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JUDUL: **MOULD DESIGN AND SURFACE ANALYSIS OF CASTED MATERIAL**

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MOLD DESIGN & STRUCTURE ANALYSIS OF CASTED MATERIAL

ANNAFI BIN MOHD KHOBORI

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering
with Manufacturing Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

UNIVERSITI MALAYSIA PAHANG
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I certify that the project entitled "*Mold design & Surface Analysis of Casted Material*" is written by *Annafi bin Mohd Khobori*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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Dedicated, truthfully for supports,
Encouragements and always be there during hard times, to
my beloved family.

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ABSTRACT

Casting is a manufacturing process where a solid is melted, heated to proper temperature, and is then poured into a cavity or mold, which contains it in the proper shape during solidification. Casting process generally is classified as expendable mold or permanent mold. These researches consist of design and fabricate mould for die casting process and analyze the structure and surfaces of the casted materials. Objective of the research is to design and fabricates mold for tensile test specimen, following ASTM E8 standard and to analysis the surface and structure of casted material. Material that has been used for mold is mild steel meanwhile casted material is aluminum alloys. Furthermore, this research is consisting of several main processes which mold is design by Solidwork software and simulation for machining process is done by mastercam software. Meanwhile, fabrication process is done by CNC milling machine and finally perform casting process to produce casted materials. Subsequently, these researches were carried out in order to analyze the effect of surface roughness, dimension and thickness values on casted material by 3 different pre-heated temperatures. For these experiments, 3 measurements were measured at 3 casted materials from three different pre-heated mold temperatures. Therefore, 100 °c, 250 °c and 350 °c temperatures were tested to observe the effects of surface roughness, dimension and thickness of casted material. For surface roughness, the analysis of results indicated the value of surface roughness does not affected by different pre-heated temperature. Other than that, the values of thickness and dimensions of the casted material were slightly decreased at different pre-heated temperature. When the dimension and thickness pre-heated at 150°c, the values decreased compared with other pre-heated temperature. For pre-heated mold temperature 150°c, the dimension and thickness values are 8.18mm and 3.29 mm. Meanwhile, for 250°c and 350°c pre-heated mold temperature, the dimension and thickness values is 12.55 mm, 12.57 mm, 3.37 mm and 3.54 mm. For pre- heated temperature 200°c and 350°c, the values of dimension and thickness not significantly different. In addition, the morphology examinations through scanning electron microscope (SEM) were examined in order to investigate the effects of porosity defects by different pre-heated mold temperature. The result shows that porosity still occurred at casted material with different pre-heated mold temperatures. However, for pre- heated 150°c mold temperature, porosity occurred more than other pre-heated mold temperature. It proved that the undesirable pre-heated mold temperatures causes more porosity will occurred on casted material. The appropriate pre-heated temperature is 280 °c and 350 °c for aluminum alloys to produce good casted products.

ABSTRAK

Tuangan merupakan salah satu proses pembuatan di mana bahan yang hendak di tuang di leburkan mengikut suhu yang sesuai dan kemudiannya di tuang ke dalam kotak acuan untuk menghasilkan produk. Secara umumnya, tuangan proses ini di kategorikan kepada 2 jenis, iaitu tuangan kekal dan tuangan tidak kekal. Di dalam dissertasi ini, proses tuangan kekal ke atas acuan akan digunakan untuk menghasilkan produk. Objektif dissertasi ini adalah untuk merekabentuk, membuat acuan tuangan kekal untuk sampel ujian ketegangan mengikut piawaian ASTM E8 dan menganalisis struktur dan permukaan pada produk. Bahan yang digunakan untuk membuat acuan adalah mild steel, manakala aluminium alloy untuk produk. Selanjutnya, dissertasi ini terdiri daripada beberapa prosess utama, yang mana acuan untuk produk di rekabentuk dengan menggunakan perisian Solidwork dan simulasi untuk proses pembuatan acuan menggunakan perisian Mastercam. Selain itu, proses pembuatan acuan adalah dengan menggunakan CNC mesin dan melakukan proses tuangan untuk mendapatkan produk. Berikutnya, dissertasi ini adalah untuk menganalisis kesan kekasaran permukaan, dimensi dan ketebalan pada produk dengan menggunakan 3 perbezaan suhu permulaan pemanasan acuan. Untuk ujikaji ini, 3 bacaan di ambil pada 3 produk yang berbeza suhu permulaan pemanasan. Suhu pada 150°c, 250°c, dan 350°c diambil untuk diperhatikan samada terdapat perbezaan kekasaran permukaan, dimensi dan ketebalan pada produk. Untuk ujikaji kekasaran permukaan, analisis menunjukkan kekasaran permukaan pada produk tidak dipengaruhi oleh perbezaan permulaan suhu. Selain itu, perbezaan permulaan suhu mempengaruhi dimensi dan ketebalan produk. Pada suhu 150°c, didapati dimensi dan ketebalan produk mempunyai nilai yang berbeza bebanding dengan permulaan suhu pada acuan yang lain. Manakala untuk suhu 250°c dan 350°c, didapati nilai dimensi dan ketebalan tidak jauh berbeza. Selain itu, pemeriksaan mikrograf di buat untuk menyiasat kehadiran liang berongga pada produk pada perbezaan permulaan pemanasan pada acuan. Keputusan ujikaji menunjukkan liang berongga tetap akan wujud walaupun dengan suhu pemanasan acuan yang berbeza. Bagaimanapun, untuk suhu 150°c, liang berongga wujud lebih banyak berbanding dengan suhu 250°c dan 350°c. Ini dapat di buktikan ketidak sesuaian pemanasan permulaan suhu pada acuan akan menyaebabkan lebih banyak kehadiran liang berongga pada produk. Suhu pemanasan permulaan yang sesuai pada acuan adalah sekitar 280°c hingga 350°c untuk aluminum alloys.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Mm	Milimeter
MPa	Megapascal
%	Percent
kg	Kilogram
g/mm	Gram / millimetre
$cm.$	Centimetre
Sec	Seconds
$cm\ /sec$	Centimeter / seconds
cm^2	Centimeter square
π	Pai
r	Radius
Ra	Roughness average
Rz	Mean peak-to valley-height
°c	Degree Celsius
µm	micronmeter

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Material
CAD/CAM	Compute aided design / computer aided manufacturing
CNC	Computer numerical control
FEA	Finite element analysis
PC	Personal computer
SEM	Scanning Electron Microscope
2D	2 dimensional
3D	3 dimensional

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Earlier metal casting was made during the period from 4000 to 3000 b.c, using stone and metal molds for casting copper. Various casting processes have been developed over time, each with its own characteristics and applications to meet specific engineering and service requirements. A larger variety of parts and components are made by casting, such as engine blocks, crankshafts, automotive components and powertrains, agricultural and railroad equipments, pipes power tools and other products related fore casting processes.

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

Die casting is the process of forcing molten metal under high pressure into mold cavities (which are machined into dies). Most die castings are made from non-ferrous metals, specifically zinc, copper, aluminium, magnesium, lead, pewter and tin based alloys, although ferrous metal die castings are possible. The die casting method is especially suited for applications where a large quantity of small to medium sized parts are needed with good detail, a fine surface quality and dimensional consistency. This level of versatility has placed die castings among the highest volume products made in the metalworking industry.

This project start with the identify the suitable products to design a mold for die casting. Mould die casting is to design by computer aided design (CAD) and simulation using a Computer Aided Manufacturing (CAM) software. Furthermore, machining process with CNC milling machine and the next process is to perform the die casting process. Then, the products will be analyzed the shape and structure.and perform mettalorgraphic examination to investigate the effects of porosity formation by different pre-heated temperature and effects of deeper harden surface by different cooling medium. Other that, effects of surface roughness values by different pre-heated temperature also investigated using a perthometer machine. At the end of the project, all the process method will combine to study and investigate the defects, structure, mechanical properties, mould design and material selection in die casting process.

This chapter discussed about project background and scopes of the projects. It includes of the problem statement and objectives. The important thing is problem statement to create the objective. The scopes were already used for this project because we don't throughout this project of out of topic.

1.2 PROBLEM STATEMENT

Die casting is one of the most economical casting processes for manufacturing precision shaped parts in mass production. It is a precise casting method in which molten metal is injected at high pressure into a die cavity. As soon as the molten metal has filled the cavity, it solidifies by fast cooling. Die-cast components are being used increasingly in the automobile, aerospace, electronic and other industries because of their premium quality, low cost and low weight.

However, products that are produced with die casting process still have defective. In most cases a given mold design will produce mostly good and some detective. It is very difficult for a mold to produce no defective parts and some defective ones. There are many defective that are found in products primarily due to gassing, pouring method, size of risers and so on. However, this kind of causes is difficult to control since process of casting is a hands-on process by human itself and not machine where it involves pouring the melted material into mould. Thus, in this project, the system for casting in terms of gating system and risers will be designed and calculated purposely to reduce the defects of part to be casted. Furthermore, the study about the microstructure and surfaces analysis of the casted material has not been an interested topic among researchers. Hence, investigation to the changes of aluminum microstructure after the casting process, as well as surface analysis by different cooling media will be examined in this project.

1.3 OBJECTIVES OF THE RESEARCH

In response to the concerns identified above, the present research is aimed at:

1. To design and fabricate the mould for tensile test specimen according to ASTM standard E8 .
2. To study and evaluate the physical, appearance and microstructure of casted material.
3. To analyze the surface roughness of the casted material, by different pre-heated temperature mold.

1.4 SCOPE OF THE RESEARCH

This project will be carried out by the specific software and machine in the process of design and fabricates the mold for die casting process. The implementation of the project will be done in two consecutive semesters for a year period of time. The scope of the project is:

1. The design of mould is according to tensile test specimen, ASTM standard E8 and it modelled by using Solid Work as the design software
2. Types of material to be used in this project are restricted to only aluminium for the casted material and mild steel as the mold.

3. Master CAM software is used to simulate the machining process of mould fabrication.
4. The fabrication process of the mould has been done by using CNC milling machine.
5. Performing casting operations and evaluate the appearance of the physical products.
6. Examination and analyze the microstructure and shape of the products.
7. Study the effects factors on casted material by different pre-heated temperature during casting operations

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides with the detail description literature review done according to title of “Structure and shape analysis of cast material and mold design”. Since the aim of this project is to design, fabricate of die casting die and anlysis structure and shape of cast productsthe using Solidwork and the suitable software such as ALGOR, MASTERCAM and other related software. Thus literature review related definition of design engineering, fundamental of metal casting, die casting prinsiples and other related of the project. This literature review will give an overview or a brief introduction of the techniques that are suitable to be used in this project.

2.2 DESIGN ENGINEERING

Engineering design is asystematic process by which solutions to the needs of humankind are obtained. Design is the essence of engineering. The design process is applied to problem (needs) of varying complexity. Engineering design is the process of a devising a system,components,or process to meet desired needs. It is a decion making process (often iterative), in which the basics science, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishments of objectives and criteria, synthesis, anlysis, contruction, testing and evaluation. The engineering design component of a cocuriculum must include most of the following features, develpment of student creativity, use of open ended problems, development and use of modern design theory and methodology, formulation of design problem statement and and specifications, consideration of alternative solutions, feasibility considerations, production process, concurrent engineering design and detailed system description. Further, it is essential to include a variety of realistic constraints such as economic factors, safety, realibility aesthetics and social impacts.

2.2.1 Principles of design

N.P Suh and his assosiates at MIT have shown that good design embodies are two basics principles (Suh 1978). (Yasuhara and Suh 1980) formally state these principles as design axioms and corollaries. The theory is further develop by (Suh 1990). Unfortanely, the axioms and corollaries are relatively abstract and difficult to apply by practicing designers.

The first principles is that the undesirable interactions between various functional requirements of a products should be avoided. The second basic principle is that good designs maximize simplicity, that is, they provides the required functions with minimal complexity. These principles can be formalized as follows, must avoided undesirable and interactions to achieved in good design. Then, the best design is the one that has the minimum information content.

