breaker geometry is designed to break chips within a particular range of chip thickness. The chip thickness directly depends on the feed rate in mm/rev. The feed rate is therefore specified in cutting tool catalogs in mm/tooth/rev (mm per tooth per revolution). It is converted to mm/min for the CNC program (note that in turning it is programmed as mm/rev) (*Cutting Speed vs Feed Rate – Milling | Blogs | CNCTimes.Com*, n.d.). Once an adequate spindle speed is determined a feed rate f (in /min) can be calculated using the following equation:

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

- FR = the calculated feed rate in inches per minute or mm per minute.
- RPM = the calculated speed for the cutter.
- T = number of teeth on the cutter.
- CL = the chip load or feed per tooth. This is the size of chip that each tooth of the cutter takes

Where T is that the wide variety of teeth at the cutter and CL is that the feed in line with enamel as depicted in Figure 2.5. Factors that have an effect on the feed price include sort of tool (e. G., a little drill vs. An outsized quit mill), floor finish desired, power available on the spindle to stop stalling of the cutter or work piece, tension of the gadget and tooling setup (potential to stand as much as vibration or chatter), strength of the work piece (excessive feed rate will crumble skinny wall tubing) and traits of the fabric being reduce (e. G., chip flow relies upon on material kind and feed rate). The advocated feeds in line with enamel for warm work metal and carbide inserts are listed Table 2.2. As shown, higher feed in step with enamel is recommended for carbide insert cutters even as cutting difficult materials like steels. Also higher feed in step with enamel is recommended for face milling than end milling. This is frequently because extra surface are in touch with the work piece in face milling therefore a better feed rate. While finishing end cut the feed rate are frequently became up if material last is minimal. Again, numbers acquired from machining handbooks most effective provide an honest start line (Chang, 2015). Greater value of feed rate means more cutting force will occurs. Then its effect will be analyzed based on the deviation and surface roughness values that occured on each the propeller blade that had been made. So it can be concluded that the greater the value of the feed rate applied, the more dimensional deviations would occured, and also the resulting surface would be coarser (Rahman et al., 2017).

Table 11.2 Recommended Feed per Tooth by Krar et al. (2010)

(a) High-Speed Steel

Workpiece Material	Face Mills in.	Face Mills mm	End Mills in.	End Mills mm
Aluminum	0.002	0.55	0.011	0.28
Brass and bronze	0.014	0.35	0.007	0.18
Cast iron	0.013	0.33	0.007	0.18
Bronze	0.012	0.30	0.006	0.15
Tool steel	0.010	0.25	0.005	0.13
Stainless steel	0.006	0.15	0.003	0.08

(b) Carbide Inserts

Workpiece Material	Face Mills in.	Face Mills mm	End Mills in.	End Mills mm
Aluminum	0.020	0.50	0.010	0.25
Brass and bronze	0.012	0.30	0.006	0.15
Cast iron	0.016	0.40	0.008	0.20
Bronze	0.012	0.40	0.008	0.20
Tool steel	0.014	0.35	0.007	0.18
Stainless steel	0.010	0.25	0.005	0.13

Figure 2.10 : Recommended Feed per Tooth

(Chang, 2015)

2.9 Surface Roughness

Surface roughness, often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose. Roughness plays an important role in determining how a real object will interact with its environment. In tribology, rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities on the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. Generally speaking, rather than scale specific descriptors, cross-scale descriptors such as surface fractality provide more meaningful predictions of mechanical interactions at surfaces including contact stiffness (Zhcai et al., 2016) and static friction (Hanaor et al., 2016).

Roughness, N	Roughness values, Ra		RMS (µin.)	Center line avg., CLA	Roughness, Rt
ISO grade numbers	micrometers (µm)	microinches (µin.)		(µin.)	(µm)
N12	50	2000	2200	2000	200
N11	25	1000	1100	1000	100
N10	12.5	500	550	500	50
N9	6.3	250	275	250	25
N8	3.2	125	137.5	125	13
N7	1.6	63	69.3	63	8
N6	0.8	32	35.2	32	4
N5	0.4	16	17.6	16	2
N4	0.2	8	8.8	8	1.2
N3	0.1	4	4.4	4	0.8
N2	0.05	2	2.2	2	0.5
N1	0.025	1	1.1	1	0.3

Figure 2.11 : Common conversion table with also roughness grade numbers

Arithmetical mean roughness Ra			Max. height Ry	Ten-point mean roughness Rz	Standard length of Ry · Rz ℓ (mm)	Triangular indication
Preferred number series	Cut-off value λc (mm)	Indication of surface texture on drawings	Preferred number series			
0.012 a	0.08	0.012√ ~ 0.2√	0.05 s	0.05 z	0.08	▽▽▽▽
0.025 a	0.25		0.1 s	0.1 z		
0.05 a			0.2 s	0.2 z	0.25	
0.1 a	0.8		0.4 s	0.4 z		
0.2 a			0.8 s	0.8 z	0.8	
0.4 a		0.4√ ~ 1.6√	1.6 s	1.6 z		▽▽▽
0.8 a			3.2 s	3.2 z		
1.6 a			6.3 s	6.3 z		
3.2 a	2.5	3.2√ ~ 6.3√	12.5 s	12.5 z	2.5	▽▽
6.3 a			25 s	25 z		
12.5 a	8	12.5√ ~ 25√	50 s	50 z		▽
25 a			100 s	100 z	8	
50 a		50√ ~ 100√	200 s	200 z		~
100 a	—		400 s	400 z	—	

Figure 2.12 : Relationship Between Arithmetical Mean Roughness (Ra) and Conventional Symbols

(*A Guide to Understanding Surface Roughness Measurement Types | Roslerblog*, n.d.)

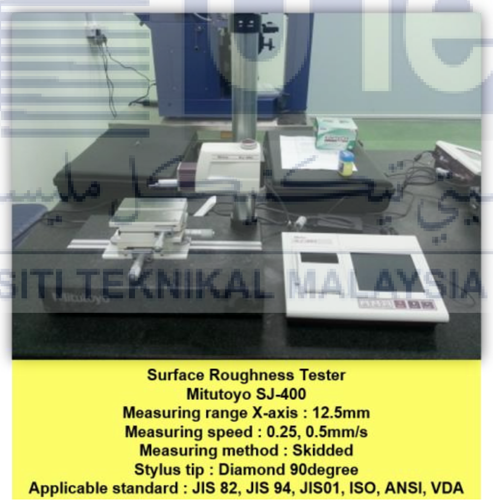


Figure 2.13 : Surface Roughness Tester

2.10 Tool use for machining

i. End Mill; End mill tool can be used in wide variety of machining process including roughing, profile countering, slotting, borehole, and helical milling process. The size of the cutter vary on its own application and operation needed.

ii. Ball mill; A ball end milling cutter is also known as a "ball nose mill". The end of this tool is ground with a full radius equal to half of the tool diameter, and the edges are center cutting. They can be single end or double end and they can be made from solid carbide or various compositions of high speed steel. They can be general purpose or high perfomance geometries. They can be used used for milling a large corner radius, grooving with a full radius, and contour or profile milling. The smaller diameters can be used for engraving. They are available in a wide variety of standard sizes and lengths.

iii. Drilling; Drilling is the method in creating a hole with a helical tool spinning to remove the material. If the size of a hole is too big, the hole-drilling process will be followed by borehole process using end mill tools. Using an increasing size of drill tool can also do the borehole process, but it will longer the machining process time.

2.11 Machining Strategies

The objective of the study presented here was to analyze the different machining strategies of a sweeping and isoparametric. The machining quality was assessed by comparing surface roughness and dimensional control parameters. These assumptions are the main focus of the application of machining strategies. In addition, the resultant reduction of cutting forces and vibrations enables an increase in the depth of cut or the length of the cutting tool, which is particularly advantageous in certain circumstances (Perez et al., 2013). CATIA software is widely used in a variety of fields and sectors all over the world, particularly in the automotive and aerospace industries. Mechanical Design, Shape Design, Analysis and Simulation, Machining Simulation, and many other modules are available in CATIA workbench. "Advanced Machining" was chosen as the main module or workbench for generating and producing the software for this study. There were many criteria need to be considered during the programming process. In this simplification method, “Isoparametric” and “Sweeping” command selected to be the main machining strategies that can help into simplifying the machining programming.

2.12 Summary

In this chapter, I can conclude that researcher come out with various of machine parameter to get the best surface roughness in term of good machining strategies to determine best machine parameter. This is because we must verify that the parameters used are appropriate in order to obtain a high-quality surface. When machining the surface of the the boat propeller hub blade mold, this can save time and reduce damage or tool wear. Machining matrices are extensively used machining techniques.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a flow to show the methodology by using a flowchart. This chapter are described to achieve the objective. Job scope of study is most important to construct the methodology. This methodology is referred to the previous chapter, which is research and literature review. In literature review, the information is collected from the journal, articles, books, and website. At this chapter are covered from beginning of the research to the last process. This section is going to be mentioned every process in conducting this research. The study aims to compare these two machining strategies in obtaining the best surface roughness.

3.2 Planning of Study

This chapter will focus on the simulation used to create the CAM technique for moulding propeller hub blades. This apart from that, the propeller hub blade was designed using the existing design. For this study, the surface mold's shape is inspected to determine machining capability. It applied to construct a CAM programme to execute the fabrication on machine CNC milling for manufacturing operations based on the current design 3D core and cavity of blade propeller Following that, the mould will be designed in order to determine the machine's and tool's capabilities. Finally, the surface core and cavity blade propeller surface roughness is determined using the parameter CAM simulation and CAM strategies.

3.3 PSM Flow Chart

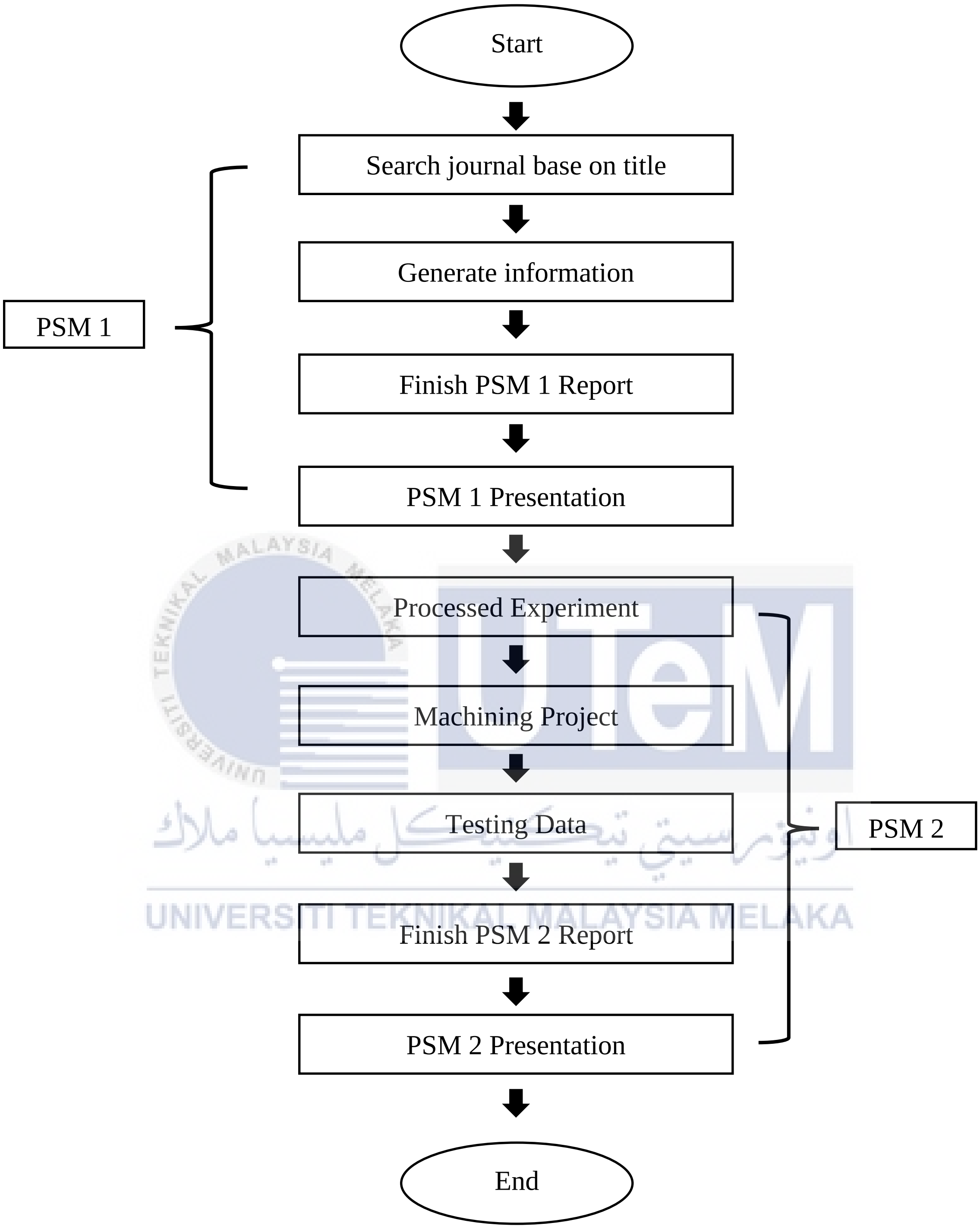


Figure 3.1 : Overall PSM Flow chart

3.4 Project Flow chart

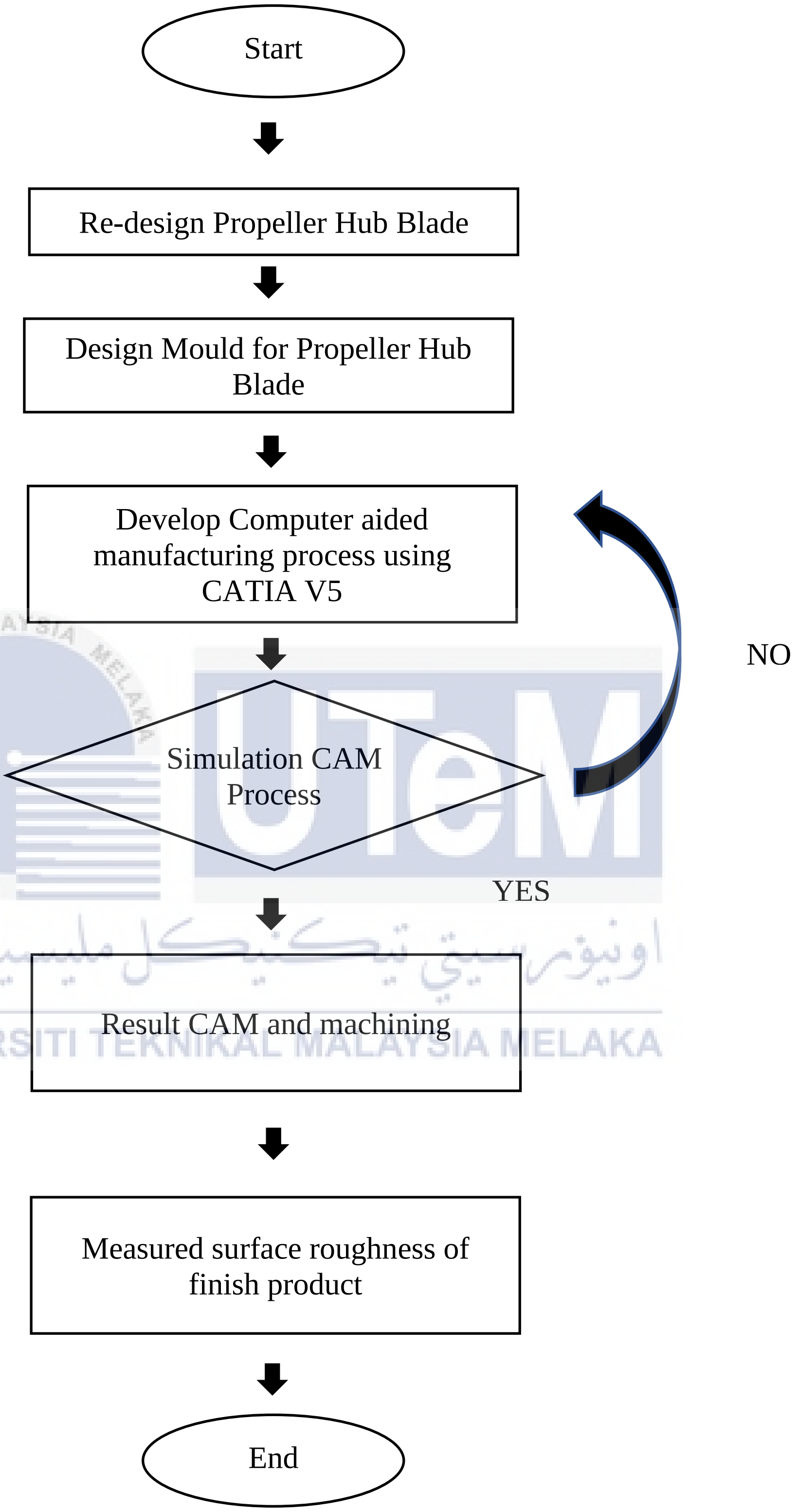


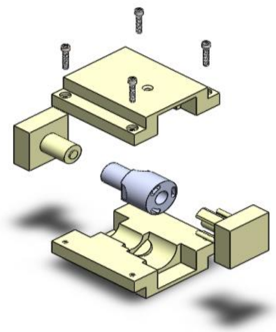
Figure 3.2 : Project Flow Chart

3.5 Literature Review of Research

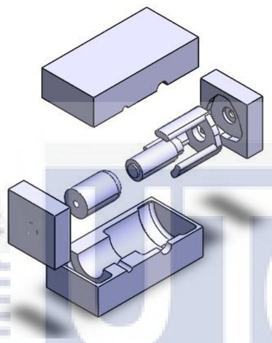
The title of this study is connected to all journal and article resources. To make this research more understandable and clear, a journal of hub blade propeller design, propeller, propeller building, CNC high-speed machining, and CAM software are gather. The project starts with a redesign hub and mould design in order to obtain a good CAD hub blade propeller. Then, using CATIA V5 software, create a CAM machining process for the hub blade propeller. The comparison of tool path style and cutting tool results of simulated machining time will be described.