The contention is that the root cause of many quality, manufacturing and perfomance problems can be traced to undesirable interactions between various components or systems of a product design. Undesirable interactions occurs when functional requirements become coupled in undesirable ways. For example, the steering function and the braking function of an automobiles interacts undesirably when application of the brakes causes the vehicles to pull to left or right. The best design would be the alternative requiring the least number of activities with the fewest intructions per activity.

2.2.2 Engineering design process

Early design decisions are those that involve the initial definition of the product design. These desicions are generally made during the engineering process, which typically involves the following design activities. Several steps is using to produce good design and products.

Firstly, clarify and define the requrements of the products and design. After that, develop a working principles or physical concept for fulfilling required products functions and decompose the physical concept into subassemblies and components, also determine the geometric arrangement of components, establish dimensional relationship betweens components.

Design which components are standard and which must be designed and also select the general type of material and basics manufacturing process to be used for each designed component. After select material and manufacturing process, determine the configurations (i.e size, shape, external and internal features of each design components). Finally, establish and supply dimension, tolerances and detailed information required for manufacture and assembly of the components

2.2.3 Conceptual design

Conceptual design involves the identification and selection of the best working principle and part decomposition for the product. There are 3 critical aspects of conceptual design.

2.2.4 Physical concept

By the physical concept, that' means the working principle or solution concept employed to provide the desired funtionality of the product. The physical consept embodies the way in which the products performs or provided its intended function. The key to achieving a high external quality often lies in identifying and , selecting the right (or best) physical consept for the products. This facts which is well known, is a primary motivation for creativity and innovation in a product design. It is also the motivation for the research and development activities conducted by manufacturing firms.

2.2.5 Part decompositions

For many designs and product, identifying and selecting the right parts decomposition can be as important or even more important than the physical consepts itself. Part decomposition determines the ease of assembly, testability, and serviceability of the products. It also determines the number and complexity of the designed parts, which in turn, influence material and manufacturing process selection, tooling cost and myriad of others factor. Other than, more than any other early design desicions detrmines total cost and internal quality of the design.

2.2.6 Design consept

The pysical consept and part decomposition together define the design consept. It is the combination of physical consepts and parts decomposition that detemine many quality related products characterictics such as robustness, reliability, maintainability, durability and operating efficiency. For many design, therefore, the selection and development of the design consept is the key to achieving high total products value.

2.3 DIE CASTING AND ITS APPLICATION

Die casting is a popular manufacturing process for casting metal products. There are two main die casting process types and several variations in process design. When molten metal is forced into mold cavities at high pressure, it is known as die casting. The process is best suited for speedy production of bulk metallic parts that require minimal post-production machining. Die casting is same as permanent mold casting the only difference is that the metal is injected into the mold at very high pressure of 10-210 Mpa.

Die casting is a process that has far-reaching applications. Any part production process that creates high-volume metal components will likely benefit from die casting. A variety of manufacturing industries currently rely on one or many types of die casting processes, including the auto, aerospace and power tools industries.

2.3.1 Types of Die Casting Processes

All die casting process types are designed with the same goal in mind-cast a mold using injected molten metal. Depending on the type of melted metal, part geometry and part size, different die casting processes can deliver superior results over alternative methods. The two main types of die casting processes are hot-chamber and cold-chamber die casting. Variations on these two types of die casting include low pressure die casting and vacumm die casting.

Hot-chamber die casting, sometimes called gooseneck casting, is the more popular of the two die casting processes. In this process, the cylinder chamber of the injection mechanism is completely immersed in the molten metal bath. A gooseneck metal feed system draws the molten metal into the die cavity. While direct immersion in the molten bath allows for quick and convenient mold injection, it also results in increased corrosion susceptibility. Due to this fact, the hot-chamber die casting process is best suited for applications that utilize metals with low melting points and high fluidity. Good metals for the hot-chamber die casting process include lead, magnesium, zinc and copper.

The cold-chamber die casting process is very similar to hot-chamber die casting. With a design that focuses on minimizing machine corrosion rather than production efficiency, the melted metal is automatically or hand-ladled into the injection system. This eliminates the necessity for the injection mechanism to be immersed in the molten metalbath. For applications that are too corrosive for the immersion design of hot-chamber die casting, the cold-chamber process can be an excellent alternative. These applications include the casting of metals with high melting temperatures, such as aluminum and aluminum alloys.

Low-pressure die casting is a process best suited for aluminum components that are symmetric around an axis of rotation. Vehicle wheels, for example, are often fabricated through low-pressure die casting. In this type of process, the mold is situated vertically above the molten metal bath and connected via a riser tube. When the chamber is pressurized (usually between 20 and 100kPa), the metal is pulled upward and into the mold. The elimination of feeders from this type of die casting process delivers the high casting yields.

Vacuum pressure casting (VPC) is a relatively new die casting process that delivers enhanced strength and minimal porosity. This process is similar to low-pressure die casting, except the locations of the die cast mold and molten metal bath are reversed. The cylinder chamber can become a vacuum, which forces the molten metal into the mold cavity. This design reduces turbulence and limits the amount of gas inclusions. Vacuum die casting is especially beneficial in applications destined for post-casting heat treatment.

Squeeze casting was created as a workable solution for casting metals and alloys with low fluidity. In this process, the molten metal fills up an open die, which then squeezes closed, forcing the metal into the recessed portions of the molding. The squeeze casting process delivers extremely dense products and is a complementary process to subsequent heat-treating. The process is most often associated with molten aluminum, and is used in applications that call for fiber reinforcement.

Semi-solid die casting, sometimes called Thixoforming, is another process that delivers minimal porosity and maximum density. A machine cuts the workpiece into smaller slugs, and then heated. Once the metal has reached the phase transition between solid and liquid, resulting in a somewhat slushy texture, a shot sleeve forces it into the mold cavity, where it hardens. The benefit of this is improved precision. Non-ferrous metals such as magnesium alloy and aluminum alloy are most often used with the semi-solid die casting process.

2.3.2 Process of Die casting

There are four major steps in the die casting process. Firstly, the mold is sprayed with lubricant and closed. The lubricant both helps control the temperature of the die and it also assists in the removal of the casting. Molten metal is then shot into the die under high pressure; between 10-175 MPa (1,500—25,000 psi). Once the die is filled the pressure is maintained until the casting has solidified. The die is then opened and the shot (shots are different from castings because there can be multiple cavities in a die, yielding multiple castings per shot) is ejected by the ejector pins. Finally, the scrap, which includes the gate, runners, sprues and flash, must be separated from the casting. This is often done using a special trim die in a power press or hydraulic press. An older method is separating by hand or by sawing, which case grinding may be necessary to smooth the scrap marks. A less labor-intensive method is to tumble shots if gates are thin and easily broken; separation of gates from finished parts must follow. This scrap is recycled by remelting it. Approximately 15% of the metal used is wasted or lost due to a variety of factors.

The high-pressure injection leads to a quick fill of the die, which is required so the entire cavity fills before any part of the casting solidifies. In this way, discontinuities are avoided even if the shape requires difficult-to-fill thin sections. This creates the problem of air entrapment, because when the mold is filled quickly there is little time for the air to escape. This problem is minimized by including vents along the parting lines, however, even in a highly refined process there will still be some porosity in the center of the casting. Most die casters perform other secondary operations to produce features not readily castable, such as tapping a hole, polishing, plating, buffing, or painting.

2.3.3 Advantages and disadvantages of die casting processes

Parts die cast are almost completely finished units and can be produced at high production rates. Little clean-up is required, 2) Dies used in die casting, while initially expensive, have relatively long wear life and, because of the large production volume, mold cost per casting is usually lower than for other casting processes, 3) When large quantities are required, die cast parts generally cost less than castings produced by other processes, 4) Little draft is required; 5) Dimensional tolerances on each part cast are more closely held than is generally possible with other major casting processes, 6) Generally a surface finish of 63 rms is readily obtainable.

The major disadvantage of die casting is the potential for air or gases in the die cavity to become entrapped in the casting and form voids. These gas holes lower the mechanical properties of the casting; if near the surface, they may cause blistering during subsequent thermal treatment. Additionally, tool modification is costly. Also, coring is generally restricted to shapes permitting straight core pull.

2.3.4 Material of die casting tool and products

The materials used for die castings dies are mild steel alloys cold and hot rolled, that are either air, oil or water hardened. These material contain 0.3 -0.4 % carbon as well as chromium,molybdenum, and vanadium as major alloying elements. A most challengging application is in the production are from this castings alloys. The reference here is to the inserts that are the heart of each die. The bill materials for each die design should specify the type of steel and its hardness for each die component.

2.3.5 Die casting defects.

A casting defect is an irregularity in the metal casting process that is undesired. Some defects can be tolerated while others can be repaired otherwise they must be eliminated. They are broken down into five main categories, gas porosity, shrinkage defects, mold material defects, pouring metal defects, and metallurgical defects.

Shrinkage defects occur when feed metal is not available to compensate for shrinkage as the metal solidifies. Shrinkage defects can be split into two different types: open shrinkage defects and closed shrinkage defects. Open shrinkage defects are open to the atmosphere, therefore as the shrinkage cavity forms air compensates. There are two types of open air defects: pipes and caved surfaces. Pipes form at the surface of the casting and burrow into the casting, while caved surfaces are shallow cavities that form across the surface of the casting.

Closed shrinkage defects, also known as shrinkage porosity, are defects that form within the casting. Isolated pools of liquid form inside solidified metal, which are called hot spots. The shrinkage defect usually forms at the top of the hot spots. They require a nucleation point, so impurities and dissolved gas can induce closed shrinkage defects. The defects are broken up into macroporosity and microporosity (or microshrinkage), where macroporosity can be seen by the naked eye and microporosity cannot.

Gas porosity is the formation of bubbles within the casting after it has cooled. This occurs because most liquid materials can hold a large amount of dissolved gas, but the solid form of the same material cannot, so the gas forms bubbles within the material as it cools. Gas porosity may present itself on the surface of the casting as porosity or the pore may be trapped inside the metal leading to an increased risk of breaking or stress corrosion. Nitrogen, oxygen and hydrogen are the most encountered gases in cases of gas porosity. For casting that are a few kilograms in weight the pores are usually 0.01 to 0.5 mm (0.00039 to 0.020 in) in size. In larger casting they can be up to a millimeter (0.040 in) in diameter.

To prevent gas porosity the material may be melted in a vacuum, in an environment of low-solubility gases, such as argon or carbon dioxide, or under a flux that prevents contact with the air. To minimize gas solubility the superheat temperatures can be kept low. Turbulence from pouring the liquid metal into the mold can introduce gases to the liquid, so the mold is often streamlined to minimize such turbulence. Other methods include vacuum degassing, gas flushing, or precipitation. Precipitation involves reacting the gas with another element to form a compound that will form a dross that floats to the top. For instance, oxygen can be removed from copper by adding phosphorus, or aluminum or silicon can be added to steel to remove oxygen. A third source are reactions of the molten metal with grease or other residues in the mold.

2.3.6 Mold material defects.

They are many types of this type of defect, but it usually occurs because of one of two reasons: the wrong mold material is used or it is improperly rammed. The first type is mold erosion, which is the wearing away of the mold as the liquid metal fills the mold. This type of defect usually only occurs in sand castings because most other casting processes have more robust molds. The castings end up with rough spots and excess material. The molding sand ends up in the casting metal and decreases the ductility, fatigue strength, and fracture toughness of the casting. This can be caused by a sand with too little strength or the pouring velocity is too fast. The pouring velocity can be slowed by redesigning the gating system to used larger runners or multiple gates. A similar concept that also occurs in sand castings are drops, which is when part of the molding sand from the cope drops into the casting while it is still a liquid. This also happens when the mold is not properly rammed.

The second type of defect is metal penetration, which is when the liquid metal penetrates into the molding sand. This causes a rough surface finish. The cause is too coarse sand particles, no mold wash, or too high pouring temperature. If the pouring temperature is too high or a sand of low refractoriness is used then the sand can fuse to the casting. When this happens the surface of the casting has a brittle, glassy appearance.

2.3.7 Pouring metal defects.

There are three main defects for this category, misruns, cold shuts, and inclusions. A misrun is when the liquid metal does not completely fill the mold cavity, leaving an unfilled portion. Cold shuts occur when two fronts of liquid metal do not fuse properly in the mold cavity, which causes a weak spot. Both are caused by either a lack of fluidity in the molten metal or the cross-section is too narrow. The fluidity can be increased by changing the chemical composition of the metal or by increasing the pouring temperature. Another possible cause is back pressure from improperly vented mold cavities.

Two more closely related problems are misruns and cold shuts, both involve the material freezing before it completely fills the mold cavity. The castability and fluidity of the material can be large factors with these problems. Fluidity affects the minimum section thickness that can be cast, the maximum length of a thin section, how fine of a detail that can be cast, and the accuracy of filling mold extremities. There are various ways of measuring the fluidity of a material, although it usually involves using a standard mold shape and measuring how far the material flows. Fluidity is affected by the composition of the material, freezing temperature or range, surface tension of oxide films, and, most importantly, the pouring temperature. The higher the pouring temperature the greater the fluidity, however excessive temperatures can be detrimental. High pouring temperatures can lead to a reaction between the material and the mold; in casting processes that use a porous mold material the material may even penetrate the mold material.

2.3.8 Metallurgy defects

There are two defects in this category: hot tears and hot spots. Hot tears are failures in the casting that occur as the casting cools. This happens because the metal is weak when it is hot and the residual stresses in the material can cause the casting to fail as it cools. Proper casting design prevents this type of defect.

Hot spots are areas on the surface of casting that are very hard because it chilled more quickly than the surrounding. This type of defect can be avoided by proper cooling practices or by changing the chemical composition of the metal

2.4 DESIGN OF DIE CASTING MOLD

Diecasting mold design consists of the selection of materials for diecasting alloys, the application of shrinkage, and the casting plan including designs of cast, gate, runner and overflow. While manufacturing die design is highly demanded for high precision and shorts the date of delivery, in most of the case, it is designed by determining product geometry .The activities of molding product and process development include molding-product design, process design, die design, and mold manufacturing process planning. Conventionally, die design is performed separately from product design and mold-manufacturing process planning. Before mold design, the product geometry is reconstructed to account for material shrinkage during the prbcessing operation. Shrinkage is the dimension to which a cavity and core should be fabricated in order to produce a part of desired shape and size. Basically, shrinkage is a function of material properties, die temperature,and part thickness, In order to design a mould, many important designing factors must be taken into consideration. These factors are mould size, number of cavity, cavity layouts, runner systems, gating systems, shrinkage and ejection systemessure, and melt temperature.

2.4.1 Design consideration of die casting mold

As all in manufacturing operations, certain guidlines and design prinsiples pertaining to casting have been developed over many years .Although these principles have been established primarily through experience,analytical methods,process simulation and modeling and computer aided design and manufacturing techniques have all come into wide use as well,thus improving productivity and the quality of castings and resulting in significant cost savings.

The primary way to control casting defects is through good mold design considerations in the creation of the casting's mold and gating system. The key is to design a system that promotes directional solidification. Directional solidification, in casting manufacture, means that the material will solidify in a manner that plan, usually as uniformly as possible with the areas farthest away from the the supply of molten metal solidifying first and then progressing towards the risers. The solidification of the casting must be such that there is never any solid areas that will cut off the flow of liquid material to unsolidified areas creating isolated regions that result in vacancies within the casting's material

There are two types of design issues in casting, geometric features, tolerances that should be incorporated into the part and mold features that are needed to produced the desired casting. As example, the following considerations are important in designing casting.

2.4.2 Mold design and gating system

Gating system design is crucial in controlling the rate and turbulence in the molten metal being poured, the flow of liquid metal through the casting's system, and the temperature gradient within the metalcasting. Hence a good gating system will create directional solidification throughout the casting, since the flow of molten material and temperature gradient will determine how the casting solidifies.

2.4.3 Riser design

Riser design is very important in metalcasting manufacture. If the passage linking the riser to the casting solidifies before the casting, the flow of molten metal to the casting will be blocked and the riser will cease to serve its function. If the connection has a larger cross sectional area it will decrease its time to freeze. Good manufacturing design, however, dictates that that we minimize this cross section as much as possible to reduce the waste of material in the casting process. By making the passageway short we can keep the metal in its liquid state longer since it will be receiving more heat transfer from both the riser and the casting.

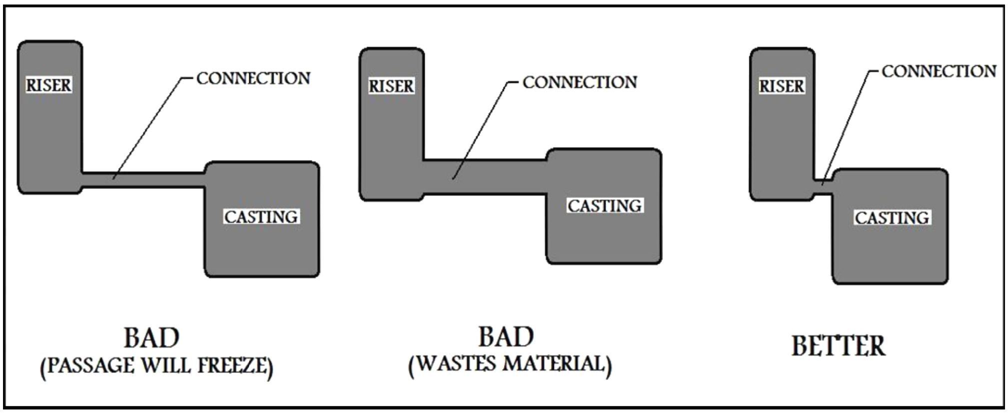

Figure 2.1 : Riser design.

Source : thelibraryofmanufacturing.com

2.4.4 Ingate Design

Another aspect of manufacturing design which relates to the flow of metal through the casting's system. The ingate, is basically where the casting material enters the actual mold cavity. It is a crucial element, and all other factors of the casting's mold design are dependent on it. In the location next to the sprue base the cross sectional area of the ingate is reduced (choke area). The cross sectional reduction must be carefully calculated. The flow rate of casting material into the mold can be controlled accurately in this way. The flow rate of the casting metal must be high enough to avoid any premature solidification.

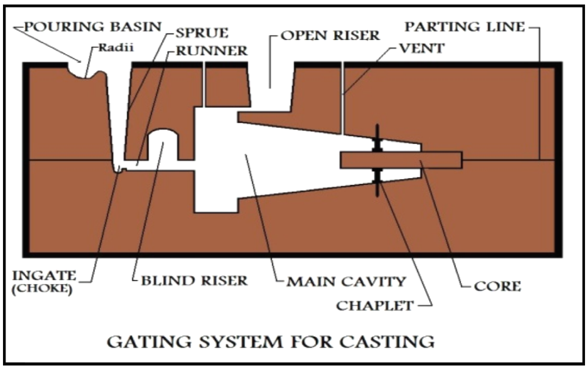

Figure 2.2: Gating system

Source : thelibraryofmanufacturing.com

2.4.5 Reduce Tubulence

When manufacturing a casting, turbulence is always a factor in our flow of molten metal. Turbulence, as covered earlier in the pouring section, is bad because it can trap gases in the casting material and cause mold erosion. Although not altogether preventable in the manufacturing process, turbulence can be reduced by the design of a gating system that promotes a more laminar flow of the liquid metal. Sharp corners and abrupt changes in sections within the casting can be a leading cause of turbulence. Their affect can be mitigated by the employment of radii.

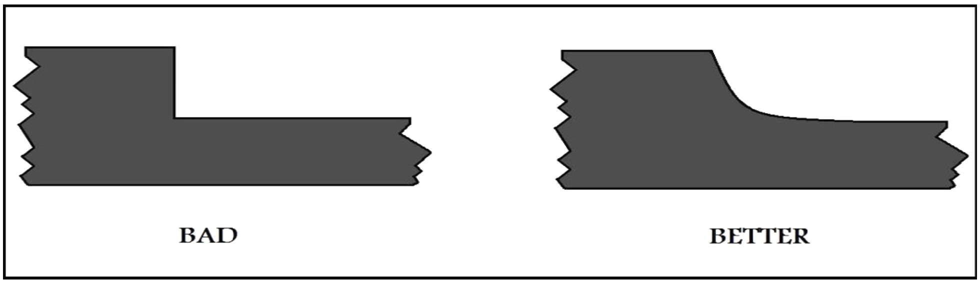

Figure 2.3: Sharp corners

Source :thelibraryofmanufacturing.com

2.4.6 Consideration for L,T,V,Y and junctions

Due to the nature of the geometry of these sections it is likely that they will contain an area where the casting's solidification is slower than the rest of the junction. These *hot spots* are circled in red in Figure 2.4. They are located such that the material around them, which will undergo solidification first, will cut of the hot spots from the flow of molten material. The flow of casting material must be carefully considered when manufacturing such junctions. If there is some flexibility in the design of the casting and it is possible you may want to think about redesigning the junction. Some possible design alternatives are shown in. These should reduced the likelihood of the formation of hot spots.

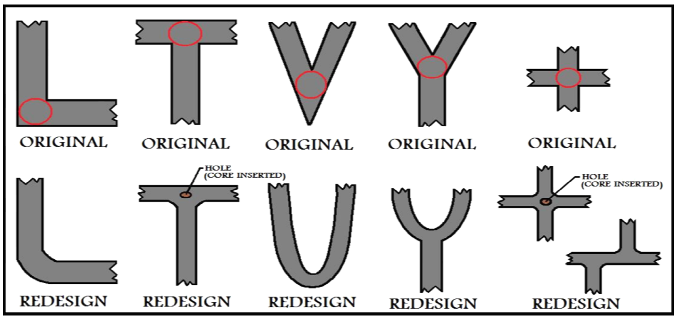

Figure 2.4 : Casting junctions

Source :thelibraryofmanufacturing.com

2.5 STRUCTURE OF DIE CASTING DIE

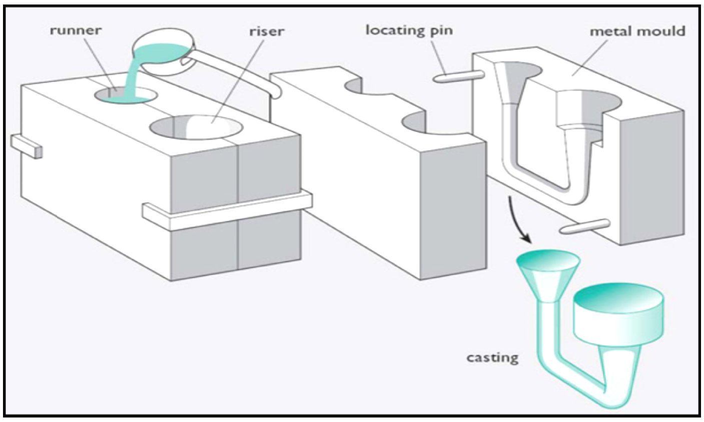

Figure 2.5 : Die casting structure

Source :thelibraryofmanufacturing.com

2.5.1 Pattern

The pattern is the principal tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The quality of the casting produced depends upon the material of the pattern, its design, and construction. The costs of the pattern and the related equipment are reflected in the cost of the casting. The use of an expensive pattern is justified when the quantity of castings required is substantial.

It usual pattern materials are wood, metal, and plastics. The most commonly used pattern material is wood, since it is readily available and of low weight. Also, it can be easily shaped and is relatively cheap. The main disadvantage of wood is its absorption of moisture, which can cause distortion and dimensional changes. Hence, proper seasoning and upkeep of wood is almost a pre-requisite for large-scale use of wood as a pattern material.