3.6 Mold Design

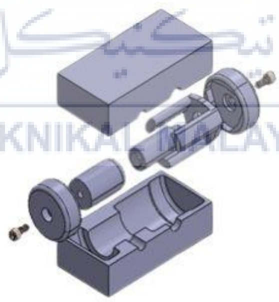
Permanent molds are made up of two separate of core and cavity (pattern of shape). The design of the mold must be suitable for hub blade shape because it determines the purpose or objective which the cavity and core side mould can separate and can be machining according to CAM process limit. Designing also need to based on the design of manufacturing and machining criteria. Solidworks software is used to create 3D models, and CATIA V5 software is used for machining. CATIA V5 is an older version, but it has a simple interface, and it is simple to select tools. As a result, Solidwork includes tools such as assembly, simulation, and rendering. Both software programmers have advantages when it comes to creating any design. The suggested design is the design that had been proposed for simulation. The part was designed in requirement to the simulation capabilities and limitations for CATIA V5 software. These mould will be produces by CNC Machining for investment casting process. Figure 3.1 show all the design created.



(a) Design 1



(b) Design 2



(c) Design 3

Figure 3.3: Designed mold

3.6.1 Selected Design

From three design created, design 3 was the most suitable based on Design for Manufacturing or Design for Manufacturability (DFM). It is because of the optimisation of a machining ability or part's design create it cheaper and more easily. Compared to design 1, the mold designed size is quite large for the propeller hub blade. This will require a high cost to buy or provide raw material compared to design 3 which is smaller and very suitable for the size of the hub that want to produce. Besides, in the design of mold 1 there are some mistakes have been encountered in the hole of pouring melted wax and there is no air flow for this mold. The pouring hole has been designed at the top of the mold, this will cause difficulty in separating between the molds and can cause cracks on the part of the pattern produced. In addition, the flow of melted wax also suffers from problems because this mold does not have good ventilation. It shown in figure 3.1.

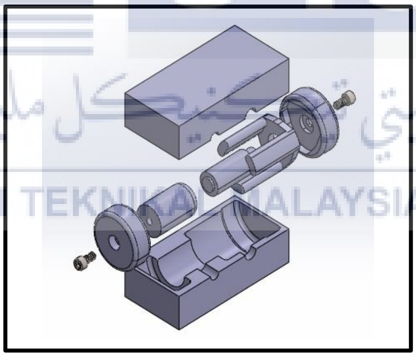


Figure 3.4 : Mold selected design

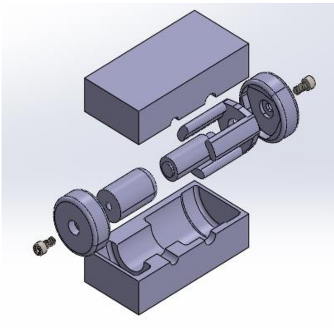
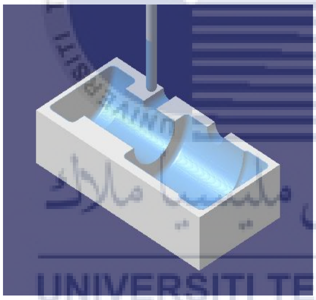
Design 2 was not selected because there have limitation in machining using cnc machine. The shape of the top and bottom insert was square and it will produce edge inside the slot that it very possible to produce by cnc machine. In design 3, the problem was fixed by producing the two inserts to be cylinder shape and have fillets on each edge. This will facilitate the process in machining this mold and it can be easy to fit to the insert between the both sides of the mold. It show in figure 3.1. Designed mold involves efficiently designing or engineering an object, generally during the product design stage, when it is easier and less expensive to do so, to reduce manufacturing costs. This allows a manufacturer to identify and prevent mistakes or discrepancies.

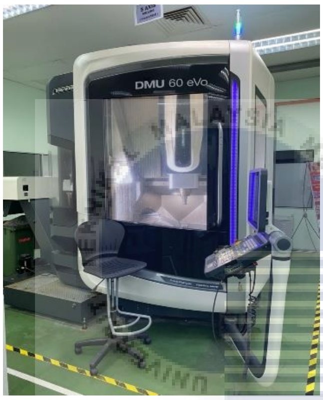
3.6.2 Design for Manufacturing

The experiment will begin with selecting the appropriate design for the process. The design need to be review and adjusted according to the CNC machining parameters and limitations. DFM involves efficiently designing or engineering an object, generally during the product design stage, when it is easier and less expensive to do so, to reduce manufacturing costs. This allows a manufacturer to identify and prevent mistakes or discrepancies.Then the machining simulations will be considered and selected for simulation. After the simulation run without errors, the experiment will proceed to the machining process. The last step to the experiment will be the analysis of the surface roughness.

3.7 Procedure of Project Fabrication

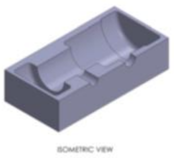
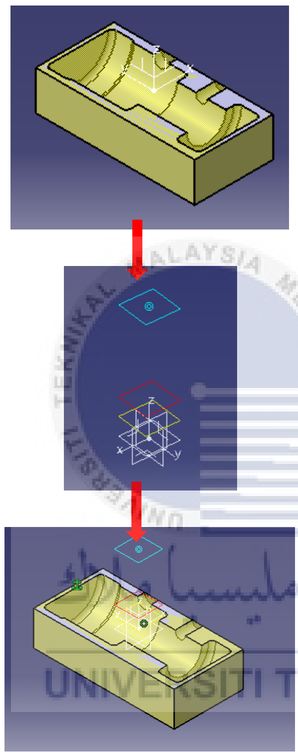
Table 1 : Procedure of Project fabrication

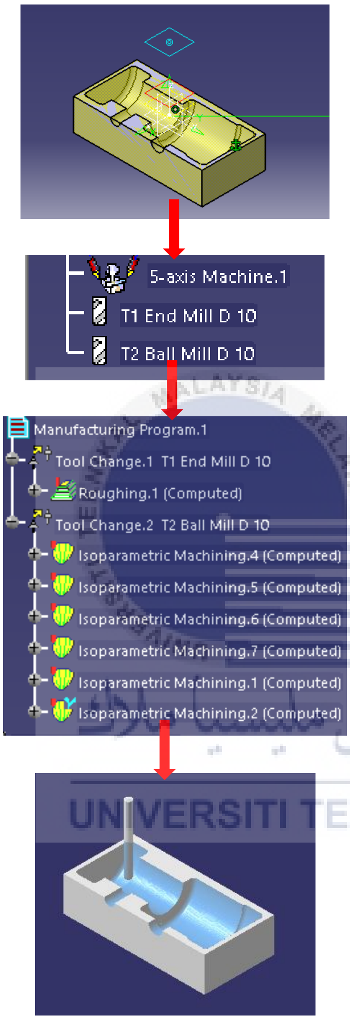
No.	Photo	Process Description
1.		**CAD –** Design the mold based on the shape of the part that want to produce in CATIA V5 software.
2.		**CAM** – After finish design of the mold, do the CAM in CATIA V5 software process such as Roughing, Isoparametric, sweeping and others to complete the machining simulation. After that, it finally can generate NC Code.
3.		**Cut Raw Material** - This process can perform when successfully accept the raw material from suppliers. Cut raw material before doing next process.

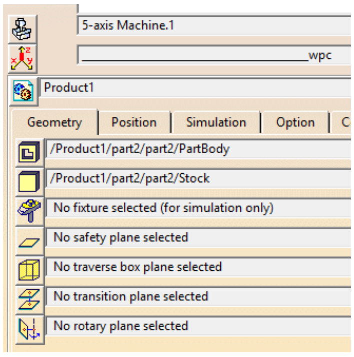
4.		**Squaring part** – By using milling machine produced squaring for all part of the mold to prepare stock for CNC machining. The stock must follow the drawing design requirement.
5.		**CNC Milling Machining –** Before running, the NC code is transferred to the machine controller for simulation. Change the cutting tools based on the slot in the programmed. After that, start the machine and monitor the entire process to get the finish product.
6.		**Surface Roughness** – Lastly do the surface roughness on the female and male mold part to find out which one is the better surface roughness result by compare between Sweeping Machining strategy and Isoparametric Machining strategy.

3.7.1 Male Mold

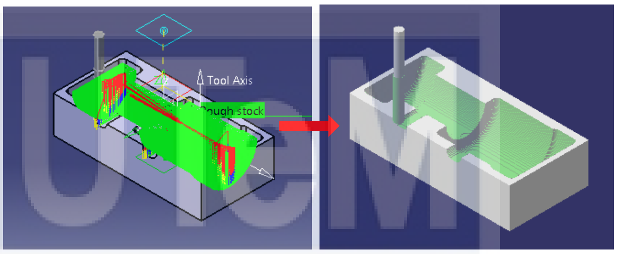
Table 2 : Procedure of Male Mold

No	Photo	Description
1.		**CAD** – Design the mold according to the propeller hub blade produced in CATIA V5
2.		**Assembly part and plane system** -definition is any machining process strategy and planning with the aid of computer software. Before start the machining, open the product file and assemble all required part, constraint the part axis with plane axis.
3.		**CAM** - Definition is any machining process strategy and planning with the aid of computer software. Then, click on “Start” – “Machining” and choose which machining required to enter CAM interface and start CAM process. Then, click on “Start” –“Machining” and choose which machining required to enter CAM interface and start CAM process. After opening the Machine Editor tab, on the top of the window, there were six choices of the machine that can be selected. The choices given were 3-Axis Machine, 3-Axis with Rotary Table Machine, 5-Axis Machine, Horizontal Lathe Machine, Vertical Lathe Machine Deprecated and Multi-slide Lathe Machine. In this machining operation, the machine that need to be selected was the 5-Axis Machine. Then select the referance machining axis system.



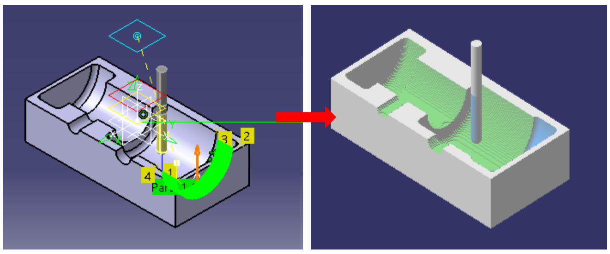


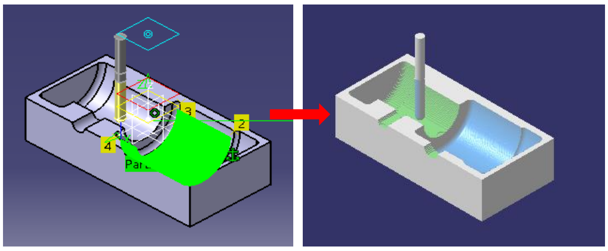
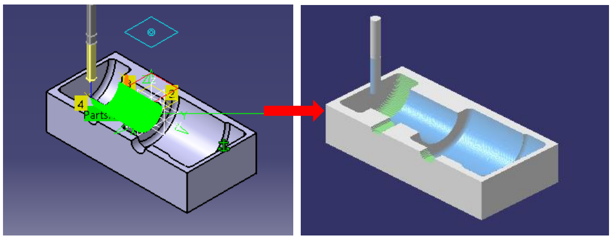
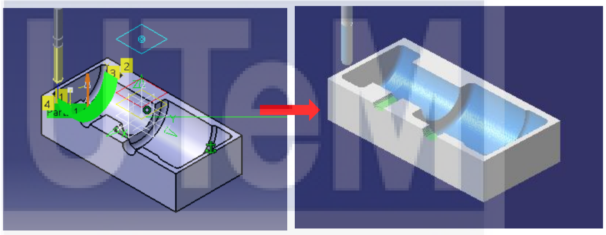
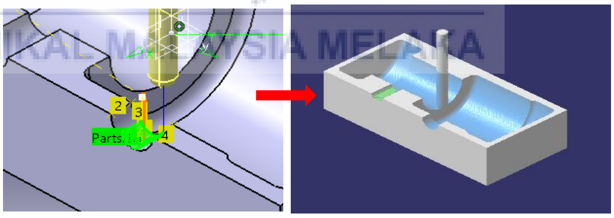
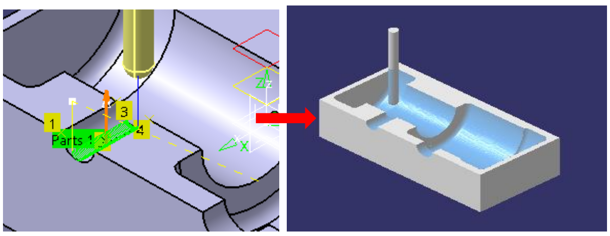
Select the part and select the stock that yellow colour. After that, click "Auxiliary Operation" then click [icon] to select the cutting tool according to the shape of the mold. For "Roughing Process" End mill D10 are selected and Ball mill D10 for all "Isoparametric Machining". After finish selected the tool continue to do "Roughing Process".



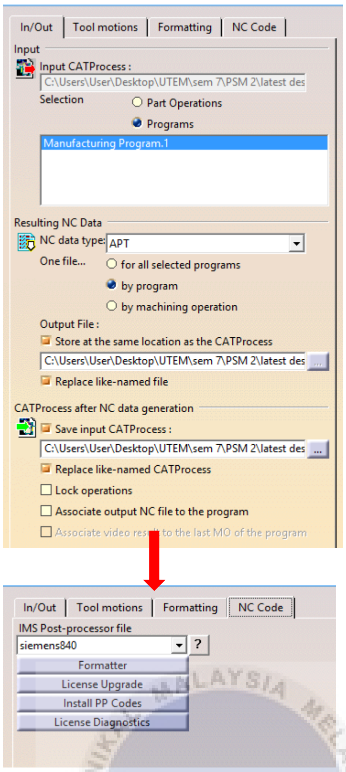
Secondly, do the "Isoparametric Machining" this area below. Zig zag tool path are selected. Machining tolarance and stepover for scallop height is 0.01mm. All of the "Isoparametric Machining" parameter set are the same;

Isoparametric Machining 1



		Isoparametric Machining 2  Isoparametric Machining 3  Isoparametric Machining 4  Isoparametric Machining 5  Isoparametric Machining 6 

4



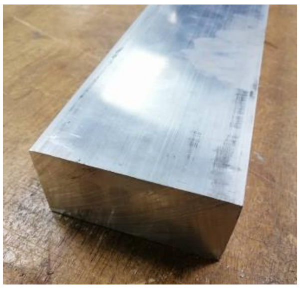
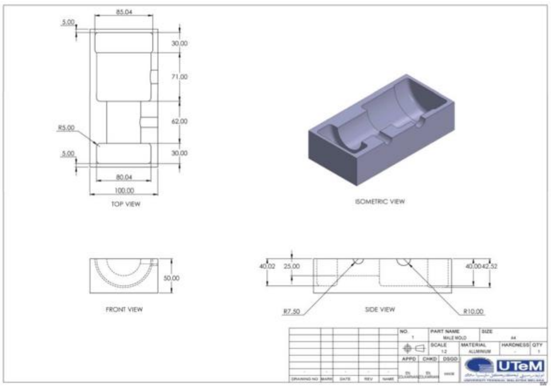
Generate NC Code – in this process that only can do after the whole machining operation are created properly. Generate the NC code applicable to the Siemens controller according to the CNC machine controller.

The header of the NC code;

```
N1 G54 G40 G90 G17 G94
N2 G54
N3 T3 M6
N4 G0 X39.52 Y93.5 S10000 M3
N5 Z15.
N6 G1 Z-3. F1500.
N7 X39.493 Z-4.46 F1800.
N8 X39.412 Z-5.919
N9 X39.277 Z-7.373
N10 X39.089 Z-8.821
N11 X38.847 Z-10.262
N12 X38.552 Z-11.692
N13 X38.205 Z-13.111
N14 X37.805 Z-14.516
```

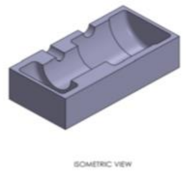
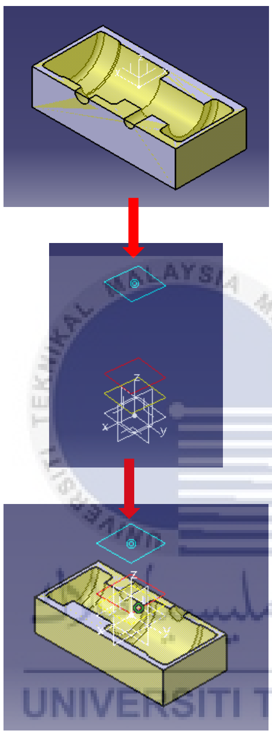
The end of the NC code;

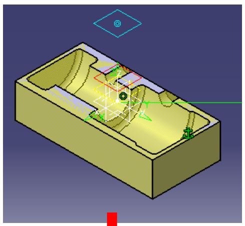
```
N35884 Y-33.778 Z-7.157
N35885 Y-33.353 Z-6.955
N35886 Y-32.855 Z-6.641
N35887 Y-32.489 Z-6.344
N35888 Y-32.078 Z-5.922
N35889 Y-31.791 Z-5.549
N35890 Y-31.49 Z-5.043
N35891 Y-31.299 Z-4.613
N35892 Y-31.124 Z-4.05
N35893 Y-31.038 Z-3.587
N35894 Y-31. Z-3.
N35895 Z15. F5000.
N35896 M30
%
```

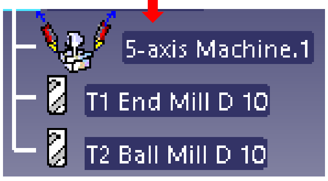
5.	 	**Milling Machine** - This process can perform when successfully accept the raw material from suppliers. Cut raw material before doing next process. By using milling machine produced squaring for part of the mold to prepare stock for CNC machining. The stock must follow the drawing design requirement. 
6.		**CNC Milling Machining** –The next step is to dry run the program as to check the machining program is properly created at the machine controller. After satisfied with the dry run, run the program with extra caution until the program have no error. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.  Make sure change the cutting tools first based on the slot in the programmed. After that, start the machine and monitor the entire process to get the finish product. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.