2.5.2 Gating System and Types

A mould cavity must be filled with clean metal in a controlled manner to ensure smooth, uniform and complete filling, for the casting to be free of discontinuities, solid inclusions and voids. This can be achieved by a well-designed gating system. The first step involves selecting the type of gating system and the layout of gating channels: the orientation and position of sprue, runner and ingate(s). The most critical design decision is the ideal filling time, based on which the gating channels are designed. The main objective of a gating system is to lead clean molten metal poured from ladle to the casting cavity, ensuring smooth, uniform and complete filling. Clean metal implies preventing the entry of slag and inclusions into the mould cavity, and minimizing surface turbulence. Smooth filling implies minimizing bulk turbulence. Uniform filling implies that all portions of the casting fill in a controlled manner, usually at the same time. Complete filling implies leading molten metal to thin and end sections with minimum resistance.

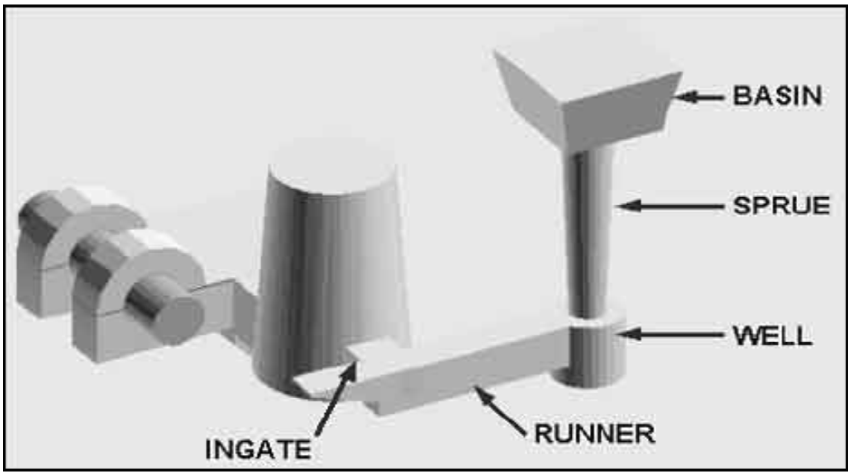

Figure 2.6 : Gating system

Source : thelibraryofmanufacturing.com

2.5.3 Major elements of a gating system

The major elements of a gating system include pouring basin, sprue, well, runner and ingate, in the sequence of flow of molten metal from the ladle to the mould cavity. The pouring basin or bush or cup is a circular or rectangular pocket that accepts the molten metal from the ladle. The sprue or downsprue, usually circular in crosssection, leads molten metal from the pouring basin to the sprue well. The sprue well or base changes the direction of molten metal by right-angle and sends it to the runner. The runner takes the metal from the sprue to close to the casting. Finally, the ingate leads the metal to the mould cavity. Another major element is filter or slag trap, usually placed in the runner or between the runner and ingate, meant for filtering out slag and other inclusions. The sprue is always vertical. The well, runner and ingate are usually located in the parting plane. Depending on the orientation of the parting plane, the gating systems can be classified as horizontal and vertical gating systems. Thus in horizontal gating systems, the sprue is perpendicular to the parting plane, whereas in vertical gating systems, the sprue is parallel to the parting plane.

Gating systems can be classified depending on the orientation of the parting plane (which contains the sprue, runner and ingates), as horizontal or vertical. Depending on the position of the ingate(s), gating systems can be classified as top, parting and bottom.

2.6 MACHINE TOOL

2.6.1 CNC Milling machine

Computer Numerical Control (CNC) Milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC Mills are classified according to the number of axes that they possess. Axes are labeled as x and y for horizontal movement, and z for vertical movement, as shown in this view of a manual mill table. A standard manual light-duty mill (such as a Bridgeport) is typically assumed to have four axes.

i. Table x
ii.Table y
iii.Table z
iv.Milling Head z

The number of axes of a milling machine is a common subject of casual "shoptalk" and is often interpreted in varying ways. We present here what we have seen typically presented by manufacturers. A five-axis CNC milling machine has an extra axis in the form of a horizontal pivot for the milling head, as shown below. This allows extra flexibility for machining with the end mill at an angle with respect to the table. A six-axis CNC milling machine would have another horizontal pivot for the milling head,this time perpendicular to the fifth axis. CNC milling machines are traditionally programmed using a set of commands known as G-codes. G-codes represent specific CNC functions in alphanumeric format.

2.7 SOFTWARE

2.7.1 Cad /cam

CAD/CAM is an acronym for Computer Aided Design / Computer Aided Manufacturing. In essence CAD is simply a drafting board in a computer and facilitates engineering and design with a monitor and a keyboard instead of a paper and pencil. Computer aided design (CAD) and manufacture is one of the fastest growing areas in engineering. The word CAD are used to emphasize the drafting task. The use of computers to extends the application and manufacturing resulted in computer aided manufacturing using a common database. Significant technological advances have been occuring in computer aided design and computer aided manufacturing,which resulted in productivity increases. CAD / CAM system helps the designer to design a product by using the speed and efficiency of a computer.

A CAD / CAM system can consists of seperate or integrated CAD and CAM software. For a system using seperate CAD and CAM packages, transfer of drawing geometry using either direct or indirect translation is required. In this case, part geometry is first created on the cad system and then transferred to the corresponding CAM system, the proggrammer specifies the tool that be used.

An integrated CAD / CAM system is a dedicated system that will allow the user to create product geometry and generate CNC programme all in one packages. Data transfer from CAD to CAM is not required, and there is no data compability problem, This is feature is important since it the accuracy and reliability of the data.

2.7.2 Solid work

Solid Works uses a feature-based "parametric" approach to modeling and assembling. In the SolidWorks 3D modeling environment the creation of a solid or surface typically begins with the definition of topology in either a 2D or 3D sketch. The topology defines the connectivity and certain geometric relationships between vertices and curves both in the sketch and external to the sketch. To this topology are added dimensions which determine the lengths and sizes for the curves and locations for the vertices in conjunction with topological constraints. The dimensions which are added are termed "parameters" because they can be changed either independently or by "parameters" created prior to their creation

2.7.3 Master cam

Master cam is one of the oldest developers of PC-based computer-aided design / computer-aided manufacturing (CAD/CAM) software. They are one of the first to introduce CAD/CAM software designed for both machinists and engineers. Mastercam, CNC Software’s main product, started as a 2D CAM system with CAD tools that let machinists design virtual parts on a computer screen and also guided computer numerical controlled (CNC) machine tools in the manufacture of parts. Since then, Mastercam has grown into the most widely used CAD/CAM package in the world.

Mastercam’s comprehensive set of predefined toolpaths-including contour, drill, pocketing, face, peel mill, engraving, surface high speed, advanced multiaxis, and many more-enable machinists to cut parts efficiently and accurately. Mastercam users can create and cut parts using one of many supplied machine and control definitions, or they can use Mastercam's advanced tools to create their own customized definitions.

Mastercam also offers a level of flexibility that allows the integration of 3rd party applications, called C-hooks, to address unique machine or process specific scenarios. Mastercam's name is a double entendre, it implies mastery of CAM (computer-aided manufacturing), which involves today's latest machine tool control technology; and it simultaneously pays homage to yesterday's machine tool control technology by echoing the older term *master cam*, which referred to the main cam or model that a tracer followed in order to control the movements of a mechanically automated machine tool.

2.8 PROPERTY OF MATERIAL SELECTION

2.8.1 Aluminium

Aluminium has been one of the most commonly utilized metals, aside from iron and steels. This should owe to the characteristics attainable from the metal itself as compared to other metals. Such characteristics are low weight, good thermal and electrical conductivity, high degree of ductility and good corrosion resistance. However, pure aluminium lacks the much-required mechanical properties for the industrial applications. Pure aluminium, although has considerable lightness and ductility, it does not possess high strength. Therefore, most aluminium is used in the form of alloys for industrial purposes. Aluminium alloys can be divided into light and heavy alloys. Most light alloys contain 85% to 98% of aluminium (Budgen 1947). There are a wide variety of elements that can be added to aluminium in order to produce alloys with increased strength and improved foundry or working properties. Nonetheless, the addition of these elements could also influence the properties of the aluminium itself. There must always be a compromise in order to gain the desired mechanical properties without sacrificing much of its original characteristics. Basically the highest mechanical strength is attainable only by heattreatment, but not all the aluminium alloys can be heat-treated.

2.8.2 Mild steel.

Mild steel is a type of steel alloy, that contains a high amount of carbon as a major constituent. designed to have specific properties Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. Alloys make it possible to compensate for the shortcomings of a pure metal by adding other elements. Mild steel can also be described as steel which is not stainless steel. Mild steel differs from stainless steel in its chromium content. Stainless steel contains a lot more chromium than ordinary carbon or mild steel.

The reason choose mild steel to produce die casting die because mild steel has low carbon steel and contains 0.16–0.29 % carbon and the temperature of mild steel higher than aluminium alloy temperature and so that is suitable to produce die casting die. Furthermore, Mild steel has a relatively low tensile strength, but it is cheap and malleable, surface hardness can be increased through carburizing. The density of mild steel is approximately 7.85 g/cm^3 (0.284 lb/in^3) and the Young's modulus is 210,000 MPa (30,000,000 psi).

2.9 FUNDAMNENTAL OF SURFACE ROUGHNESS.

The concept of roughness is often described with terms such as ‘uneven’,‘irregular’, ‘coarse in texture’, ‘broken by prominences’, and other similar ones (Thomas 1999). Similar to some surface properties such as hardness, the value of surface roughness depends on the scale of measurement. In addition, the concept roughness has statistical implications as it considers factors such as sample size and sampling interval The characterization of surface roughness can be done in two principal planes (Thomas 1999).

Using a sinusoidal curve as a simplified model of the surface profile, roughness can be measured at right angles to the surface in terms of the wave amplitude, and parallel to the surface in terms of the surface wavelength. The latter one is also recognized as texture. The technique used to measure roughness in any of these two planes will inevitably have certain limitations. The smallest amplitude and wavelength that the instrument can detect correspond to its vertical and horizontal resolution, respectively. Similarly, the largest amplitude and wavelength that can be measured by the instrument are the vertical and horizontal range.

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

Methodology is one of the most important parts in doing project. In order to complete a project, methodology is important to be considered to ensure that the project will run smoothly and will get the expected results which the one that we needed the most. This chapter provides a discussion of the methodology used in conducting this project from starting until it is completed. Furthermore, this chapter also presents the overall methodology of the project. To achieve the goals and objective of this project, a structure of overall methodology has been planned carefully and illustrated as a guideline. There are several main methods of conducting this project and they are design concepts and modelling, simulation and fabrication and casting process. Each method is explained clearly under each of the. This chapter begins with design of project study, where the methodology used in conducting this project is discussed.

3.1 FLOWCHART OF THE PROJECTS.

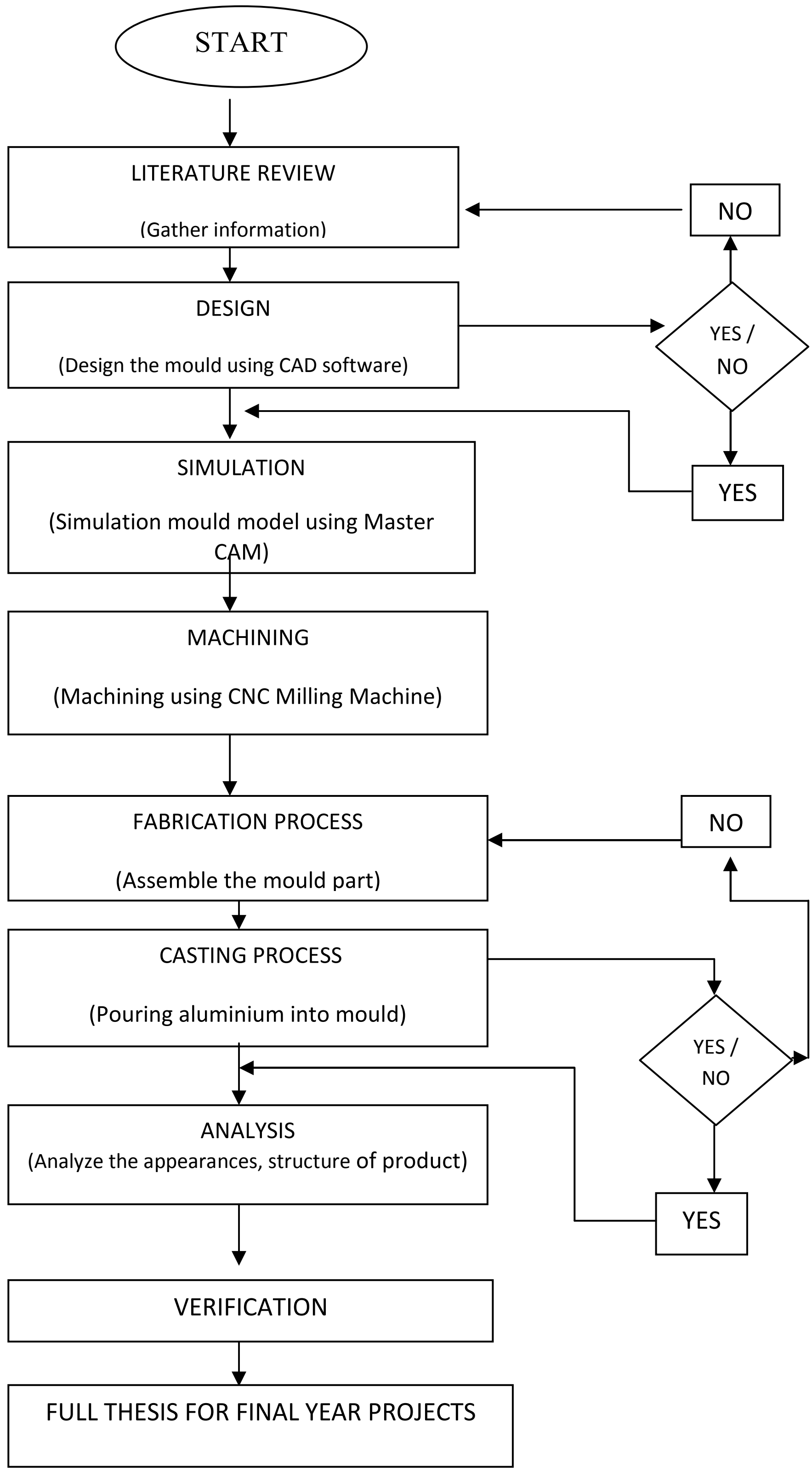

Figure 3.1: Flowchart of the projects

3.2 DESIGN THE MOULD

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Before designing the die casting mold, information on the current die casting mold is gathered. The information of the die casting process and die casting mold is needed to ensure this design will follow the general requirement for the die casting mold design to operate and function accordingly.

As general requirement the die casting mold must have gating system such as sprue, runner, ingate and well. Gating system design is crucial in controlling the rate and turbulence in the molten metal being poured, the flow of liquid metal through the casting's system, and the temperature gradient within the metalcasting. Hence a good gating system will create directional solidification throughout the casting, since the flow of molten material and temperature gradient will determine how the casting solidifies.

After gather information about die casting in reference books, internet and journal, sketching of the design is the most important things before drawing the actual design by using cad software. Several ideas regarding the design are sketch and the best design idea is selected to be the project design. All parameters in design process are determined to avoid problems in the future especially while to design the mould in Solid Work. The figure below show all the sketching idea for gating system mold dies casting and mold design.

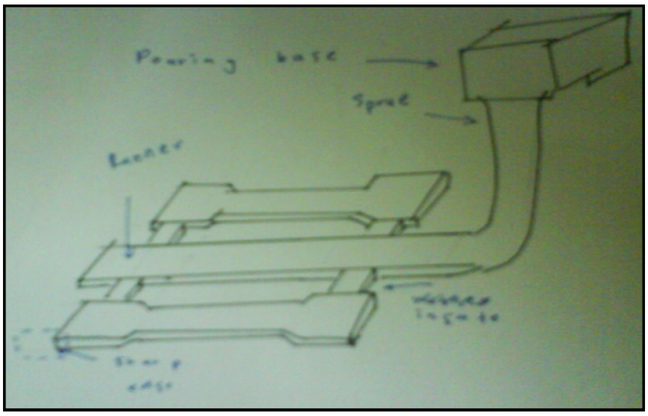


Figure 3.2: Sketching of design 1

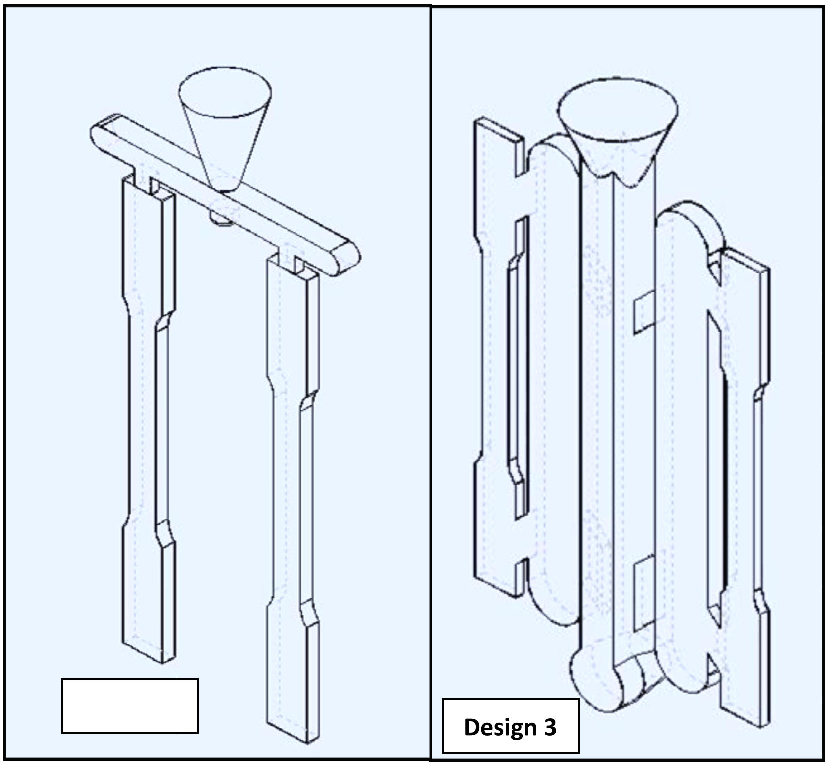


Figure 3.3: Sketching of design 2 & 3

3.2.1 Selection for type of gating system

Based on from Figure 3.2, design was sketched with minimum requirements of gating systems in casting process. There are no crucial elements such as well, tapered sprue, and riser design. Design 1 must be changed and improved to ensure molten metal can solidifies smoothly.

Design 2 is a vertical gating system, whereas in vertical gating systems, the sprue is parallel to the parting plane. For design 2, runner is situated in front of mold cavity, and tapered sprue is used to take into account the gain of velocity of the metal as it flow down reducing the air trapped. Design 2 also have 'well' below sprue. Sprue well have been added to ensure that the runner bar is filled, constrains the first metal as it exits from the sprue and prevents splashing. The main crucial well design is to prevent turbulence flow when molten metal poured into the cavity. Unfortunately, design 2 still have some disadvantages and need to be improved.

Furthermore, design 3 is created after several discussion with instructor engineer, lecture and references book. This design is almost same with design 2, but riser design to be added and position of well, runner change accordance to vertical gating systems .

Comparing for all these design, the most appropriate and suitable design is design 3. In design 1, refer from journal, references a book, this design is bad because it has no decelerating effect on the metal. Furthermore, design 1 have a parallel sprue,no choke or well and have too much sharp corners. So its causes stress raiser and may cracking and tearing of the metal during solidification. Since there is no 'choke' at the bottom of the sprue, neither it nor the pouring basin ever fill up completely. Besides that, design 1 have runner bar situated between the casting products and the design is not suitable for general die casting requirement and waste time for maching process.

Design 3 is selected because it has follow the design considerations in die castings process. Design 3 have been riser which the main function of riser is to Provide extra metal to compensate for the volumetric shrinkage and extra metal pressure on the solidifying mold to reproduce mold details more exact. Also, riser design allow mold gases to escape and without a riser heavier parts of the casting will have shrinkage defects, either on the surface or internally.

In order to produce parts without any defects, a tapered sprue can be readily moulded into vertically-parted moulds, but is more difficult to produce in horizontally-part moulds because the sprue pattern has to be withdrawn from the top of the mould.

Fillet radius should be selected to reduce stress concentrations and to ensure proper liquid metal flow during pouring. However, it the fillet radius too large, the material in these regions also is large and consequently the rate cooling is lower. Furhermore, draft angle (typically) is provided in casting products to enable removal of the pattern without damaging the mold. Draft angles usually range from 0.5° to 2. °

3.3 GATING SYSTEM CALCULATIONS AND CONSIDERATION

The main objective of a gating system is to lead clean molten metal poured from ladle to the casting cavity, ensuring smooth, uniform and complete filling. Clean metal implies preventing the entry of slag and inclusions into the mould cavity, and minimizing surface turbulence. Runner and gating systems play a very important role in the die casting of high quality products.

Poor gating designs can lead to various defects such as gas porosity, shrinkage porosity, low lines, cold shuts and poor surface finish. In casting design, the quality of the final component and the yield of the casting are two major considerations. Several calculations is needed to avoid casting products defects. These calculations includes sprue, runner, ingate and other elements in mold die casting. The calculations below show all the important part in the die castings mold.

3.3.1 Properties and Weight of the Casting products

Casting weight	= $0.04363\ kg$ (1 Cavity)
Total Casting weight (2 cavities)	= $0.04363kg\ x\ 2$
	$= 0.0876kg$
Casting Volume	= $16296.84\ mm^2$
Casting density	=$0.00278\ g/mm^2$

After calculate the weight the product , the allowance of reserving weight for pouring weight also must be calculate. If the product has less machining surface, the weight of casting product should be considered 1.1 times the finished product. The weight of gating system must also be included. The molten metal prepared must be 10% more than above weight (weight of casting and weight of gating system).

Casting weight x molten metal allowance	= $0.08726\ x\ 1.1$
	= $0.0959\ kg$
Flask height	= $60\ cm.$

3.3.2 Pouring time

The main objective for the gating system is to be filling the mould in the smallest time. The time for complete filling of a mould is called pouring time. Too long a pouring time requires a higher pouring temperature and too less a pouring time means turbulent flow in the mould which makes the casting defect prone. The pouring time depends on the casting materials, complexity of the casting, section thickness and casting size. For this project, the part is too small, so the time pouring can estimate is 2.5 second.

Pouring time = 2.5sec

3.3.3 Gating ratio

In order to fill quickly and quietly a mould with molten metal, the cross sectional areas of the sprue, runner and ingate need to be adequately balanced. Ratios between these cross sectional areas are called gating ratio. When runner is branched into multiple ingates, the flow of molten metal and temperature distribution must be properly arranged to minimize the casting stress and strain.

Table 3.1: Gating ratio

Material	Sectional area of sprue	Sectional area of runners	Sectional area of ingates
Steel	1	1.2 ~ 2	1.5 ~ 2.5
Cast Iron	1	0.75	0.5
Cast steel	1	1	1
Aluminum alloy	**1**	**4**	**4**
Magnesium alloy	1	2	2

For this project, the casting material is aluminium alloy. The gating ratio system can be calculated as the formula below:

Gating ratio = **1 : 4 : 4**

3.3.4 Average Velocity of the metal

The optimal filling time is determined such that gating channels can be designed to avoid surface turbulence and minimize bulk turbulence within the gating channels as well as the mould cavity. This mainly depends on the velocity of the molten metal, which varies widely within the gating channels as well as inside the mould cavity. For a given location in the casting, the velocity also changes with time, from the start to end of filling. The most important event is that of molten metal emerging from the ingate, just after the filling of gating channels and before the filling of mould cavity. The metal is both hot and fast at this location and instant, and can lead to considerable damage if not controlled properly. The velocity of molten metal at the ingate depends on mainly two parameters:

a) The metallostatic head and
b) The ratio of cross-sections of sprue exit, runners and ingates, referred to as the gating ratio.