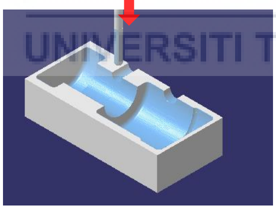
3.7.2 Female Mold

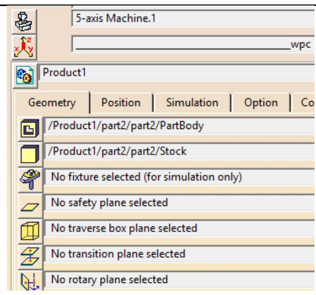
Table 3 : Procedure of Female Mold

No	Photo	Description
1.		**CAD** – Design the mold according to the propeller hub blade produced in CATIA V5
2.		**Assembly part and plane system** - Definition is any machining process strategy and planning with the aid of computer software. Before start the machining, open the product file and assemble all required part, constraint the part axis with plane axis.
3.		**CAM** - Definition is any machining process strategy and planning with the aid of computer software. Then, click on “Start” – “Machining” and choose which machining required to enter CAM interface and start CAM process. Then, click on “Start” – “Machining” and choose which machining required to enter CAM interface and start CAM process. After opening the Machine Editor tab, on the top of the window, there were six choices of the machine that can be selected. The choices given were 3-Axis Machine, 3-Axis with Rotary Table Machine, 5-Axis Machine, Horizontal Lathe Machine, Vertical Lathe Machine Deprecated and Multi-slide Lathe Machine. In this machining operation, the machine that need to be selected was the 5-Axis Machine. Then select the referance machining axis system.

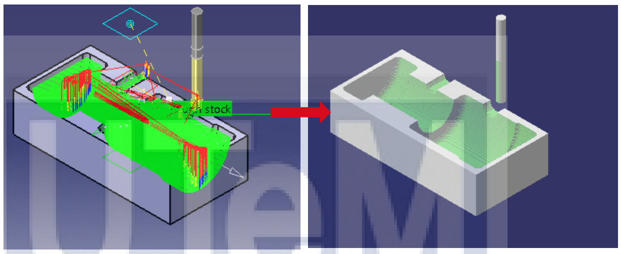




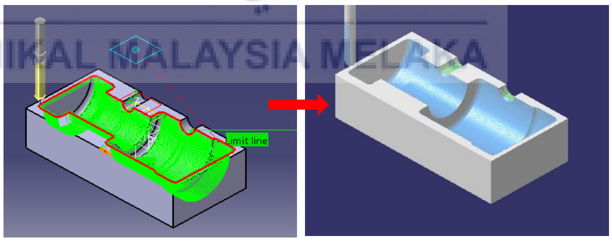




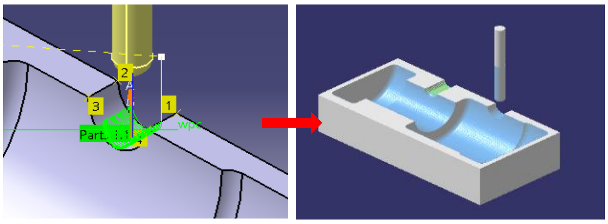
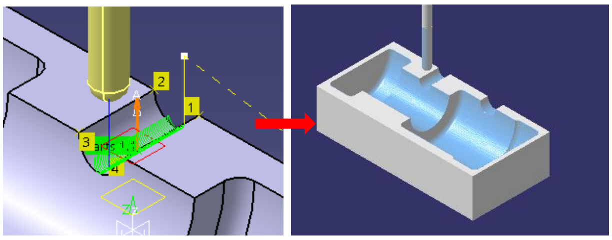
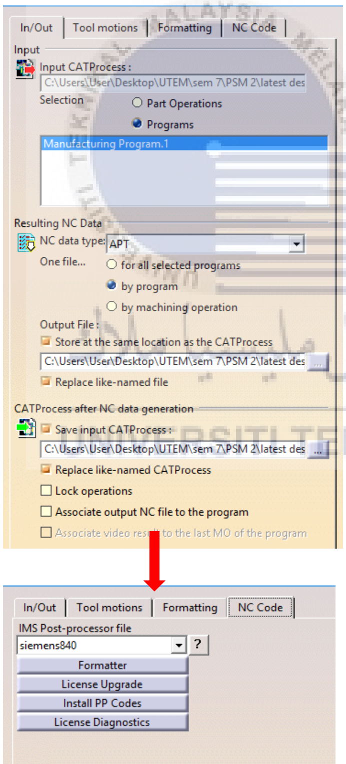
Select the part and select the stock that yellow colour. After that, click "Auxiliary Operation" then click  to select the cutting tool according to the shape of the mold. For "Roughing Process" End mill D10 are selected and Ball mill D10 for "Sweeping Machining" and "Isoparametric Machining" . After finish selected the tool continue to do "Roughing Process".

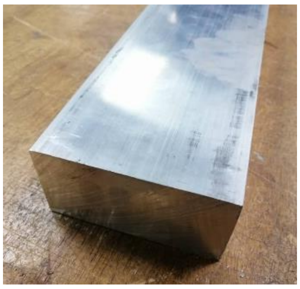
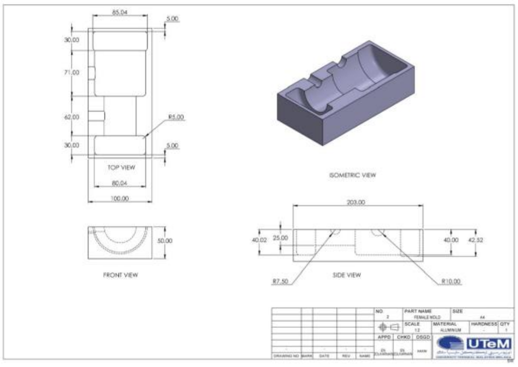
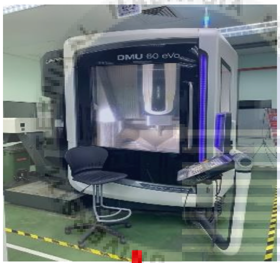


Secondly, do the "Sweeping Machining" this area below. Zig zag tool path are selected. Machining tolarance and stepover for scallop height is 0.01mm.



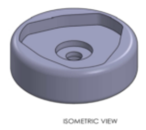
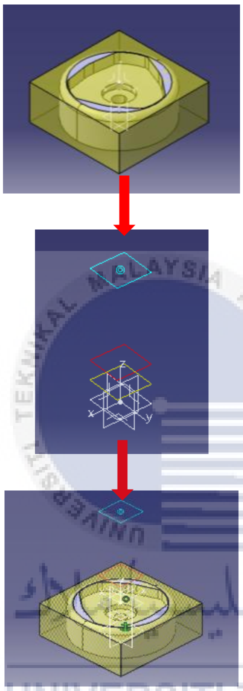
Then, do the next process with is "Isoparametric Machining" this area below. Zig zag tool path are selected. Machining tolarance and stepover for scallop height is 0.01mm. All of the "Isoparametric Machining" parameter set are the same;

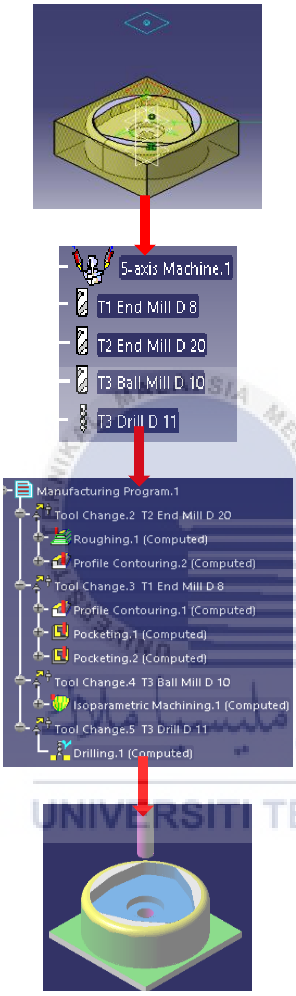
		Isoparametric Machining 1  Isoparametric Machining 2 
4.	 	**Generate NC Code** – In this process that only can do after the whole machining operation are created properly. Generate the NC code applicable to the Siemens controller according to the CNC machine controller. The header of the NC code; N1 G54 G40 G90 G17 G94 N2 G54 N3 T1 M6; endmill 10 N4 G0 X-29.87 Y19.695 S8000 M3 N5 Z10.1 N6 G1 Z.1 F1250. N7 X-29.872 Y21.253 Z-.317 N8 X-29.897 Y21.731 Z-.446 N9 X-29.967 Y22.204 Z-.574 N10 X-30.276 Y23.765 Z-1. N11 X-30.658 Y24.926 F1500. N12 X-31.066 Y25.792 N13 X-31.769 Y26.887 N14 X-33.049 Y28.403 The end of the NC code; N105822 Y-35.354 N105823 X-23.897 Y-34.992 Z-7.448 N105824 X-23.987 Y-34.642 Z-7.348 N105825 X-24.095 Y-34.354 Z-7.222 N105826 X-24.261 Y-34.016 Z-7.012 N105827 X-24.467 Y-33.678 Z-6.712 N105828 X-24.64 Y-33.435 Z-6.41 N105829 X-24.797 Y-33.236 Z-6.06 N105830 X-24.906 Y-33.106 Z-5.72 N105831 X-24.976 Y-33.027 Z-5.364 N105832 X-25. Y-33. Z-5. N105833 Z15. F5000. N105834 M30

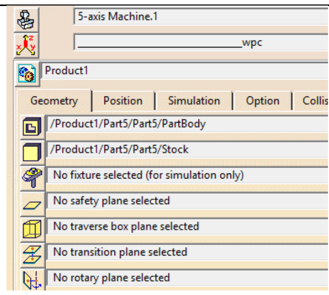
5.	 	**Milling Machine** - This process can perform when successfully accept the raw material from suppliers. Cut raw material before doing next process. By using milling machine produced squaring for part of the mold to prepare stock for CNC machining. The stock must follow the drawing design requirement. 
6.	  	**CNC Milling Machining** –The next step is to dry run the program as to check the machining program is properly created at the machine controller. After satisfied with the dry run, run the program with extra caution until the program have no error. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.  Make sure change the cutting tools first based on the slot in the programmed. After that, start the machine and monitor the entire process to get the finish product. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.

3.7.3 Bottom Insert

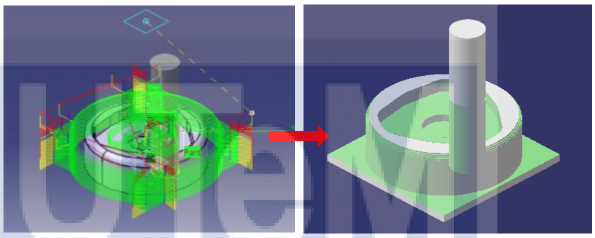
Table 4 : Precedure of bottom Insert

No	Photo	Description
1.		CAD – Design this bottom insert part for function located the the bottom insert pin 1 and 2 in CATIA V5. The design need high precision because this part need to assembly with the insert pin and both side mold. The clearance are provide for critical area of assembly at their dimension.
2.		**Assembly part and plane system** - Definition is any machining process strategy and planning with the aid of computer software. Before start the machining, open the product file and assemble all required part, constraint the part axis with plane axis.
3.		**CAM** - Definition is any machining process strategy and planning with the aid of computer software. Then, click on “Start” – “Machining” and choose which machining required to enter CAM interface and start CAM process. Then, click on “Start” – “Machining” and choose which machining required to enter CAM interface and start CAM process. After opening the Machine Editor tab, on the top of the window, there were six choices of the machine that can be selected. The choices given were 3-Axis Machine, 3-Axis with Rotary Table Machine, 5-Axis Machine, Horizontal Lathe Machine, Vertical Lathe Machine Deprecated and Multi-slide Lathe Machine. In this machining operation, the machine that need to be selected was the 5-Axis Machine. Then select the referance machining axis system.

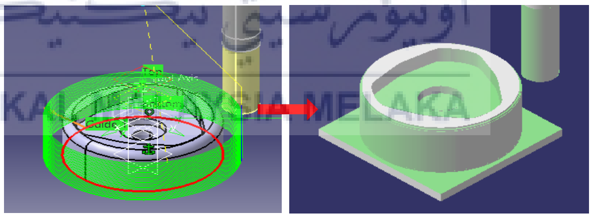
<table>
<tr>
<td></td>
<td>


</td>
<td>


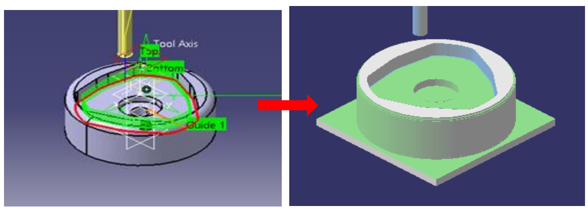
Select the part and select the stock that yellow colour. After that, click “Auxiliary Operation” then click to select the cutting tool according to the shape of the mold. For “Roughing Process” and “Profile Contouring 1” End mill D20, “Profile Contouring 2”, “Pocketing 1,2” End mill D8, “Isoparametric Machining” Ball mill D10 are selected and lastly Drill D11 for “Drilling”. After finish selected the tool, continue to do “Roughing Process”;



Profile Contouring 1



Profile Contouring 2



</td>
</tr>
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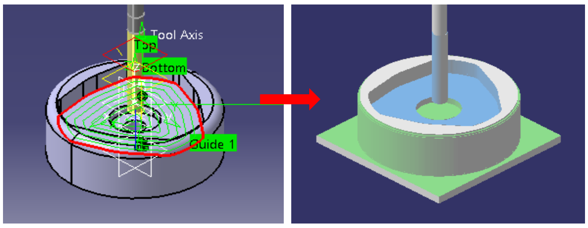
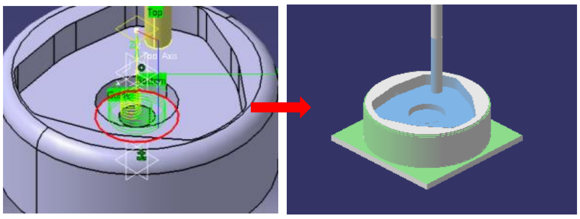
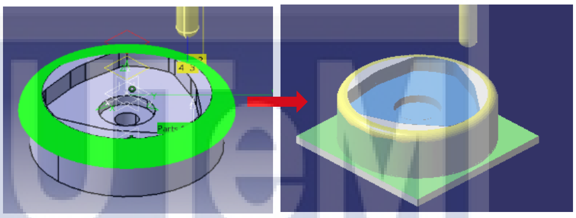
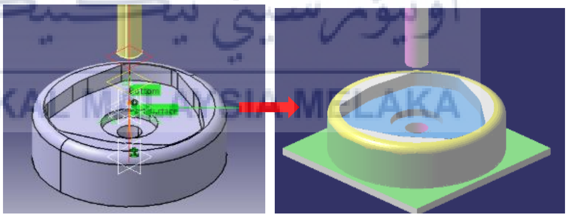
		Pocketing 1  Pocketing 2  Isoparametric Machining  Drilling 

<table>
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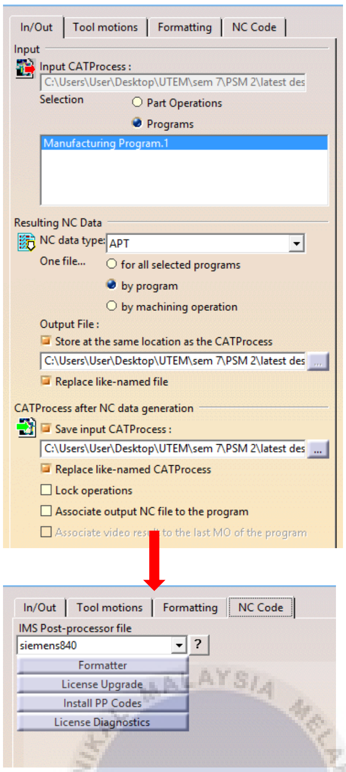
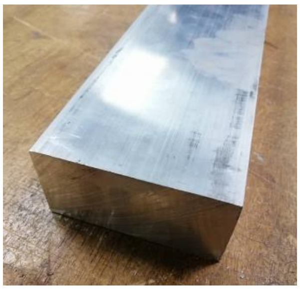
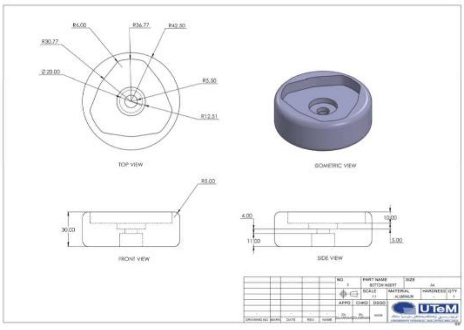
<td>
</td>
<td>Generate NC Code – In this process that only can do after the whole machining operation are created properly. Generate the NC code applicable to the Siemens controller according to the CNC machine controller.