Average Velocity $= c\sqrt{2\ x\ g\ (H - 0.5\ h\ )}$

$$= 0.35\sqrt{2\ x\ 980\ (\ 6 - 0.5\ (0.5\ )}$$

$$=\ 37.17\ \ cm\ /sec$$

3.3.5 Ingate design

The metal entering the sprue is directed into one or more passages, or runners. Near the die cavity, the cross-sectional area of the runner decreases to form a gate designed to direct the metal into the die cavity. The main function of the runner and gating system is to deliver molten metal passed into the mould into all section of the molten cavity. Runner and gate are major components in this design system. Once mechanical properties of cast are input and the filling speed of molten material into dies is selected, the gate area is calculated. Design of ingate must consider following points:

a) Ingate should not be located near a protruding part of the mould to avoid the striking of vertical mould walls by molten metal stream.
b) Ingates should be preferably be place along the logitudinal axis of the mould wall.
c) Ingates should not be placed near a core print or chill.

Ingate section $= \dfrac{w}{v\ x\ t\ x\ p}$

$= \dfrac{0.08726}{43.13\ x\ 2.5\ x\ 0.0028}$

$0.368\ cm^2$

2 ingate $= 0.368\ cm^2 / 2$

$= 0.184\ cm^2$

Gating ratio = **1 : 4 : 4**

(sprue) : (runner) : (ingate)

$0.092cm^2$: $0.368cm^2$: $0.368cm^2$

3.3.6 Runner design

The main function of the runner is to slow down the molten metal, which speeds up during its free fall through the sprue, and take it to all the ingates. This implies that the total cross-sectional area of runner must be greater than the sprue exit. In general, a ratio of 1:4:4 is recommended. The second implication is that the runner must fill completely before letting the molten metal enter the ingates. Finally, in casting where more than one ingate is present, the runner cross-section area must be reduced after each ingate connection (by an amount equal to the area of that ingate), to ensure uniform flow.

Base on gating ratio 1:4:4 so

Runner area $a^2 = 0.28\ cm^2$

$a = 0.52\ cm^2$

$a = 5.2\ mm$

3.3.7 Sprue design

The sprue should be tapered to take into account the gain in velocity of the metal as its flow down reducing the air aspiration. The exact tapering can be obtained by equation of continuity. Sprue design also must be designed to minimize turbulence and air aspiration.

Sprue area $a^2 = 0.95\ cm^2$

$\pi r^2 = 0.95\ cm^2$

$r = 0.54\ cm$

$r = 5.40\ mm$

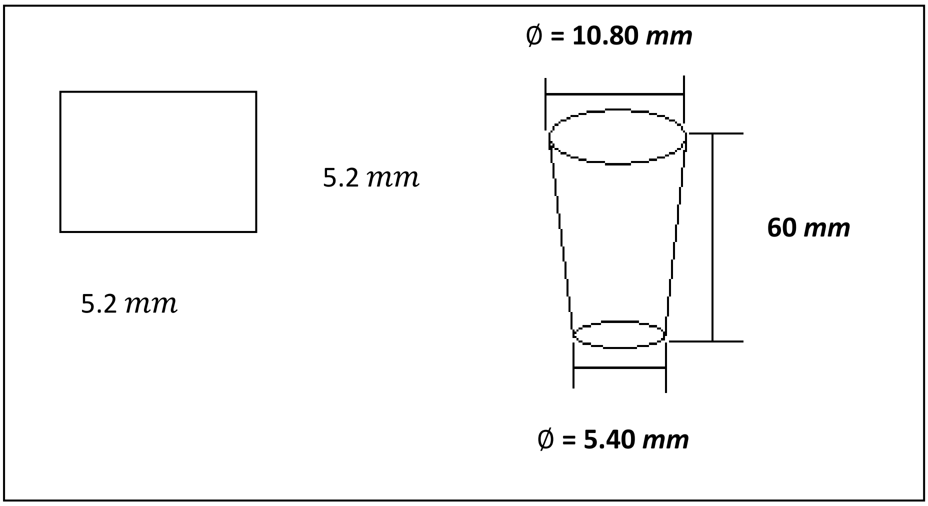


Figure 3.4: Dimension of sprue & runner

3.4 MATERIAL SELECTION

In this project, the material selection is very important part to consider during conduct the machining and fabrication process. The material selection should not be solely based on cost. The proper material selection technique involves carefully defining the application requirement in terms of mechanical, thermal, environmental, and chemical properties. Based on this project, the material required to use during the process are mild steel.

The reason choose mild steel (machining process) to produce fabricate the die because mild steel has low carbon steel and contains 0.16–0.29 % carbon and the temperature of mild steel higher than aluminium alloy temperature and so that is suitable to produce die casting die. Furthermore, Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. The density of mild steel is approximately 7.85 g/cm^3 (0.284 lb/in^3)[3] and the Young's modulus is 210,000 MPa (30,000,000 psi).

3.5 ENGINEERING DRAWING USING CAD SOFTWARE

Application of CAD software becoming more and more important nowadays and easy to used and it give clearer visuals aid of the design. Solid works 2009 is to be used to design and draw the engineering drawing for the die casting mold. In this project, the design for each component of the die casting mold is draw. There are several components to be draw, such as gating systems, ejector pin, cope and drag mold and other related components with die casting mold. The properties of the components such as material and weight are assigned accordingly in the solid works software. The material use for this project is the mild steel. The base dimension is 200 mm x 300 mm x 40 mm.

After the all components completed in draw, all the components need to be assembled using assembly command in Solid works. In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. Solid Works also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

Finally, drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards the components are assembly base on the idea from design 2

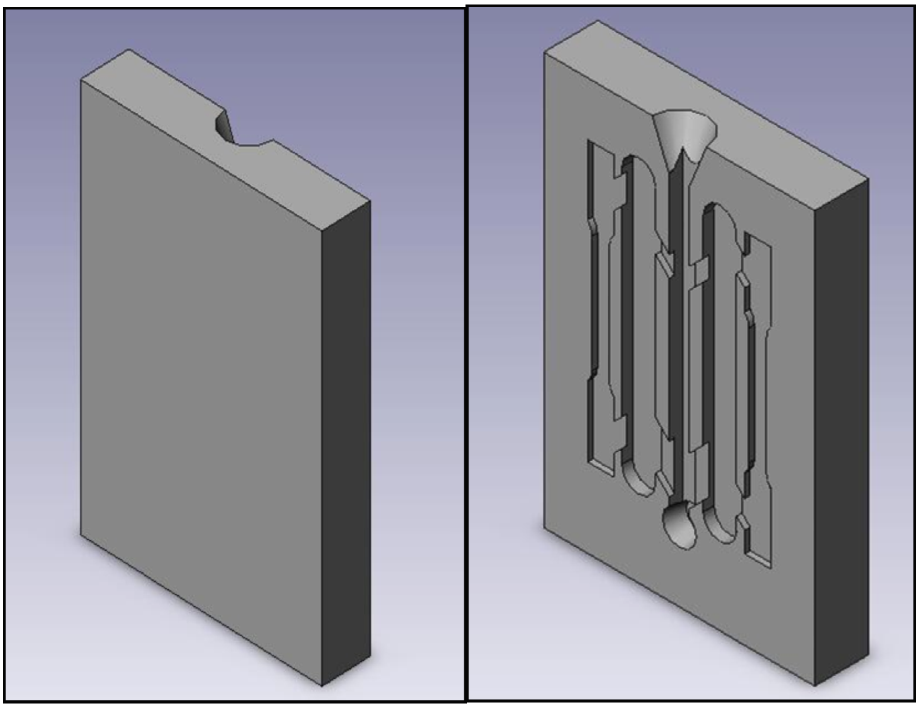


Figure 3.5: 3D drawing of front and back side mold.

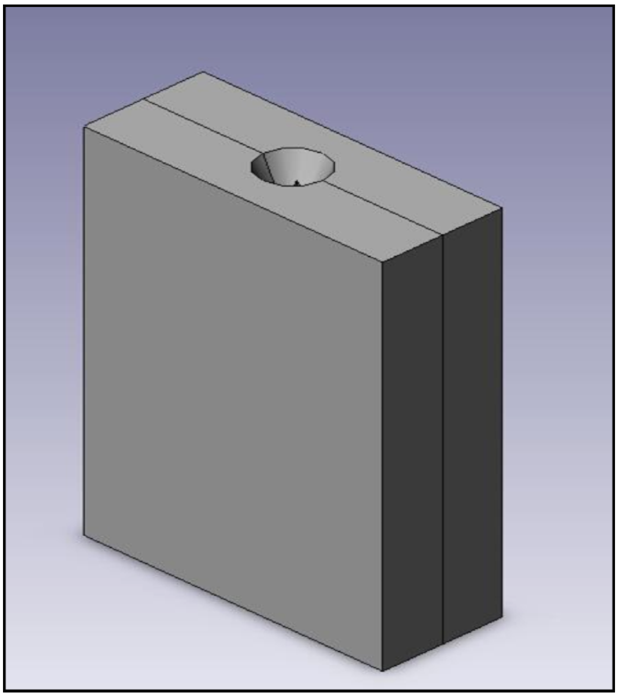


Figure 3.6: Assembly drawing of mold

3.6 SIMULATION PROCESS

After design in Solid work complete and suitable with dimensions and specification, the drawing should be converting to the Master CAM format. Master cam software will be used to show the all simulation process in CNC machining such as drilling, contour process and finishing process. There are also can get the G codes and M codes for CNC Milling Machine needed to fabricate the mold. In these projects, 9 cutting tools that used to complete fabrication of die casting mold. Further, in this process, the errors of design will be detected while simulation running. The figure below shown the types of cutting tool were used and several step in simulation process by Master Cam software.

Table 3.2: Types of cutting tools were used in simulation

No of process	Type of tool	Diameter	RPM	Feed rate
1.	End mill	20mm	500	50
2.	End mill	12mm	800	80
3.	Center drill	5mm	1300	65
4.	Drill	18mm	360	18
5.	End mill	8mm	1200	60
6.	End mill	10mm	1000	50

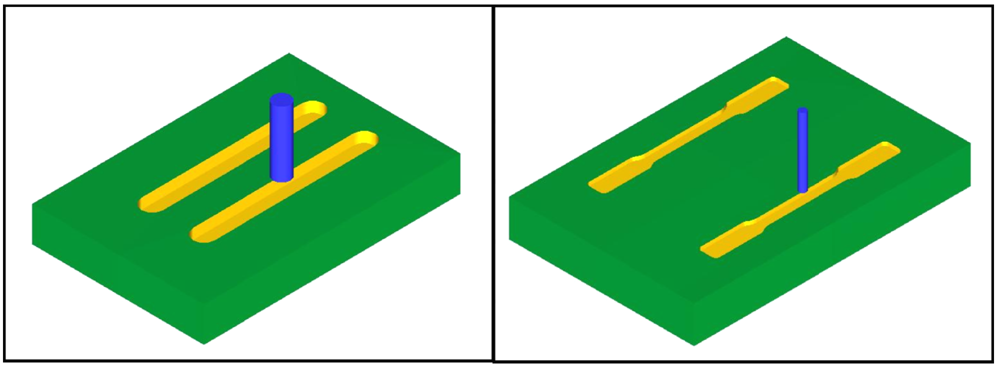


Figure 3.7: Pocketing process

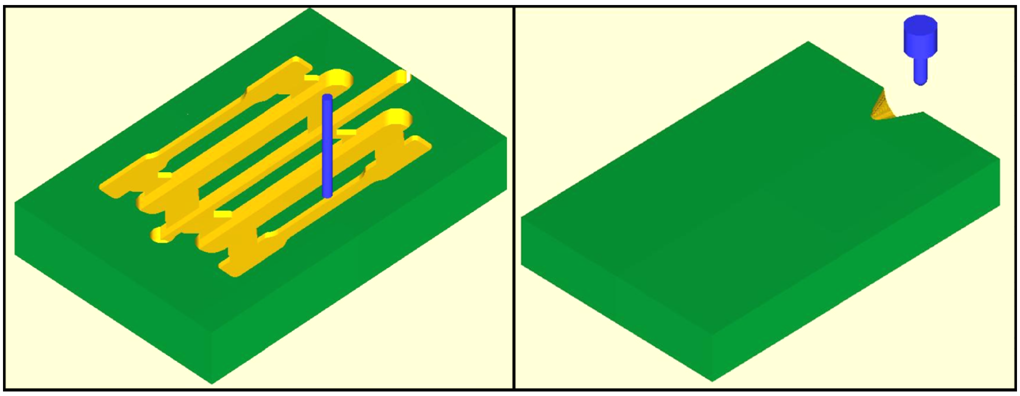


Figure 3.8: Finishing process

3.7 MACHINING PROCESS

For these projects, CNC machining will be used to produce die casting mold**.** This operation is fully will be conducted by the machine. Firstly, the material is placed at the platform of the machine and the exact dimension of the material must be follow the CAD data drawing.Furthermore, cutting tools which needed are setup to the machine. It is crucial to make the machining more appropriate.