The header of the NC code;

N1 G54 G64 G40 G90 G17 G94 G49 G80
N2 G54
N3 T4 M6; endmill 20
N4 G0 X-58.01 Y44.996 S6000 M3
N5 Z9.
N6 G1 Z-1. F1250.
N7 X-45.
N8 Y45. F1500.
N9 X-24.559
N10 X-24.806 Y44.869
N11 X-26.422 Y43.937
N12 X-28.001 Y42.948
N13 X-29.541 Y41.904
N14 X-31.043 Y40.804

The end of the NC code;

N45114 G54
N45115 T3 M6 ; drill 11
N45116 G0 X0 S1000 M3
N45117 Z100.
N45118 Z30.
N45119 Z15.
N45120 Z-5.
N45121 Z-14.
N45122 Z-15.
N45123 CYCLE81 (-15. , -15. , 0 , -33.175)
N45124 Z-5.
N45125 Z30.
N45126 M30
%</td>
</tr>
<tr>
<td>5.</td>
<td>
</td>
<td>Milling Machine - This process can perform when successfully accept the raw material from suppliers. Cut raw material before doing next process. By using milling machine produced squaring for part of the mold to prepare stock for CNC machining. The stock must follow the drawing design requirement.

</td>
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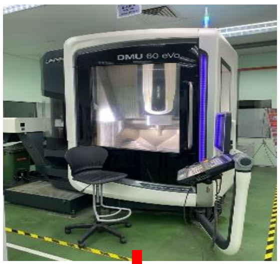
<table>
<tr>
<td>6.</td>
<td>

</td>
<td>CNC Milling Machining –The next step is to dry run the program as to check the machining program is properly created at the machine controller. After satisfied with the dry run, run the program with extra caution until the program have no error. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.

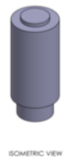
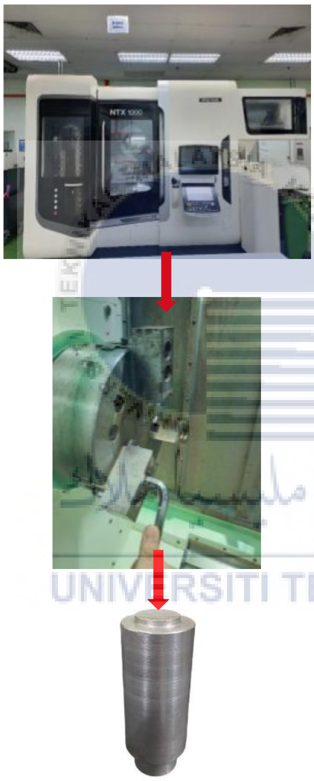
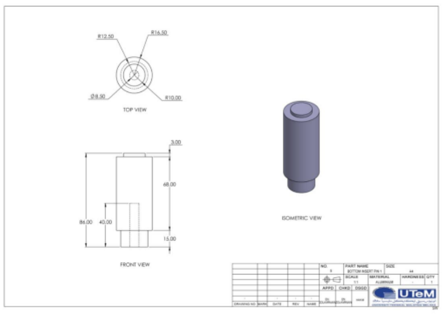
Make sure change the cutting tools first based on the slot in the programmed. After that, start the machine and monitor the entire process to get the finish product. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.</td>
</tr>
<tr>
<td>7.</td>
<td>

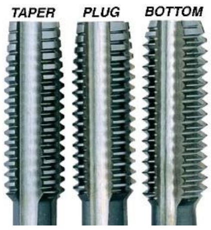
</td>
<td>CNC Turning - Load or install tools in the tool carousel as listed in the CNC program tool list. Mount or fix the work-piece at the vice. Place the work-piece or part to be machined firmly to the vice. In this machine, it use jaw for round part. Manually adjust the jaw so that the indicator on jaw is in the box. It is required as for it to grip effectively. The installed jaw were called hard jaw. Clamp the workpieces properly tight. It must do properly to avoid any incident.

Machining program can also be created from the machine as it also contain variety of different program including turning, milling, hole drilling and threading. Manual program assist by Assistant Engineer of this lab in CNC Turning control due to the simple operation involved. This process purpose remove the clamping purpose leaved.</td>
</tr>
</table>

3.7.4 Bottom Insert Pin 1

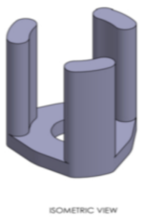
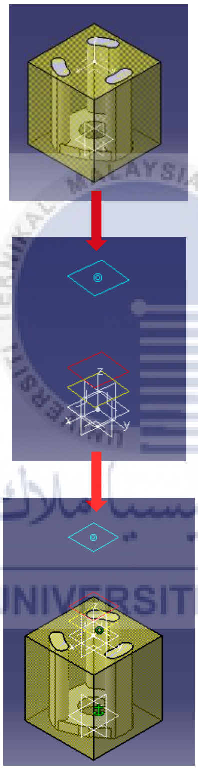
Table 5 : Procedure of Bottom Insert Pin 1

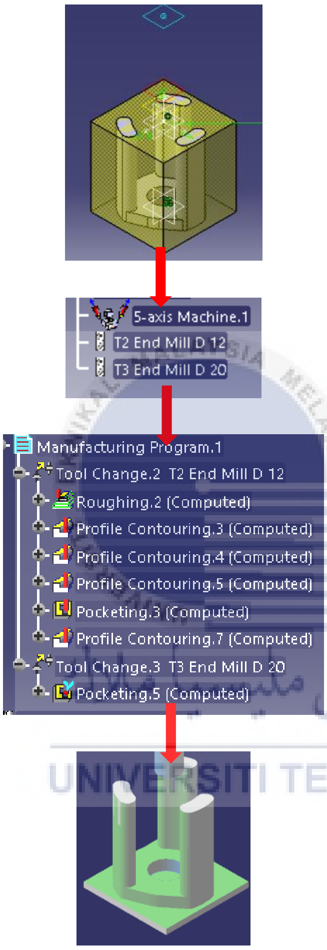
No	Photo	Description
1.		CAD – Design the mold according to the bottom hole of propeller hub blade produced in CATIA V5
2.		**CNC Turning -** Load or install tools in the tool carousel as listed in the CNC program tool list. Mount or fix the work-piece at the vice. Place the work-piece or part to be machined firmly to the vice. In this machine, it use jaw for round part. Manually adjust the jaw so that the indicator on jaw is in the box. It is required as for it to grip effectively. The installed jaw were called hard jaw. Clamp the workpieces properly tight. It must do properly to avoid any incident.  Machining program can also be created from the machine as it also contain variety of different program including turning, milling, hole drilling and threading. Manual program assist by Assistant Engineer of this lab in CNC Turning control due to the simple operation involved. 

3.		**Hand Tapping For M10 –** Use the correct cutting oil on the tap when cutting threads.Turn the tap clockwise one-quarter to one-half turn, then turn back three-quarters of a turn to break the chip. Do this with a steady motion to avoid breaking the tap. Remove the chips from the hole before using the bottoming tap. Use the tapper step by step from tapper to the bottom tool. 

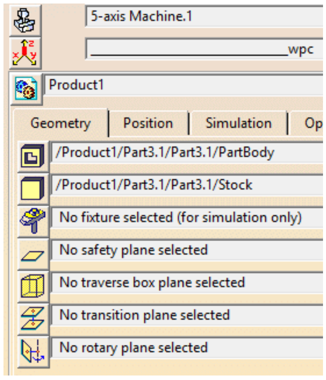
3.7.5 Bottom Insert Pin 2

Table 6 : Procedure of Bottom Insert Pin 2

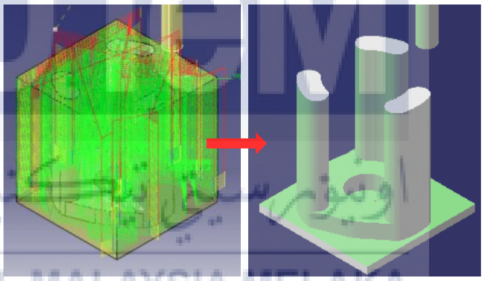
No	Photo	Description
1.		**CAD** – Design the insert according to the propeller hub blade hole at bottom side produced in CATIA V5. This insert pin located into bottom insert.
2.		**Assembly part and plane system** - Definition is any machining process strategy and planning with the aid of computer software. Before start the machining, open the product file and assemble all required part, constraint the part axis with plane axis.
3.		**CAM** - Definition is any machining process strategy and planning with the aid of computer software. Then, click on "Start" – "Machining" and choose which machining required to enter CAM interface and start CAM process. Then, click on "Start" – "Machining" and choose which machining required to enter CAM interface and start CAM process. After opening the Machine Editor tab, on the top of the window, there were six choices of the machine that can be selected. The choices given were 3-Axis Machine, 3-Axis with Rotary Table Machine, 5-Axis Machine, Horizontal Lathe Machine, Vertical Lathe Machine Deprecated and Multi-slide Lathe Machine.



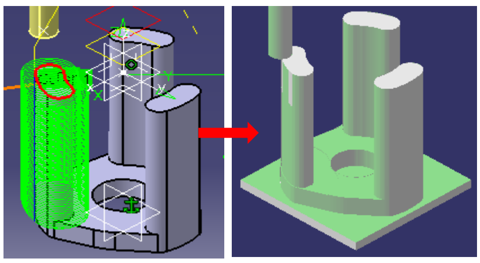
In this machining operation, the machine that need to be selected was the 5-Axis Machine. Then select the referance machining axis system.

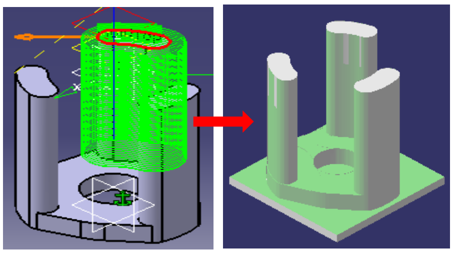
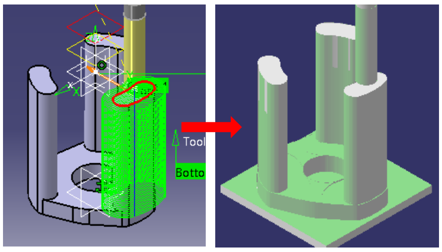
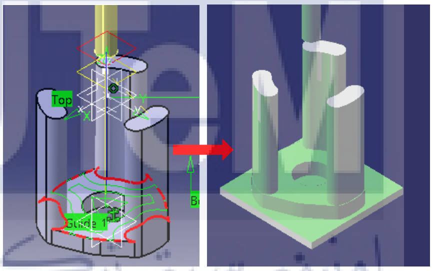
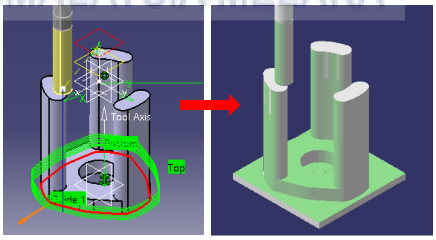
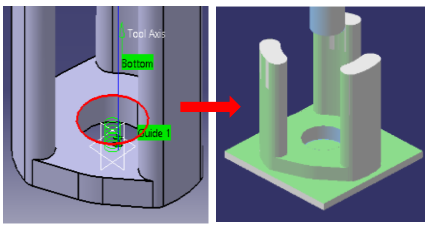


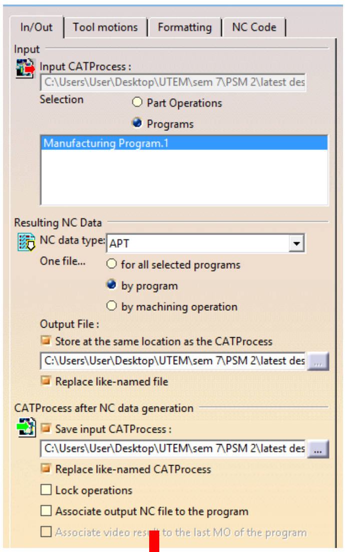
Select the part and select the stock that yellow colour. After that, click "Auxiliary Operation" then click to select the cutting tool according to the shape of the mold. For "Roughing Process", "Profile Contouring" and "Pocketing 1" End mill D12 are selected and End mil D20 for "Pocketing 2". After finish selected the tool continue to do "Roughing Process".

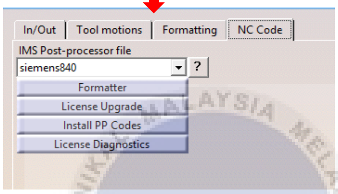


Profile countouring 1



		Profile countouring 2  Profile countouring 3  Pocketing  Profile countouring 4  Pocketing 2 

<table>
<tr>
<td>4.</td>
<td>


</td>
<td>Generate NC Code – In this process that only can do after the whole machining operation are created properly. Generate the NC code applicable to the Siemens controller according to the CNC machine controller.

The header of the NC code;

<code>N1 G54 G40 G90 G17 G94
N2 G54
N3 T2 M6; endmill 12
N4 G0 Y-49.01 S8000 M3
N5 Z8.5
N6 G1 Z-1.5 F1250.
N7 Y-40.
N8 X-18.8 F1500.
N9 X-18.529 Y-39.959
N10 X-18.061 Y-39.868
N11 X-17.018 Y-39.623
N12 X-16.588 Y-39.504
N13 X-15.877 Y-39.28
N14 X-15.525 Y-39.157</code>

The end of the NC code;

<code>N79569 X2.998 Y-.121
N79570 X2.978 Y.362
N79571 X2.882 Y.835
N79572 X2.71 Y1.286
N79573 X2.469 Y1.704
N79574 X2.164 Y2.078
N79575 X1.802 Y2.398
N79576 X1.394 Y2.656
N79577 X.95 Y2.846
N79578 X.481 Y2.961
N79579 X0 Y3.
N79580 Z15. F5000.
N79581 M30
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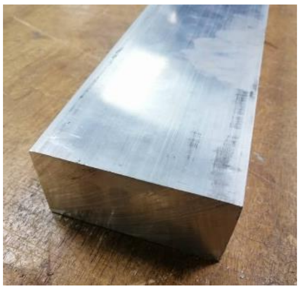
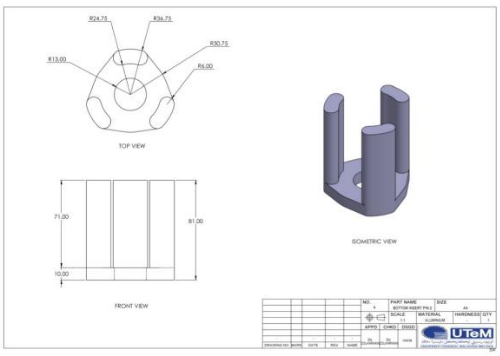
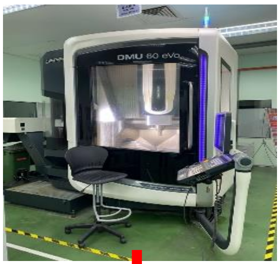
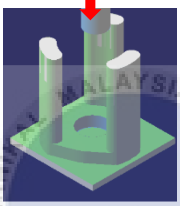
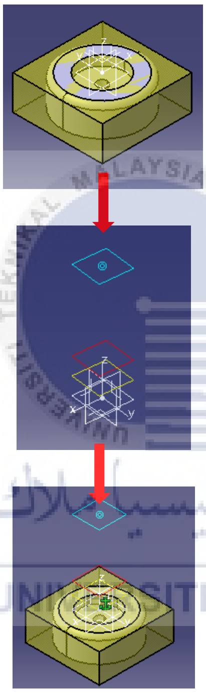
</tr>
<tr>
<td>5.</td>
<td>
</td>
<td>Milling Machine - This process can perform when successfully accept the raw material from suppliers. Cut raw material before doing next process. By using milling machine produced squaring for part of the mold to prepare stock for CNC machining. The stock must follow the drawing design requirement.

</td>
</tr>
</table>

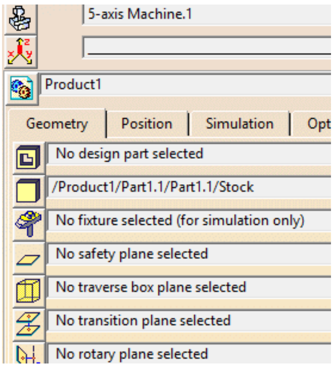
6.	  	**CNC Milling Machining** –The next step is to dry run the program as to check the machining program is properly created at the machine controller. After satisfied with the dry run, run the program with extra caution until the program have no error. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.  Make sure change the cutting tools first based on the slot in the programmed. After that, start the machine and monitor the entire process to get the finish product. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.
7.	  	**CNC Turning** – Load or install tools in the tool carousel as listed in the CNC program tool list. Mount or fix the work-piece at the vice. Place the work-piece or part to be machined firmly to the vice. In this machine, it use jaw for round part. Manually adjust the jaw so that the indicator on jaw is in the box. It is required as for it to grip effectively. The installed jaw were called hard jaw. Clamp the workpieces properly tight. It must do properly to avoid any incident.  Machining program can also be created from the machine as it also contain variety of different program including turning, milling, hole drilling and threading. Manual program assist by Assistant Engineer of this lab in CNC Turning control due to the simple operation involved. This process purpose remove the clamping purpose leaved.