Cutting tools must be insert accordance to the settings so it would not mistakenly choose tools while machining. Double checking is needed to be done to avoid any mistakes. After that,face mill tool will be used to cut and ensure surface of the material flat and clear from any impurities and machining process will be smooth The next step is run the machining process with follow intruction from Mastercam software. However, simulations at the machine were performed to ensure programmed tool path free from any problem. After finish the setup machine and simulate the program by using simulator, the process fabrication will continue with machining the part After complete machining process, mold already takes out from the machine for further finishing operation.

Figure 3.9: Machining process for riser design

Figure 3.10: Machining process for tapered sprue

Figure 3.11: Finishing process using surface grinder machine.

3.8 CASTING PROCESS PROCEDURE AND PREPARATION

Preparation of casting process is one most important thing to ensure casting parts free from any defects during casting process. Therefore, procedure for preparing aluminium ingots for casting must to be carried out carefully as safety is one of the key concerns, whether in a university laboratory or in industry. Outlined below are the stages involved in heating and charging a crucible and then pouring the molten aluminium.

Firstly, the crucible is preheated. It's important to removes any moisture from the furnace and crucible. Gas is usually turned half on in order to avoid rapid heating. The aluminium ingots to be used are placed on top of the furnace so that they warm up. As the aluminium begins to melt a small amount of 'flux' is sprinkled over the aluminium. A spoon can be used to sprinkle the flux powder. The flux prevents oxidisation (oxygen entering the molten aluminium). If oxygen enters the molten aluminium, when it is poured into the mould the final casting can have bubbles which can ruin the finish of the cast shape.

After the aluminium has melted fully and is approximately 700 degrees centigrade the gas is turned off and degassing tablet was added. This is to removes any impurities, in the form of gas. It is important that a good extraction system is used to remove the fumes caused by the tablet.

Meanwhile, mold for die casting need to be preheated to make sure the molten metal of aluminium can fill completely in the mold. Oxy Astilene is used to pre-heated mold with desired temperature. For aluminium, the optimum temperature is 280°c - 320°c which half from melt temperature of aluminium. Judging the temperature of the molten aluminium and mold is sometimes difficult. Using an infrared thermometer, the instrument used for testing temperature, allows accurate measurement. Infrared thermometers also use infrared energy to detect temperatures. Since they are detecting actual energy levels, the physical thermometer does not need to actually touch the surface for an accurate temperature measurement The temperature can be read on the meter, near the handle.

Subsequently, the aluminium is poured into the runner and when the cavity is full, the casting parts will be take out from the mold and several analyses will be performed to investigate the physical, structure and mechanical properties of casted material**.**

Figure 3.12: Infrared thermometer

Figure 3.13: Pre-heated the mold

Figure 3.14: Molten metal is poured into the mold

Figure 3.15: Molten metal were carried out from the furnace

3.9 CASTING PARTS ANALYSIS

When casting products removed from the mold, analysis of the casted materials were performed to investigate the appearance, structure and mechanical properties of the casted material. For this research, there are 4 types of analysis and experiments will be made. The detail explanation of the experiments will be discussed in this subchapter

3.9.1 Surface Roughness analysis

Surface roughness plays an important role in many areas and is a factor of great importance in the evaluation of machining accuracy. The surface roughness was measured by using Perthometer, the surface roughness tester as shown in Figure 3.17. The value of surface roughness of the specimens in each different pre-heated temperature are stated down for further analyze. Surface roughness value is taken 3 times for in account of accuracy.

Figure 3.16: Perthometer machine

3.9.2 Analysis Structure and shape of products

There are several types to analysis structure and shape of casted products. In this project, only casting defects was be analyzed. There are many types of defects which result from many different causes. They are broken down into five main categories: gas porosity, shrinkage defects, mold material defects, pouring metal defects, and metallurgical defects. Therefore, analysis of casting defect is important to obtain how defects can occur in casting process and reduce defect in casting.

Otherwise, effects of dimension and thickness by different pre-heated temperature were examined. For these experiments, 3 measurements were done which 3 parts from three different pre-heated mold temperatures were selected. Subsequently, 3 point from casting part as shown in Figure 3.18 was measured to obtain the different dimension of the casting parts. Each point was measured 3 times and average values are record on the table. The dimensions and thickness of measurement was measured by digital vernier calliper. Digital calliper is used because it is a precise instrument that can be used to measure internal and external distances extremely accurately.

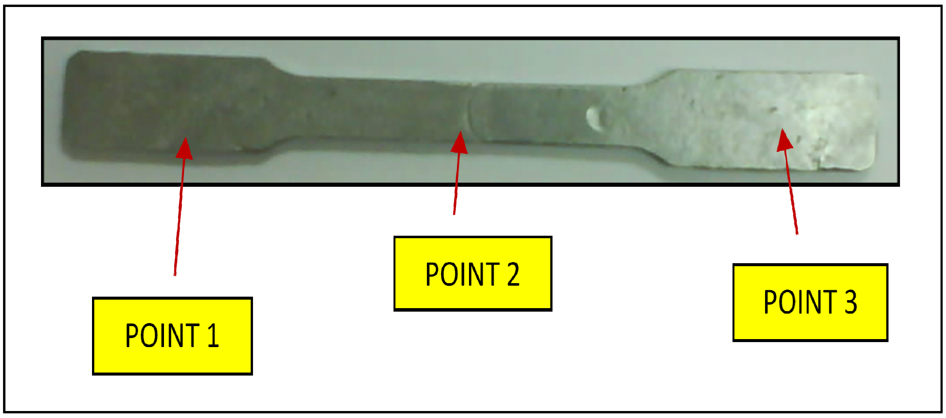


Figure 3.17: Point measured during analysis

3.9.3 Micrographs Examination of Casting products

The aim of this study is, to investigate the effects of porosity by different pre-heated temperature and effects of cooling rate by different cooling media to the thickness of hardened casted material. 3 sample from different pre-heated temperature were selected and cut in parts with dimensions 30 mm x 25 mm x 6 mm. For analysis of thickness of hardened surface, all samples must be immersed with same volume of cooling medium and same volume of container. Air, water and oil were used as a cooling medium.

All specimens needed for metallographic examination must first undergo with grinding and polishing process to allow micrograph of material can be seen clearly. The machine that used in this experiment is Scanning electron microscopy (SEM). The specimens for microstructure examination were prepared by grinding to obtain the smooth and flat surface of material.

The sectioned specimens were mounted with phenolic for better handling. These mounted specimens were ground with abrasive SiC papers, starting with lower grade of P320 up to P4000. The ground specimens were then subjected to a final polishing with Struers Silica OPS suspension (0.5 μm) in order to remove residual scratches from the previous stage, until a mirror-like surface could be obtained on the specimens.1 micron diamond of abbrasive materials is used for this polishing process. After polishing, these specimens were dried and etched with a solution of 1% hydrofluoric acid and 99 % distilled water in order to enhance the microstructural features of the specimens when they were observed under microscope. The images were captured with the image analyzer software at various magnifications

The experimental material can already test on optical microscope to view the microstructure. The microstructure’s image will be adjusted by the viewer until the image of the structure appears on screen of computer by using its own software. From that, the image can be seeing clearly.

Figure 3.18: Scanning Electron Microscope.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter discuss the results obtained from the mold design fabrication and several analysis of casted material. Further, there are 4 types of experiments were performed to investigated the physical and mechanical properties of casted material. The results will be expressed in tables and graphs to provide the reader with clear view. The experimental result will then be analyzed and compared. Recommendation will be given for future improvements.

4.2 MOLD DESIGN ANALYSIS

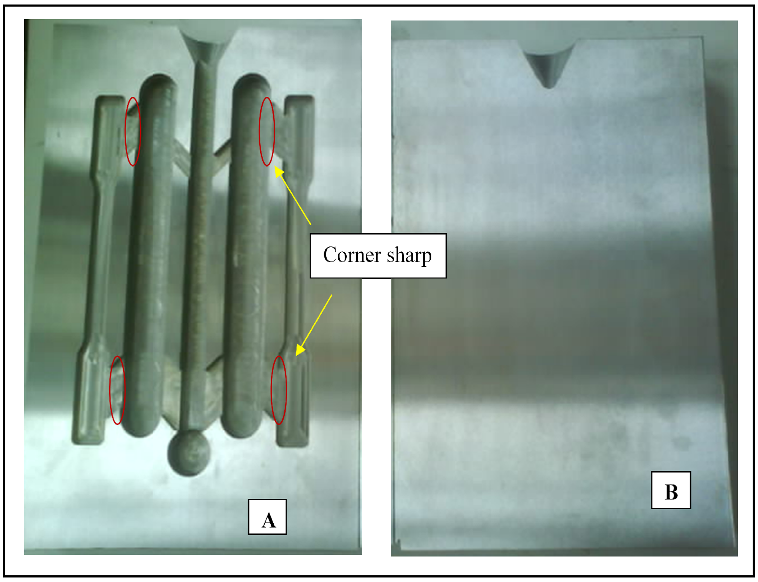
After the mold fabrications were done, analysis of the mold is needed to ensure final products free from any defects. Figure 4.1 shows the mold after fabrication and finishing process.

After several investigation of the mold, some problem found such as too much corner sharp between riser and cavity. Moreover, the mold has no venting system and poor surface finish for casting parts due to the tool bit during machining process. The main reason the mold have corner sharp, because there are no suitable cutting tools in CNC machine can that machining for draft angle.

Corner sharp should be avoided as much as possible, because they act as stress raisers and may cause cracking and tearing of the metal (as well of the dies) during solidifications (Kalpakjian 2000). Fillet radius should be selected to reduce the stress concentrations and to ensure proper liquid metal flow during pouring.

Fillet radius usually ranges from 3 to 25 mm, although smaller radius may be permissible in small castings and in specific applications. However, if the fillet radius is too large, the volume of the materials in those regions also is large, and consequently, the rate of cooling is lower (Kalpakjian 2000). Otherwise, too much corner sharps also caused casting parts are difficult to take out when the molten metal solidifies.

Furthermore, vent system are important for maintaining casting quality and reducing castings defects. Venting system can reduce or eliminate this pouring time variation and subsequent defects. Besides that, air grinder was used to create fillet radius and venting system and the results of the addition fillet radius and venting system were observed.



Figures 4.1: The final mold after fabrication, a) left side view. b) Right side view

4.3 CASTED MATERIAL ANALYSIS

After improvement of mold was done, mold is pre-heated with 3 different temperatures to obtained different condition of casted material. Then, molten metal poured into the mold and solidifies in the mold. Casted material was taken out from the mold and quenched with different quenching media to investigate the strength, structure of casted material.