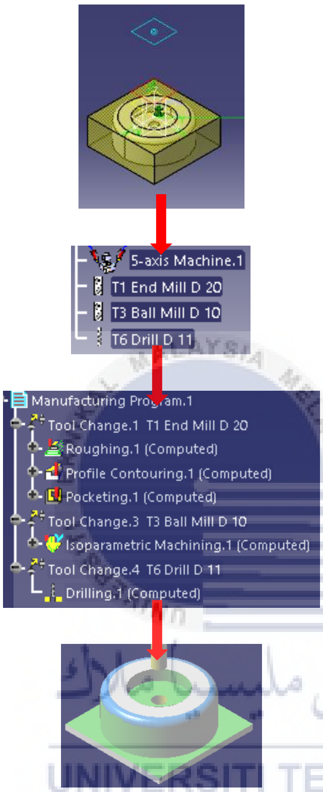
3.7.6 Top Insert

Table 7 : Procedure of Top Insert

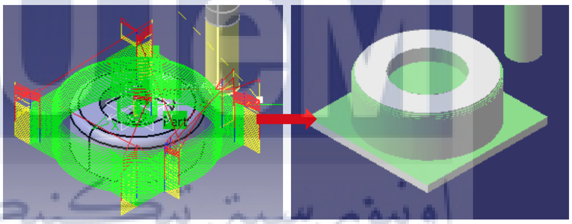
No	Photo	Description
1.		**CAD** – Design this top insert part for function located the top insert pin in CATIA V5. The design need high precision because this part need to assembly with the insert pin and both side mold. The clearance are provide for critical area of assembly at their dimension.
2.		**Assembly part and plane system** - Definition is any machining process strategy and planning with the aid of computer software. Before start the machining, open the product file and assemble all required part, constraint the part axis with plane axis.
3.		**CAM** - Definition is any machining process strategy and planning with the aid of computer software. Then, click on "Start" – "Machining" and choose which machining required to enter CAM interface and start CAM process. Then, click on "Start" – "Machining" and choose which machining required to enter CAM interface and start CAM process. After opening the Machine Editor tab, on the top of the window, there were six choices of the machine that can be selected. The choices given were 3-Axis Machine, 3-Axis with Rotary Table Machine, 5-Axis Machine, Horizontal Lathe Machine, Vertical Lathe Machine Deprecated and Multi-slide Lathe Machine. In this machining operation, the machine that need to

be selected was the 5-Axis Machine. Then select the referance machining axis system.

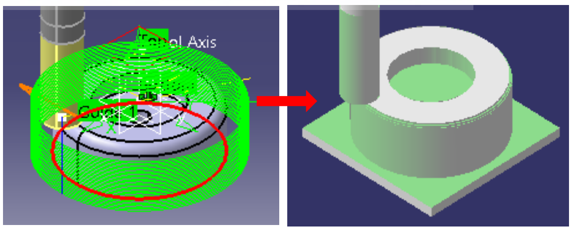




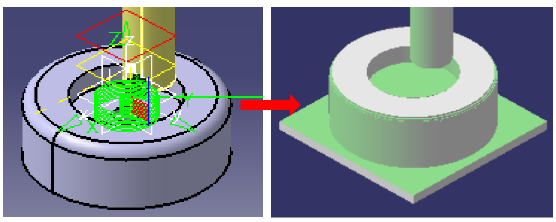
Select the part and select the stock that yellow colour. After that, click "Auxiliary Operation" then click to select the cutting tool according to the shape of the mold. For "Roughing Process" an "Profile Contouring" and "Pocketing". "Isoparametric Machining" Ball mill D10 are selected and lastly Drill D11 cutting tool for "Drilling". After finish selected the tool, continue to do "Roughing Process";

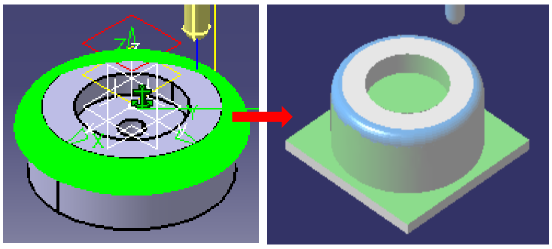
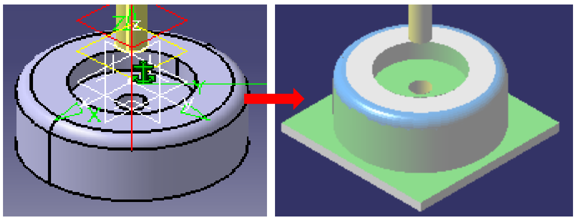
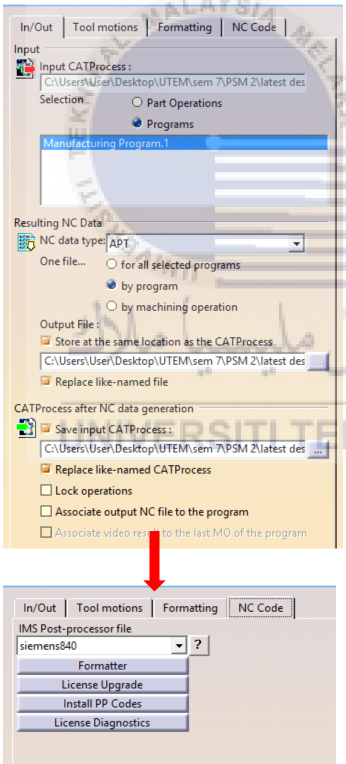


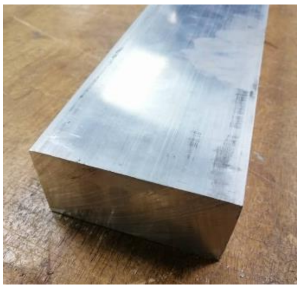
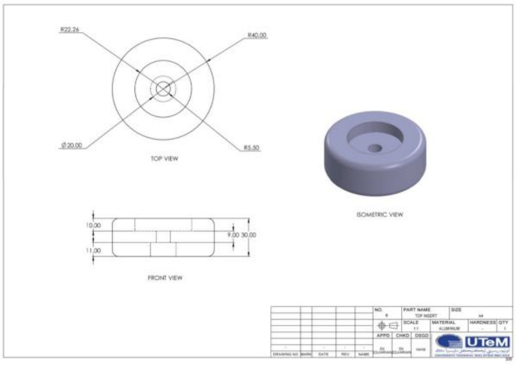
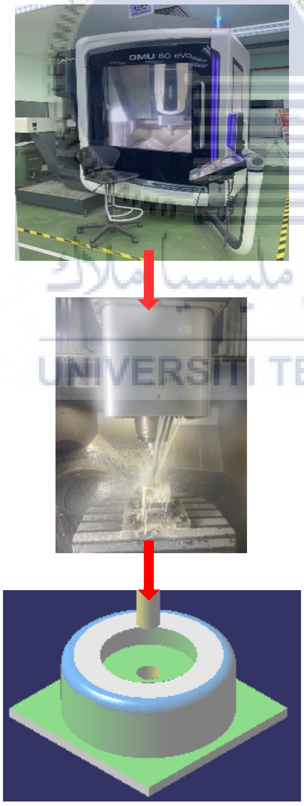
Profile Contouring



Pocketing



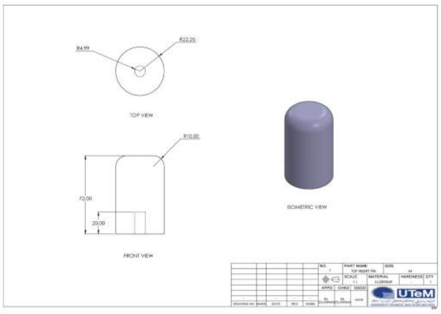
		Isoparametric Machining  Drilling 
4.		**Generate NC Code** – In this process that only can do after the whole machining operation are created properly. Generate the NC code applicable to the Siemens controller according to the CNC machine controller. The header of the NC code; N1 G54 G40 G90 G17 G94 N2 G54 N3 T1 M6 ; endmill 20 N4 G0 X-44.997 Y58.01 S6000 M3 N5 Z9. N6 G1 Z-1. F1250. N7 Y45. N8 X-18.782 F1500. N9 X-19.903 Y44.524 N10 X-21.554 Y43.748 N11 X-23.177 Y42.911 N12 X-24.771 Y42.01 N13 X-26.318 Y41.059 N14 X-27.837 Y40.045 The end of the NC code; N45565 G54 N45566 T6 M6; drill 11 N45567 G0 X0 S1000 M3 N45568 Z100. N45569 Z30. N45570 Z15. N45571 Z0 N45572 Z-9. N45573 Z-10. N45574 CYCLE81 (-10. , -10. , 0 , -33.175) N45575 Z0 N45576 Z15. N45577 M30 %

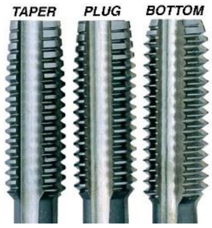
5.	 	**Milling Machine** - This process can perform when successfully accept the raw material from suppliers. Cut raw material before doing next process. By using milling machine produced squaring for part of the mold to prepare stock for CNC machining. The stock must follow the drawing design requirement. 
6.	 	**CNC Milling Machining** –The next step is to dry run the program as to check the machining program is properly created at the machine controller. After satisfied with the dry run, run the program with extra caution until the program have no error. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.  Make sure change the cutting tools first based on the slot in the programmed. After that, start the machine and monitor the entire process to get the finish product. Always observe the machining process to avoid any collisions, machine vibration or incident. Control manually the dial for percentage of feed-rate and rapid positioning applied.

7.	  	**CNC Turning -** Load or install tools in the tool carousel as listed in the CNC program tool list. Mount or fix the work-piece at the vice. Place the work-piece or part to be machined firmly to the vice. In this machine, it use jaw for round part. Manually adjust the jaw so that the indicator on jaw is in the box. It is required as for it to grip effectively. The installed jaw were called hard jaw. Clamp the workpieces properly tight. It must do properly to avoid any incident.  Machining program can also be created from the machine as it also contain variety of different program including turning, milling, hole drilling and threading. Manual program assist by Assistant Engineer of this lab in CNC Turning control due to the simple operation involved. This process purpose remove the clamping purpose leaved.

3.7.7 Top Insert Pin

Table 8 : Procedure of Top Insert Pin

No	Photo	Description
1.		CAD – Design the insert according to the top hole propeller hub blade produced in CATIA V5.
2.		**CNC Turning -** Load or install tools in the tool carousel as listed in the CNC program tool list. Mount or fix the work-piece at the vice. Place the work-piece or part to be machined firmly to the vice. In this machine, it use jaw for round part. Manually adjust the jaw so that the indicator on jaw is in the box. It is required as for it to grip effectively. The installed jaw were called hard jaw. Clamp the workpieces properly tight. It must do properly to avoid any incident.  Machining program can also be created from the machine as it also contain variety of different program including turning, milling, hole drilling and threading. Manual program assist by Assistant Engineer of this lab in CNC Turning control due to the simple operation involved. This process purpose remove the clamping purpose leaved. 

3.		**Hand Tapping For M10 –** Use the correct cutting oil on the tap when cutting threads.Turn the tap clockwise one-quarter to one-half turn, then turn back three-quarters of a turn to break the chip. Do this with a steady motion to avoid breaking the tap. Remove the chips from the hole before using the bottoming tap. Use the tapper step by step from tapper to the bottom tool. 

3.8 Machining Strategies for Main Part

Propeller processing usually is required roughing, semi-finishing and finishing. When generating tool paths for the five-axis machining, one should consider accuracy, machining time, and interference between the workpiece and the moving part of the machine. Deciding effective tool orientation while avoiding interference is crucial for five-axis machining of propellers. However, due to the complex shape of propellers hub blade, it may be time-consuming for computing an efficient tool path with a general purposed CAD/CAM system. If the five-axis machining of propeller hub blade is performed using a dedicated CAD/CAM system, the time for modelling and manufacturing a propeller can be reduced significantly. This is because the subsequent processes such as tool selection, tool path generation, and machining simulation can be efficiently carried out on the same system. In this simplification method, “Isoparametric” for male mold and “Sweeping” command for female mold selected to be the main machining strategies that can help into simplifying the machining programming and can continue to measured surface roughness of both strategy.

3.8.1 Tool Selection

Tool selection was selected based on the accessibility of the tool to all regions of the surface propeller hub blade mold. After finish setup part operation, it selected the tools would be used according the dimension of CAD part of propeller hub blade mold. The selected cutting tools and operation involved on project shown in Table 1.

Table 9 : Detail Dimension of Selected Cutting Tool

Male Mold		
Tool	Dimension	Operation involved
End Mill 10mm(ø)	db = 10mm D = 10mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing
Ball Mill 10mm(ø)	db = 10mm D = 10mm Rc = 5mm Lc = 50mm L = 100mm l = 60mm	Isoparametric
Female Mold		
End Mill 10mm(ø)	db = 10mm D = 10mm Rc = 0mm Lc = 50mm L = 100mm l = 60mm	Roughing
Ball Mill 10mm(ø)	db = 10mm D = 10mm Rc = 5mm Lc = 50mm L = 100mm l = 60mm	Multi-axis Sweeping

db = body diameter, D = Nominal diameter, Rc = Corner radius, Lc = Cutting length, L = Overall length, I = Length

3.8.2 Sweeping Strategy (Female Mold)

Sweeping strategies were used for the machining study in CAM software. Prior to the experimental design for finishing part, a rough machining operation with standard parameters was applied get the finishing surface. Sweeping strategies were adopted to finishing processes. Sweeping is a semi-finishing and finishing operation that is used after a part has been rough machine. and that machines the whole part. The tool paths are executed in vertical parallel planes. The first setting was the tool path style or cutting direction style. In this option, we were given two choices, zig zag and one way cut. Zig zag strategy was chosen for this option.

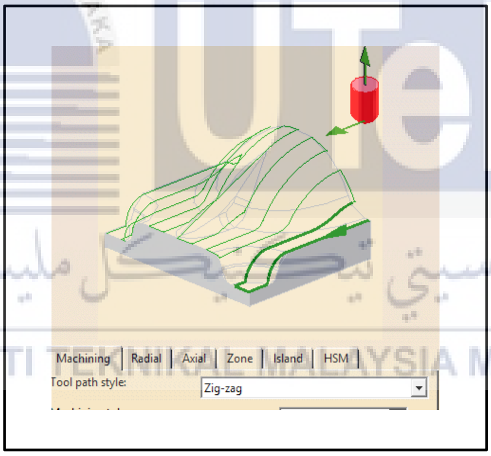


Figure 3.5 : Tool path style selected

The second setting was the most important setting that control the number of tool path that going to be produced. The option used for this command was scallop height and the Figure 3.4 set was 0.01 mm. The value set was the smallest and the finest allowable value. The final setting that needs to be done was the setting on the tool position.

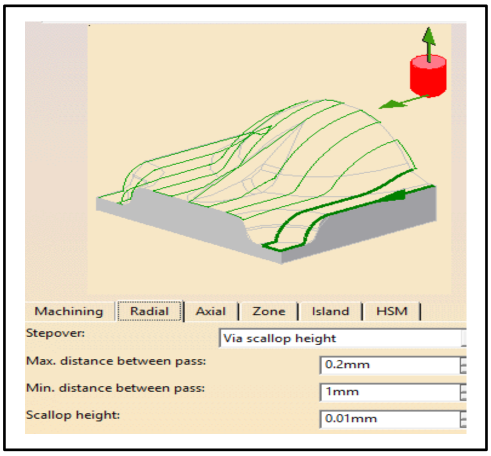


Figure 3.6 : Scallop Height Setting

Sweeping methods can generate high quality hexahedral meshes for swept volumes. The procedure used in most sweeping methods first classifies the surfaces of the input swept volume into source surfaces, target surfaces and linking surfaces, where the source and target surfaces are called cap surfaces. Then, the source surface is meshed with a quadrilateral mesh and the linking surfaces are meshed with structured quadrilateral meshes.. Finally, the swept is generated in a layer-by-layer style along the sweep direction. According to the number of source surfaces and target surfaces, sweeping operation can be classified into the most easiest, which are all suitable for generating sweeping operation, and many mature methods have been proposed by now. Figure 3.5 show the tool path of this sweeping strategy.

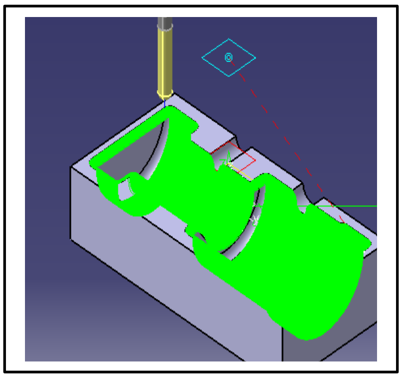


Figure 3.7 : Tool path movement

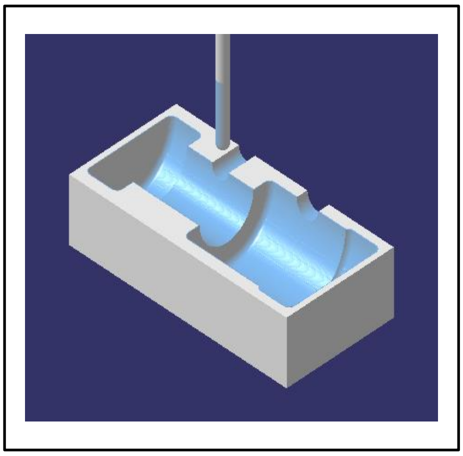


Figure 3.8 : Result CAM simulation of Sweeping command

3.8.3 Isoparametric Strategy (Male Mold)

Isoparametric machining command was capable to give both three and five axis tool path movement. It was definitely depending on how the program created or customized. For this research, there were three major settings that been set to ensure the five-axis shape program can be cut using three-axis program. All settings took place in the first page of the "Isoparametric" interface windows or namely cutting strategy window. The first setting was the tool path style or cutting direction style. In this option, we were given two choices, zig zag and one way cut. Zig zag strategy was chosen for this option. The main reason one way cutting selected was to avoid high vibration and chattering during actual cutting.

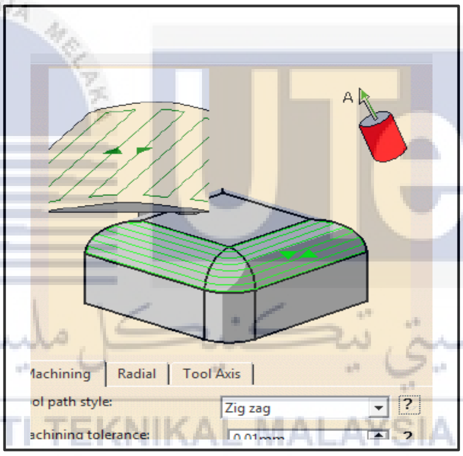


Figure 3.9 : Tool path style selected

The second setting was the most important setting that control the number of tool path that going to be produced. The option used for this command was scallop height and the Figure 3.4 the value set 0.01 mm. The value set was the smallest and the finest allowable value. The final setting that needs to be done was the setting on the tool position.

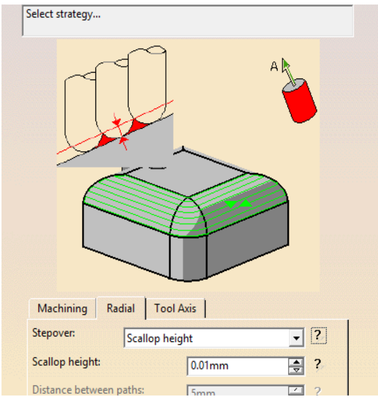


Figure 3.10 : Scallop Height Setting

This command usually used to solve the shapes of chamfering, fillet radius and complex contouring. The main rule that has been set in order to perform this process was by using ball nose tools. The movement generated from this command is zig zag direction, this shown in Figure 3.5. That was the reason why we need to use the ball mill tool to avoid any high force cutting at the approach level of machining which can caused high chattering and the worst case broken the cutting tool.

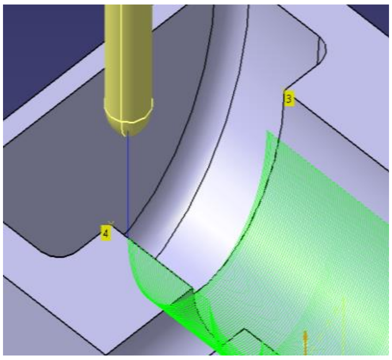


Figure 3.11 : Tool path movement

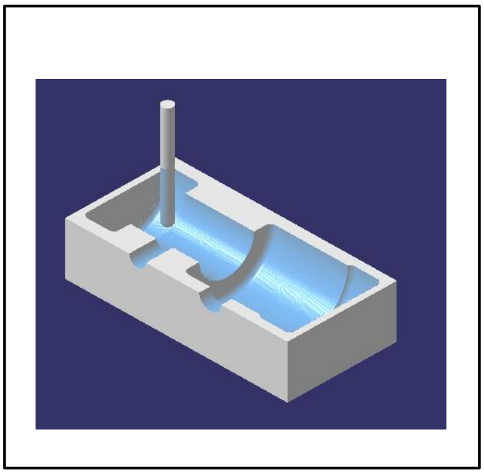


Figure 3.12 : Result CAM simulation of Isoparametric command

Table 10 : Machining parameter of Sweeping and Isoparametric

Strategy / Parameter	Sweeping	Isoparametric
Machine feed rate (mm/min)	1800	1800
Spindle speed (rpm)	10000	10000
Cutting tool	Ball mill D10	Ball mill D10
Total time (min)	57.71	16.67
Machining time (min)	57.57	16.51
Machining tolarance (mm)	0.01	0.01
Retract feed rate (mm/min)	5000	5000
Approach feed rate (mm/min)	1500	1500
Tool path style	Zig zag	Zig zag
Stepover mode	Via scallop height	scallop height
Max. Distance between path (mm)	0.01	0.01

3.8.4 Machining Parameter

The three important machining parameters involved are cutting speed, feed rate, and depth of cut, which affected the surface roughness of machined surface. There are all set by the same value that are the most suitable parameter for this strategies to avoid tool wear, vibration and others. Beside that, machining tolarance also give more impact to the result of surfac roughness the less value of machining tolarance, the less result of surface roughness will produce. Machining tolarance are set 0.01mm for both strateies. Furthermore, Choosing the wrong cutting tool for the process may often result in poor quality material finishes. This could be seen as rough edges, cutter marks on the surface, raised marks, or burn marks on the material's edges or corners. Extensive tool wear may result from this error and for this strategies Ball mill D10 was choosing for the better result.

3.9 Surface Roughness

3.9.1 Surface Roughness Tester

The surface roughness will be evaluate using Surface Roughness Tester, Mitutoyo SJ-400 as in Figure 3.11 below. It uses stylus of 90 degree diamond material tip. The machined work-piece will be placed on top of the testing table and the stylus will run through the surface as in Figure 3.12, detecting the changes of roughness on the surface.

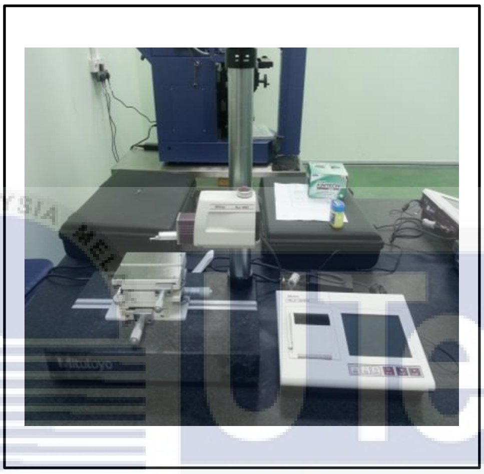


Figure 3.13 : Mitutoyo SJ-400 surface roughness tester

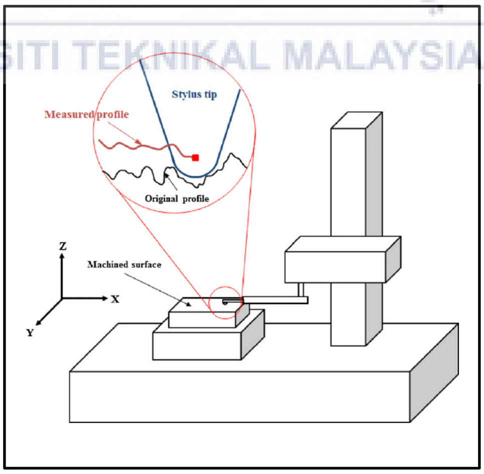


Figure 3.14 : Stylus surface analysis

(Lee & Cho, 2012)

3.9.2 Surface Roughness Testing Preparation

The procedures 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 sample/part on the test table.

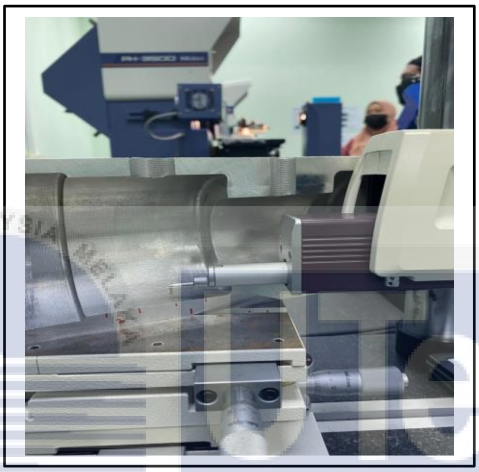


Figure 3.15 : Part on the test table

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the result of the study will be presented and discuss. The data of the results were taken from surface roughness testing and at figuring out whether the CATIA V5 software different machining strategy can reflect the surface roughness.

4.2 Results of Mold Fabrication

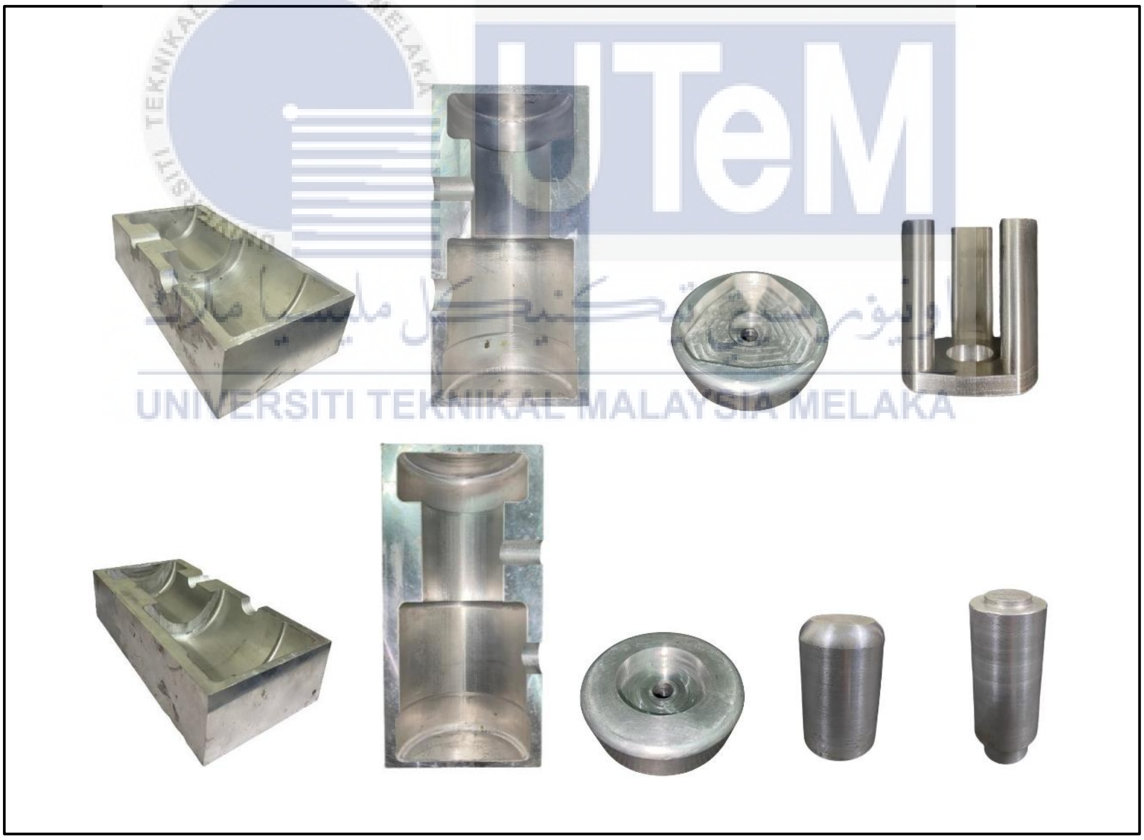
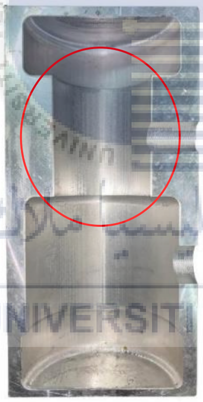
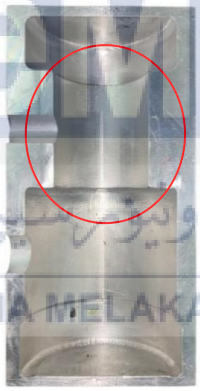


Figure 4.1: Result of mold fabrication

4.3 Surface Roughness

The surface roughness testing only done to two parts which is female mold and female mold. Both of the part finished inside diameter which was needed for surface roughness testing. These two parts perform different machining strategy but with same parameter. Each specimen will do ten surface roughness testing and the average will be calculated. The final result will then be compared based on result of the surface roughness.

Table 11 : Surface Roughness results table

Machining Strategy	
Sweeping	Isoparametric
Part Inspected Area	
Female mold	Male mold
	
Surface Roughness (µm)	
0.348	0.431
0.356	0.452
0.341	0.423
0.371	0.447
0.363	0.485
0.344	0.473
0.357	0.451
0.351	0.427
0.342	0.416
0.349	0.453
Average	
0.352	0.446

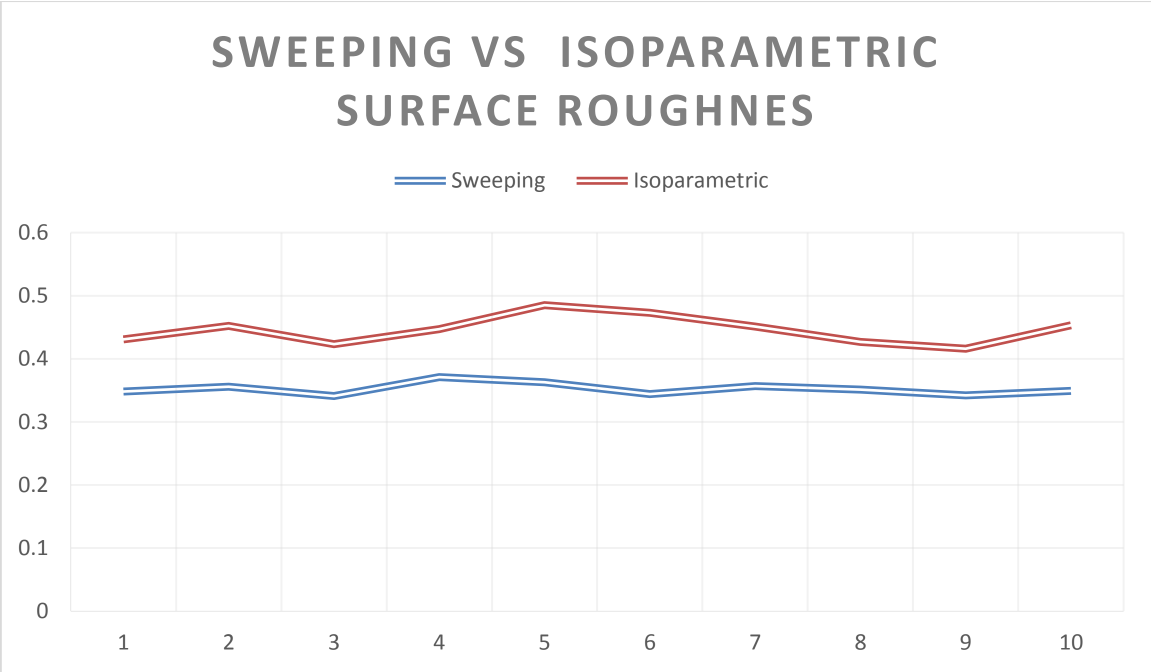


Figure 4.2 : Graph Sweeping Machining Vs Isoparametric

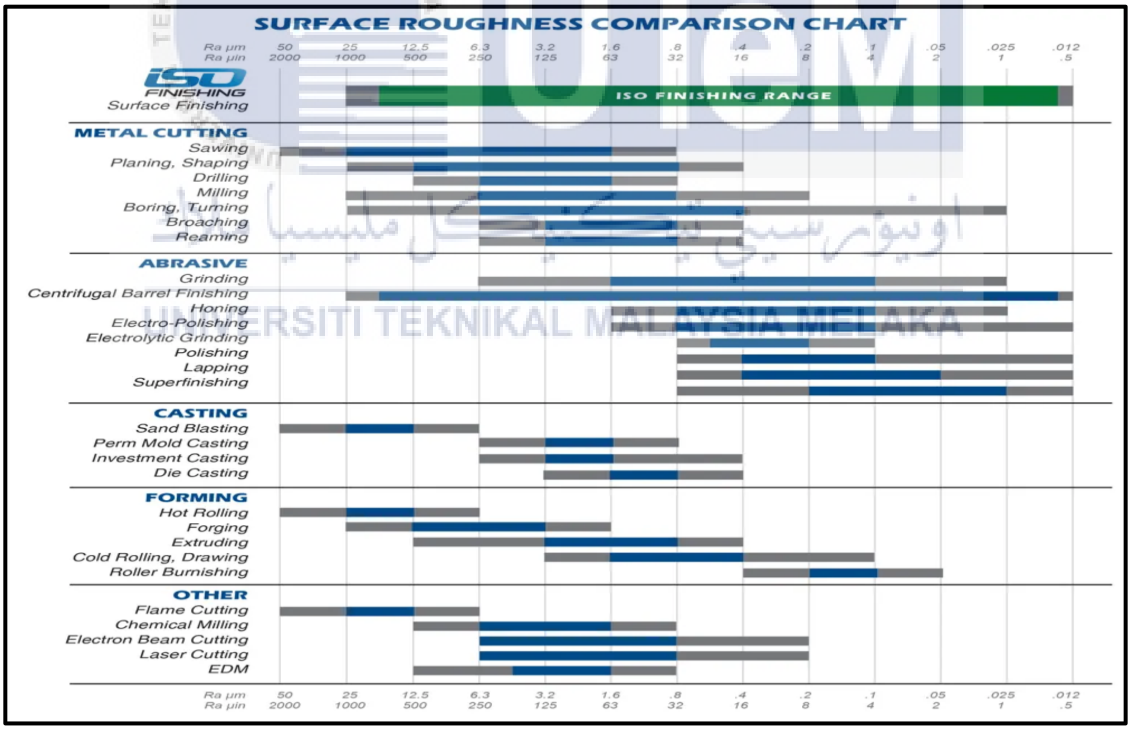


Figure 4.3 : Surface Finish Roughness Average (Ra) chart (Rodrigue, 2015)

Based on graph Figure 4.2 and Table 3 shown the result of the surface roughness of both mold with the different machining strategies. The average surface roughness, Ra were recorded and the result shows that the surface roughness value does not varies much using the same parameters. This shows that with the right value of parameter such as cutting speed, feed-rate and depth of cut, the surface roughness can be decreased. It happen to the sweeping machining strategies that surface roughness result much better using that parameter than the isoparametric machining strategy it is because the machining parameter need to combine with their machining properly and need more study to get the best surface roughness result. Even the different of surface roughness for both mold can be seen with the naked eyes.

The project surface roughness average value results were ranged from 0.3µm up to 0.4µm. This value is better than the value of Ra for investment casting and die casting. The investment casting Ra ranged from 0.4µm to even 6.3µm while the die casting was slightly better with Ra ranged from 0.4 up to 3.2µm. Refer Figure 4.3. Since the actual part will be produced using investment casting, it can be seen that increasing the certain parameters such as cutting speed and feed rate can be considered as long as the surface quality of investment casting lies within it prescribe range.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Introduction

This chapter is to conclude the project findings and results. Besides, a conclusion is done based on objective which is to fabricate propeller hub blade mold for investment casting and find the best surface roughness result through different strategy machining. It also have some recommendation for improvement.

5.2 Conclusion

The purpose of this paper is to fabricate, produce CAM and plan machining process of a propeller hub blade mold. The propeller hub blade mold for mold investment casting process were produced succesfully. By study Sweeping and Isoparametric machining strategies to optimize the marine boat hub blade propeller mold has been well using CNC high speed machining and CATIA V5 software. Then, the design has been reviewed and modified according to the CAM and machining requirement. The design suggested were complex design which too hard but still possible to machine. However, due to the availability of the tools and other factors, the design still need to be modified to fit the machining process planned. The tools that capable of doing the job is unavailable and need to be purchased but with high price.

As a result, the design had to be modified to allow the use of UTEM provided. The machining method or process planned was far from perfect and need more study and update. The machining processes in this experiment had to use two machine and manual machine program to get the best result in shorter time. Although the CAM was done based on machine and tools, it still need to be modified once the machining encounters problem. The CNC machine is really advance with its variety of function. The work also easier because the machine equipped with great sensor and positioning technology. The DMU 60 eVo by DMG MORI for example, can generate machining simulation done in the machine database which can be a great help in predicting error. However, this project experienced some problems while performing surface roughness testing. The curve produced on the mold make it difficult for the stylus detector to touch it due high depth of the curve. But, this problem have been solve and successfully prove that sweeping machining strategies is the best surface roughness in this project compare to isoparametric machining strategy.

5.3 Recommendation

The recommendation for this project is to create the special jig and fixture to open top and bottom insert of the mold. It facing difficulties to open that insert when the wax is apply to the mold. This problem that found after do testing the mold with pouring melted wax to the mold it shown in Figure 5.1 below. More study is required on CNC machine to produce the best design with less time consume machining processes. Hopefully, in the future, this paper can act as the reference for further study of this project.

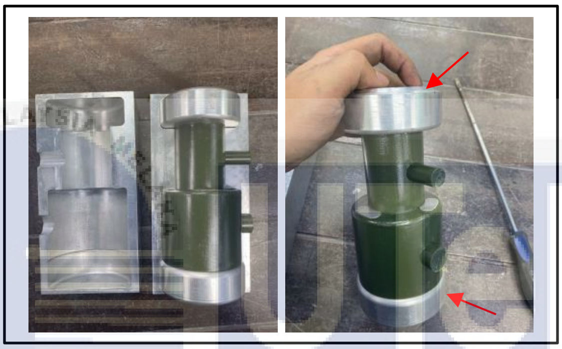


Figure 5.1: Wax pattern

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APPENDICES

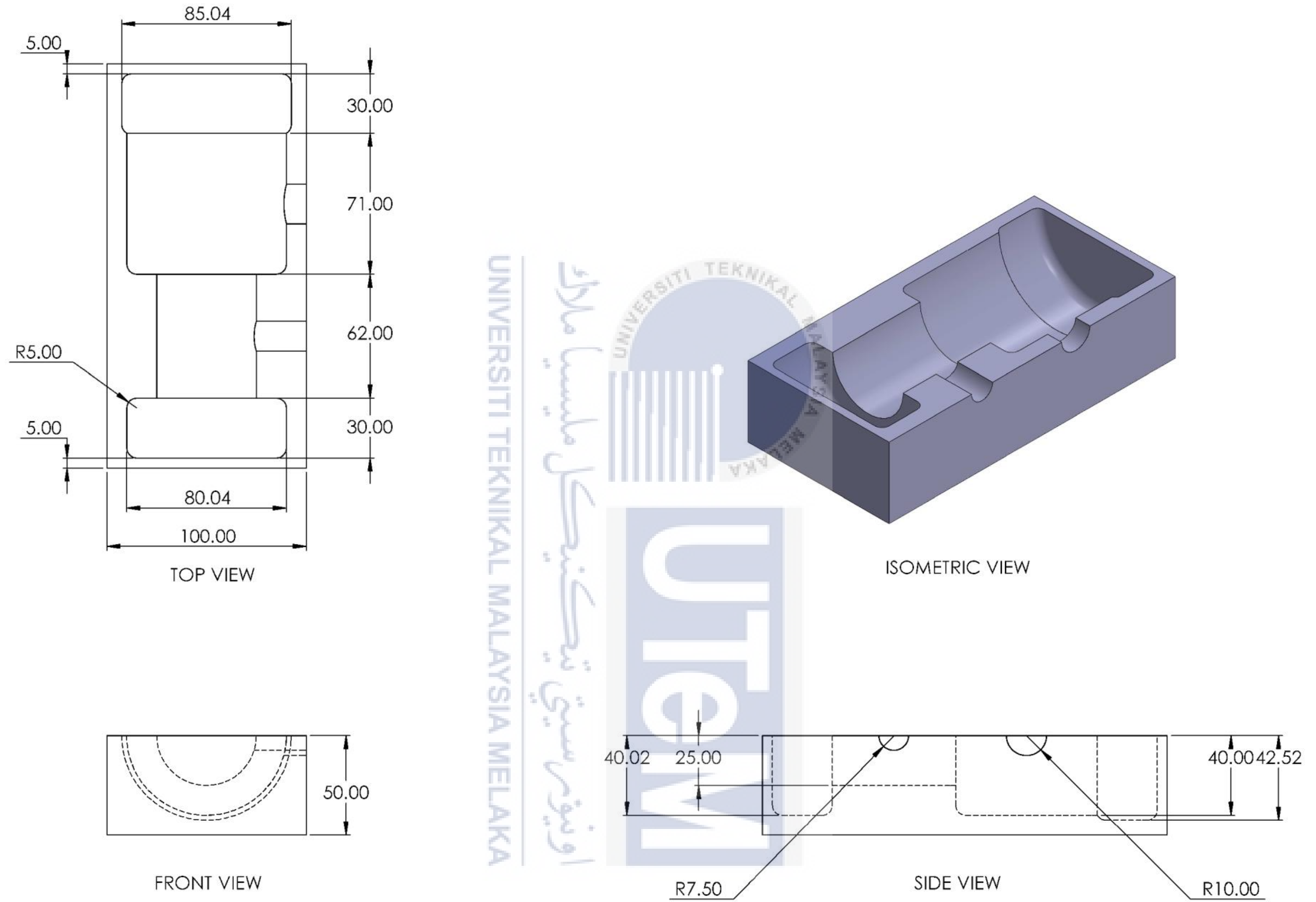
Appendix 1 : Gantt chart semester 2 2020/2021

Project Activity	Weeks														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	15/3-19/3	22/3-26/3	29/3-2/4	5/4-9/4	12/4-16/4	19/4-23/4	26/4-30/4	3/5-7/5	17/5-21/5	24/5-28/5	31/5-4/6	7/6-11/6	14/6-18/6	21/6-25/6	28/6-2/7
Choose and confirm project title															
Collecting data and information															
Problem statement and objectives															
Chapter 1 : Introduction															
Find and research article															
Chapter 2 : Literature Review															
Chapter 3 : Methodology															
Fill the log book															
Compile a report															
Submit a report to the supervisor and panel															
Presentation PSM 1															

Appendix 2 : Gantt chart semester 1 2021/2022

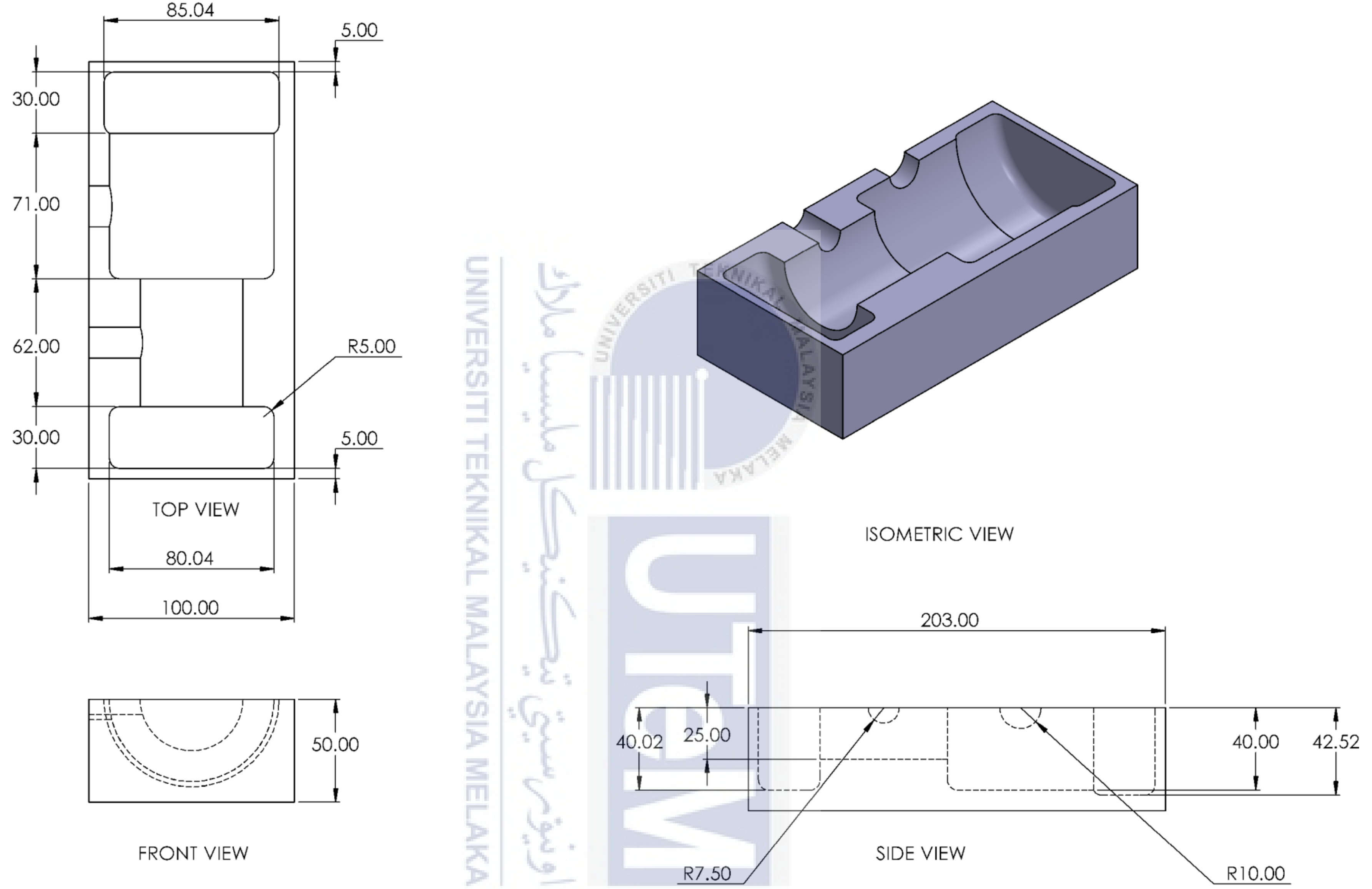
Project Activity	Weeks														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	11/10 - 15/10	18/10 - 22/10	25/10 - 29/10	1/11 - 5/11	8/11 - 12/11	15/11 - 19/11	22/11 - 26/11	29/11 - 3/12	6/12 - 10/12	13/12 - 17/12	20/12 - 24/12	27/12 - 31/12	3/1- 7/1	10/1- 14/1	17/1- 21/1
Fabricate the Mold															
Surface roughness testing															
Testing the mold (Pouring melted wax)															
Starting collecting data															
Chapter 4 : Result & Discussion															
Chapter 5 : Conclusion & Recommodation															
Compile all chapter															
Fill the log book															
Submit report															
Preparation slide															
Presentation PSM 2															

Appendix 3 : Detail Drawing



					NO. 1	PART NAME MALE MOLD		SIZE A4
						SCALE 1:2	MATERIAL ALUMINIUM	HARDNESS - / QTY 1
					APPD	CHKD	DSGD	
-	-	-	-	-	EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM	UTeM UNIVERSITI TEKNIKAL MALAYSIA MELAKA
DRAWING NO	MARK	DATE	REV	NAME				

SW



DRAWING NO	MARK	DATE	REV	NAME	APPD	CHKD	DSGD
-		-	-	-	EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM

NO.	PART NAME	SIZE		
2	FEMALE MOLD	A4		
	SCALE	MATERIAL	HARDNESS	QTY
	1:2	ALUMINIUM	-	1

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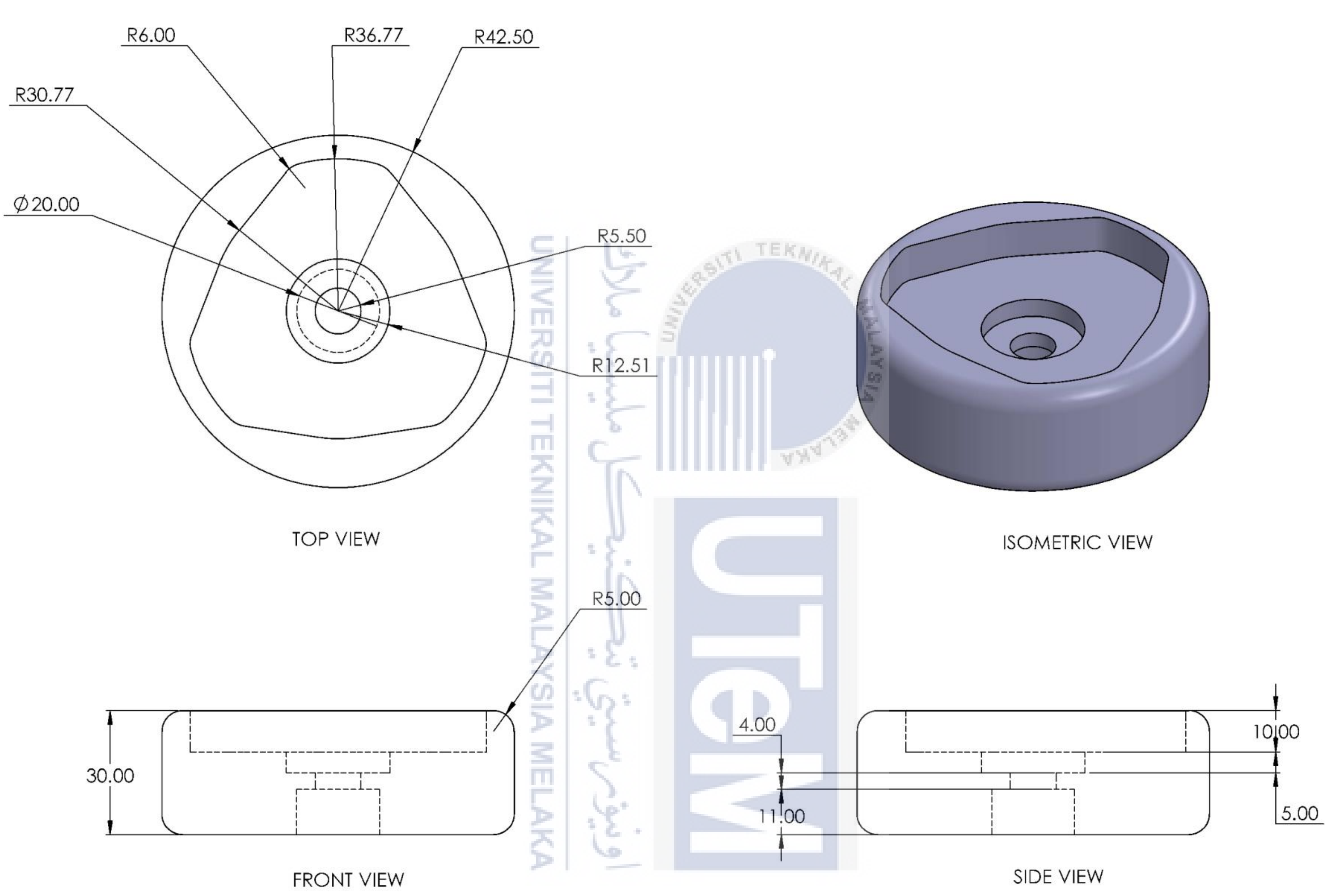
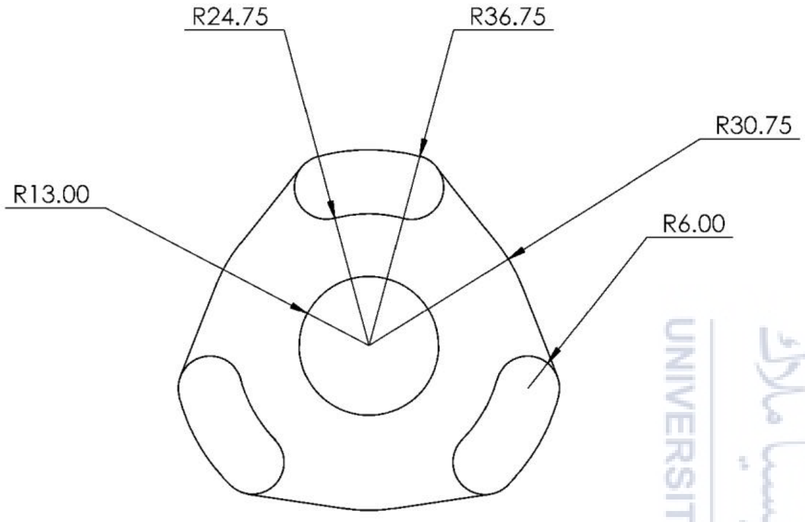
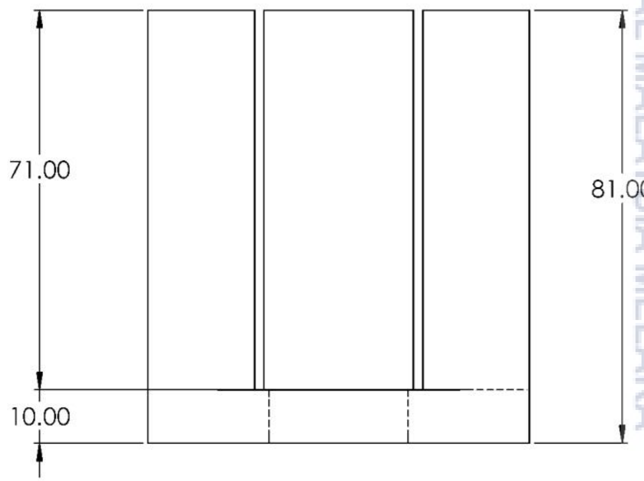


					NO. 3	PART NAME BOTTOM INSERT		SIZE A4	
						SCALE 1:1	MATERIAL ALUMINIUM	HARDNESS -	QTY 1
					APPD	CHKD	DSGD		
-		-	-	-	EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM	UTeM اونيۏرسيتي تيكنيكل مليسيا ملاك UNIVERSITI TEKNIKAL MALAYSIA MELAKA	
DRAWING NO	MARK	DATE	REV	NAME					

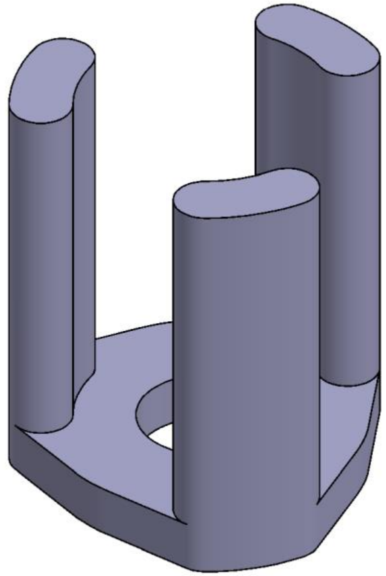
SW



TOP VIEW



FRONT VIEW



ISOMETRIC VIEW

NO.	PART NAME		SIZE	
4	BOTTOM INSERT PIN 2		A4	
	SCALE	MATERIAL	HARDNESS	QTY
	1:1	ALUMINIUM	-	1
APPD	CHKD	DSGD		
EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM		

DRAWING NO	MARK	DATE	REV	NAME
-		-	-	-

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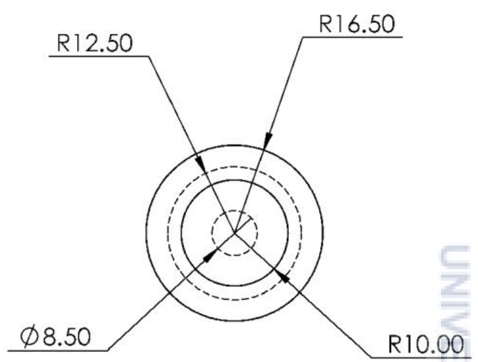
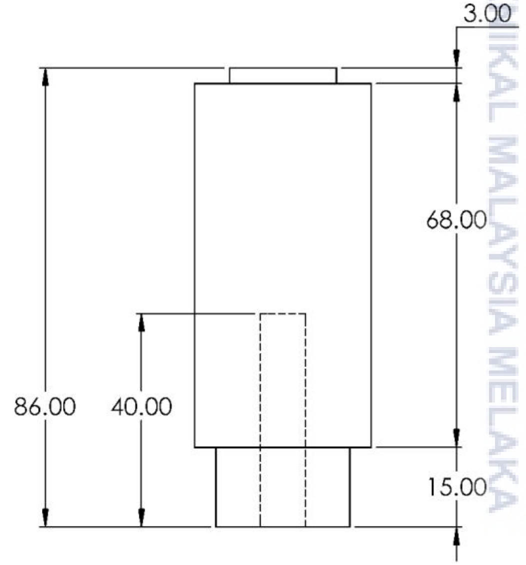
SW



TOP VIEW



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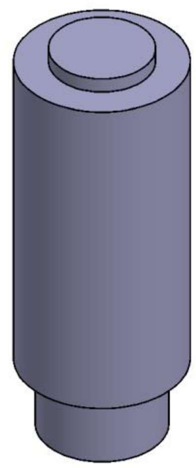

ISOMETRIC VIEW

NO.	PART NAME	SIZE		
5	BOTTOM INSERT PIN 1	A4		
	SCALE	MATERIAL	HARDNESS	QTY
	1:1	ALUMINIUM	-	1
APPD	CHKD	DSGD		
EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM		

DRAWING NO	MARK	DATE	REV	NAME
-		-	-	-

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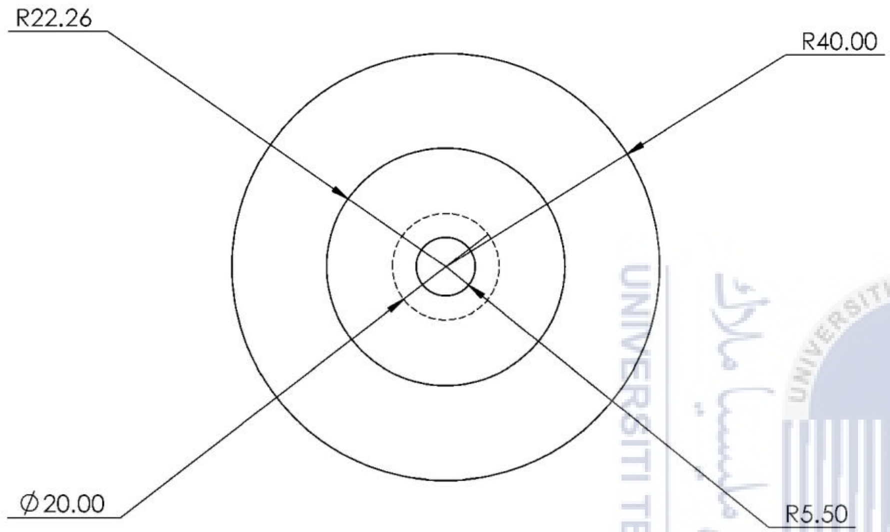
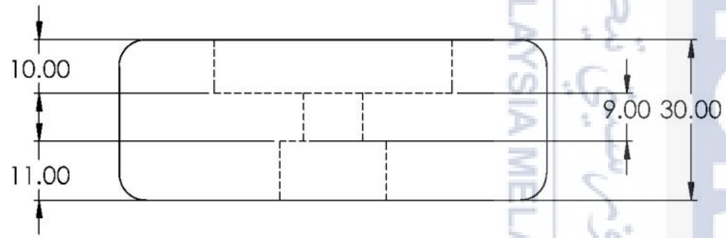


TOP VIEW



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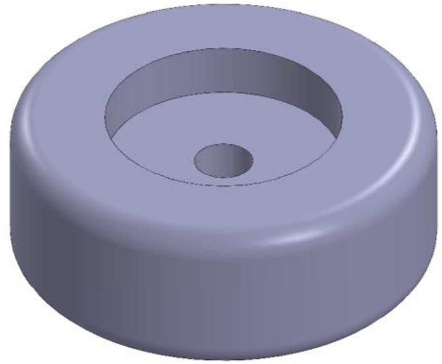
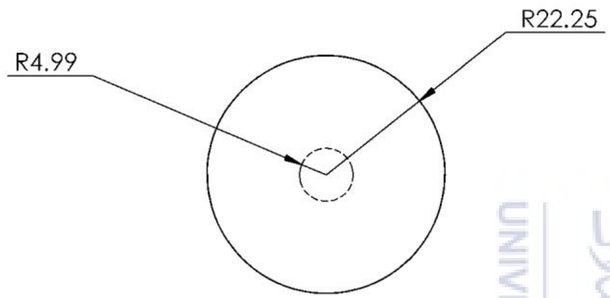
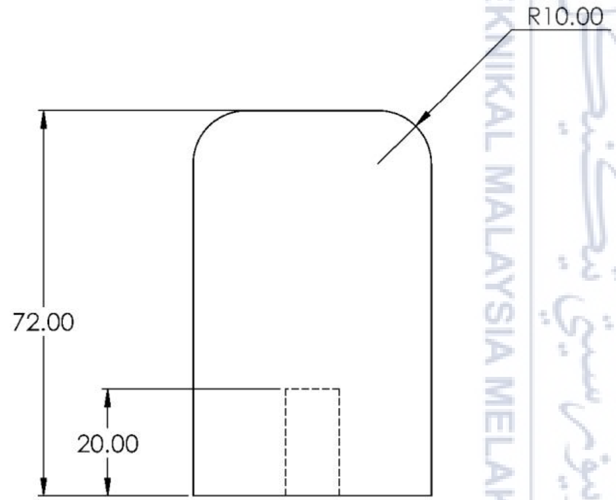


ISOMETRIC VIEW

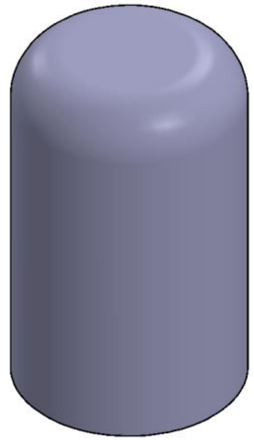
					NO.	PART NAME	SIZE	
					6	TOP INSERT	A4	
						SCALE	MATERIAL	HARDNESS	QTY
						1:1	ALUMINIUM	-	1
					APPD	CHKD	DSGD	
-		-	-	-	EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM	
DRAWING NO	MARK	DATE	REV	NAME				



TOP VIEW



FRONT VIEW

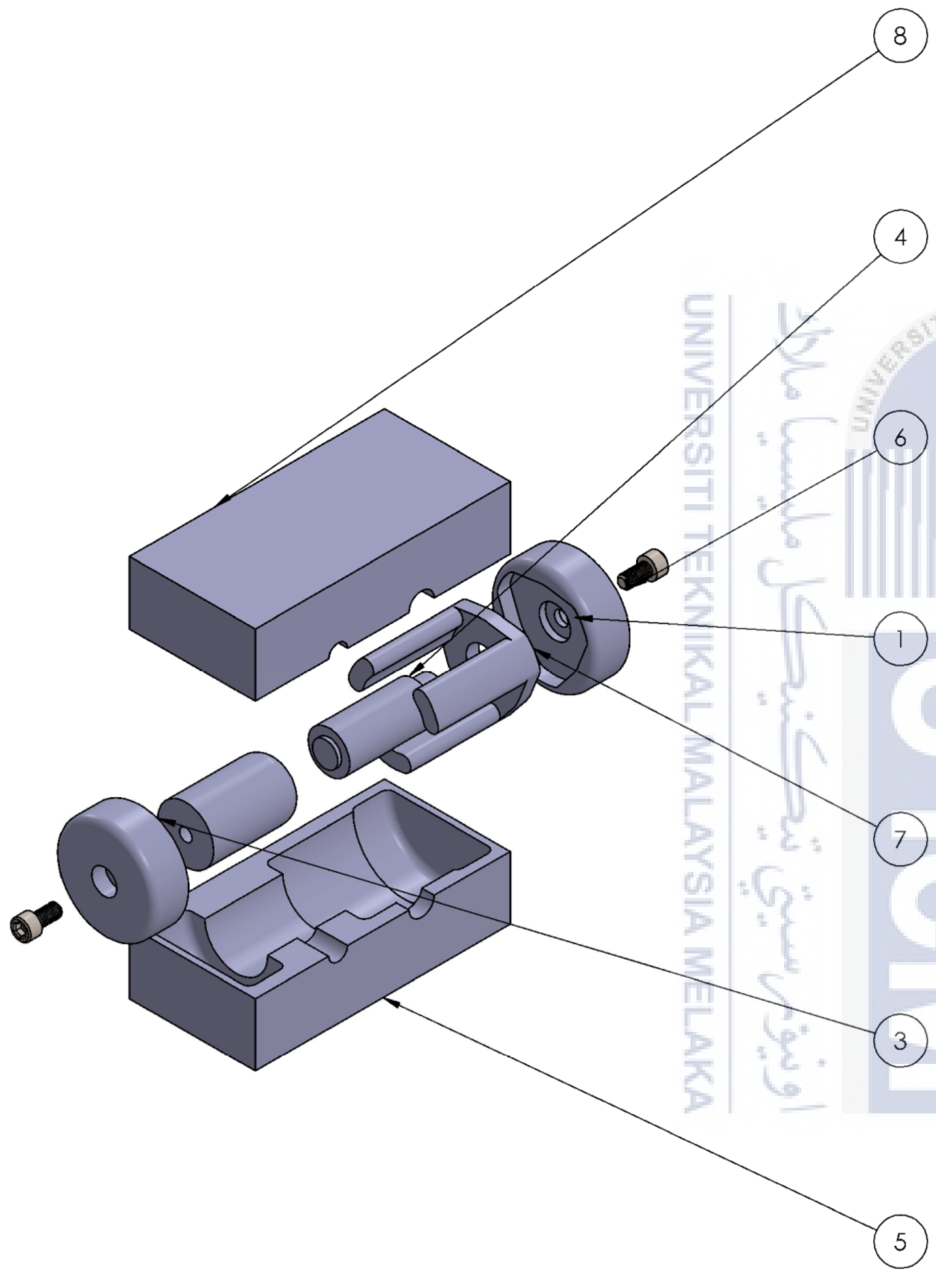


ISOMETRIC VIEW

					NO.		PART NAME		SIZE	
					7		TOP INSERT PIN		A4	
							SCALE	MATERIAL	HARDNESS	QTY
							1:1	ALUMINIUM	-	1
					APPD	CHKD	DSGD			
-		-	-	-	EN. ZOLKARNAIN	EN. ZOLKARNAIN	HAKIM	UTeM UNIVERSITI TEKNIKAL MALAYSIA MELAKA		
DRAWING NO	MARK	DATE	REV	NAME						

SW

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	bottom insert		1
2	top insert		1
3	top insert pin		1
4	bottom insert pin 1		1
5	male mold		1
6	M10x20		2
7	bottom insert pin 2		1
8	female mold		1



NO. 9		PART NAME BILL OF MATERIAL		SIZE A4			
		SCALE 1:3		MATERIAL ALUMINIUM		HARDNESS -	QTY 1
APPD	CHKD	DSGD					
EN. ZOLKARNAIN	EN. ZOLKARNAIN	AKIM					

DRAWING NO	MARK	DATE	REV	NAME
-		-	-	-

SW

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

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Tajuk Tesis: Design and Fabrication of Marine Boat Propeller Hub Mould for Investment Casting.

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
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Saya yang menjalankan amanah,

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Nama Pelajar : Mohammad Lukman Nurhakim Bin Ahmad Daham

Program : 4 Bmmp 1/2 No. Matrik: B091810150

Nama Penyelia : Ts. Muhammad Syafiq Bin Jumali

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	STUDENT MATRIC NO. : no spacing with Student Name		
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	YEAR: 2022		
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	Student Names: Capitalized Each Word, maximum 2 line Times New Roman,12		
	Program : Bachelor Of XXX Engineering Technology (Write Your Program Here) With Honours (Capitalized Each Word, Times New Roman,12)		
	Year: 2022 (the submission year),12		
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	Student Names: ALL CAPS, maximum 2 line, 12		
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	Table number (chapter. No of table) before Table Title, just separate the title number and and the title using ONLY ONE tab		
	Figure number (chapter. No of figure) before Figure Title, just separate the title number and and the title using ONLY ONE tab		
11.	**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**		
	• Student signature,		
	• SV digital signature & Stamp		
12.	**Turnitin Report –** dilampirkan,		
	• SV digital signature & Stamp		

Ulasan:

Semakan: Disahkan:

AJK Tesis Muktahir PSM Pengerusi JKPPU (PSM)

Catar alir Semakan Tesis Muktahir PSM (Library Version)