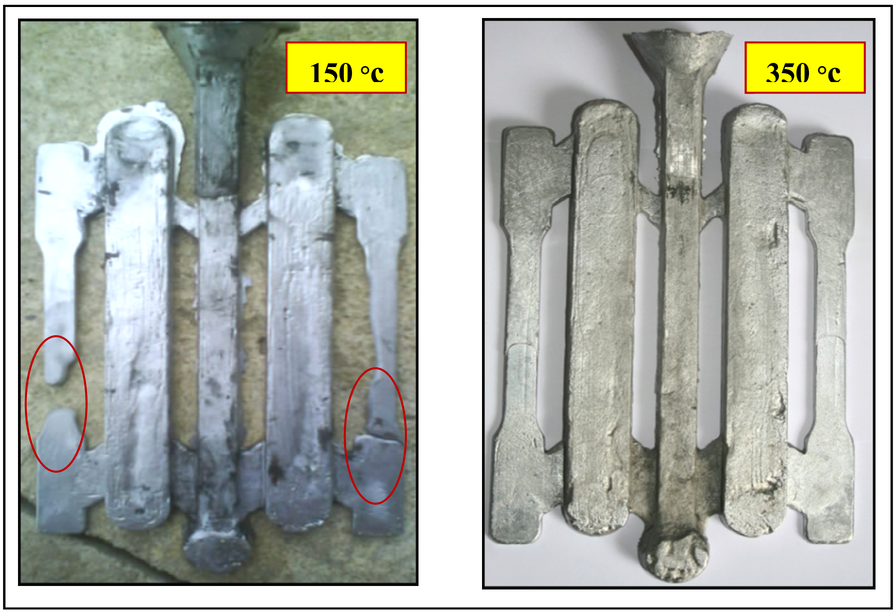


Figure 4.2: Casted material for temperature 150 °c & 350°c.

Figure 4.3: Casted material for 200 °c pre –heated mold temperature.

Figures 4.2 & 4.3 have shown the casted material after poured at different pre-heated mold temperature. For pre-heated temperatures 150°c, casted material cannot fill completely and caused shrinkage and misrun defects even though the mold have fillet radius and venting systems. Also, if the shrinkage occurred, porosity becomes and will be affects structure of the casted material. Moreover, misrun defects can be seen for casted material at temperature 150°c**.** Misrun defects appear when the molten metal failure to fill completely, because the temperature of mold during pre-heated is not enough. For the temperature 200°c & 350°c, perfect casted material can be seen but the shrinkage still occurred at the riser.

4.4 THE EFFECT OF DIFFERENT PREHEATED MOULD TEMPERATURE ON THE SURFACE ROUGHNESS OF CASTED MATERIAL

The aim of at this study is to investigate the effect of different preheated mold temperature on surface roughness of casted material. For each group point, 3 measurements were done. The surface roughness measurements were conducted by perthometer machine in metrology laboratory, University Malaysia Pahang.

Average roughness (Ra) and peak to valley height (Rz) were considered to evaluate effect of surface roughness on different preheated mold temperature. Three different casting parts from three different pre-heated mold temperatures were selected. Subsequently, the points of roughness measurements were selected on 3 different points on surface of the castings parts. The detail explanations of roughness measurement of the surface were described in chapter 3.

R_a is the average distance from the profile to the mean line over the length of assessment or surface tracing length and R_z can be defined as an average of five equal consecutive peaks to valley heights within the complete tracing length. Figure 4.5 shows typical surface roughness profiles of the specimen obtained from 3 different locations of the parts for different temperature.

Table 4.1: Surface roughness value of the part taken at the point 1

Point 1						
	Mold Temperature					
	150°c		**200°c**		**350°c**	
	Ra (µm)	**Rz (µm)**	**Ra (µm)**	**Rz (µm)**	**Ra(µm)**	**Rz (µm)**
Reading 1	1.413	7.621	1.130	7.765	1.463	9.664
Reading 2	1.526	7.520	1.242	7.820	1.530	9.546
Reading 3	1.544	7.710	1.223	7.845	1.596	9.610
No of Sample	3	3	3	3	3	3
Average	1.4954	7.617	1.198	7.810	1.529	9.606

Table 4.2: Surface roughness value of the part taken at point 2

Point 2						
	Mold Temperature					
	150°c		**200°c**		**350°c**	
	Ra(µm)	**Rz(µm)**	**Ra(µm)**	**Rz(µm)**	**Ra(µm)**	**Rz(µm)**
Reading 1	2.560	14.320	0.734	5.860	1.176	1.176
Reading 2	2.603	14.235	0.965	5.960	1.260	1.269
Reading 3	2.532	14.369	0.863	5.790	1.196	1.230
No of Sample	3	3	3	3	3	3
Average	2.565	14.369	5.870	5.870	1.210	1.225

Table 4.3: Surface roughness value of the part taken at point 3

Point 3						
Mold Temperature						
	150°c		**200°c**		**350°c**	
	Ra (μm)	**Rz(μm)**	**Ra(μm)**	**Rz(μm)**	**Ra(μm)**	**Rz(μm)**
Reading 1	2.437	12.200	2.552	14.102	1.603	10.403
Reading 2	2.510	13.102	2.490	14.880	1.783	10.530
Reading 3	2.480	12.679	2.542	14.132	1.660	10.450
No of Sample	3	3	3	3	3	3
Average	2.475	12.526	2.542	14.360	1.682	10.401

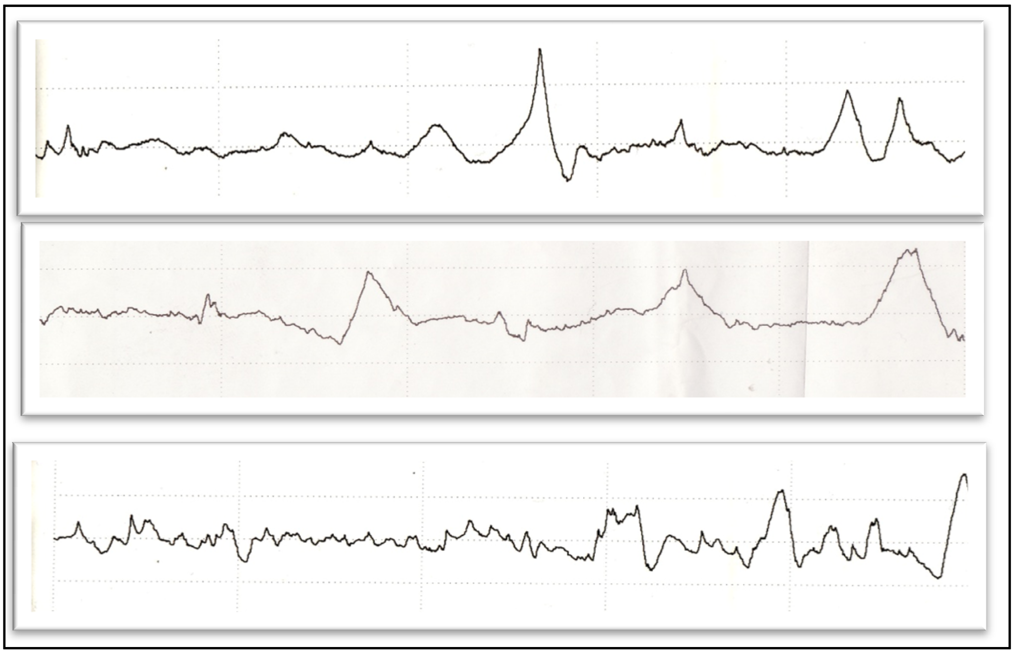


Figure 4.4: Surface roughness profiles of the specimens taken from point 3 of the casting parts (Pre-heated for 200°c).

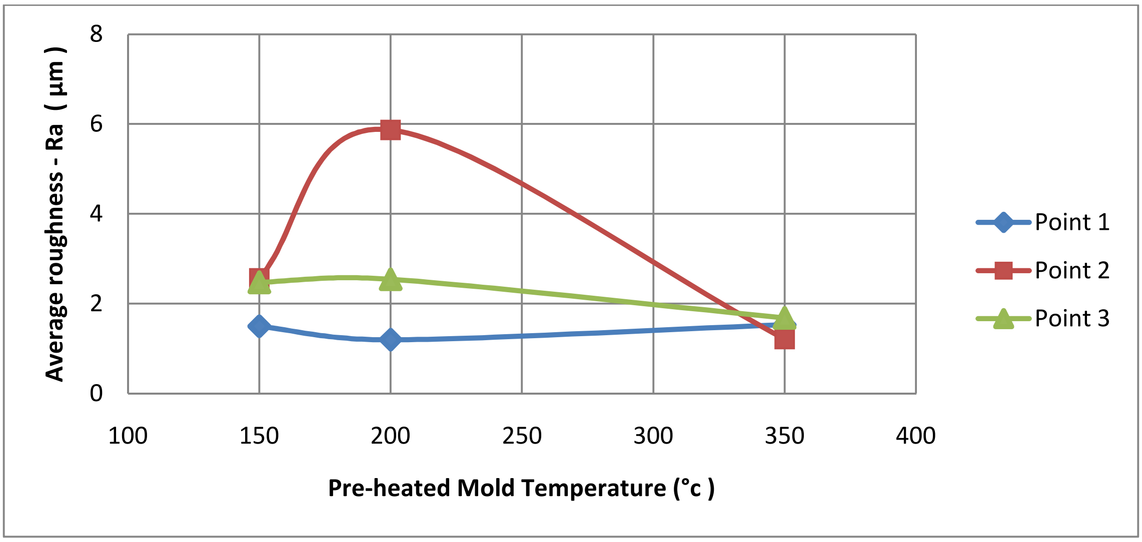


Figure 4.5: Average roughness (Ra) of casting parts taken from three different points for three different pre-heated mold temperatures.

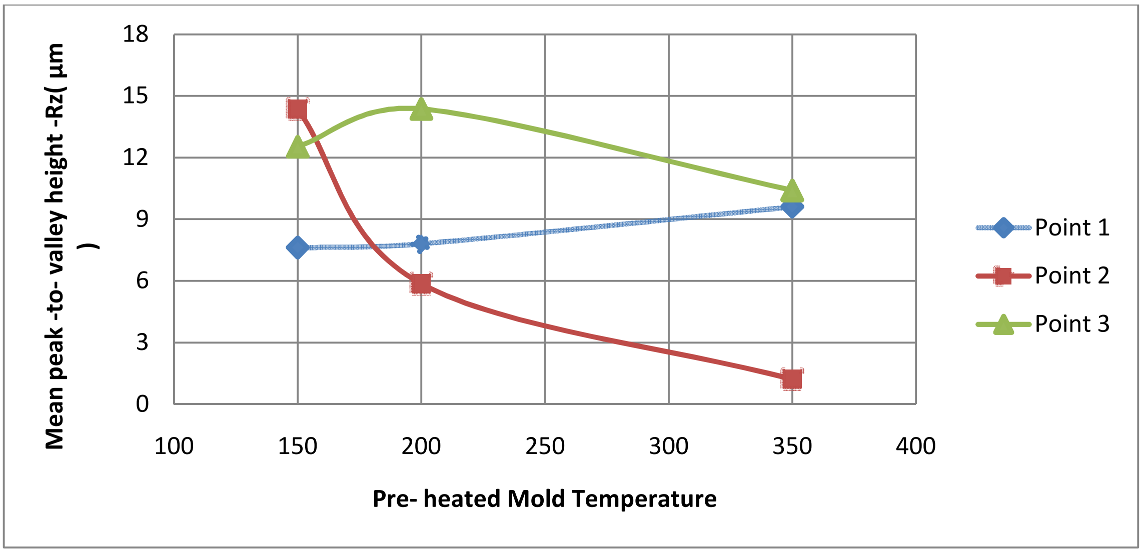


Figure 4.6: Mean peak to valley height (Rz) of casting parts taken from three different points for three different pre-heated mold temperatures.

4.4.1 Discussion

Table 4.1-4.3 shows average values of the two roughness parameters taken from the 3 different points on the surfaces of the casting parts. The results were illustrated in figures 4-5. The Figure 4.1 displays the surface roughness values of the casting parts for pre-heated mold temperature of 150°c, 200°c and 350°c respectively. The average roughness value shows the different value for different pre-heated mold temperature.

The highest value roughness was obtained for point 2 in temperature 200°c. It is because the surfaces for point 2 have some defects, which mean the surface roughness values also increased. Subsequently, surface roughness value doesn't have significant different between different values of mold temperature. It is because the values of roughness were measured in μm and not gives a trend in the graph.

Furthermore, from the Figure 4.6, it can conclude the temperature of the mold during pre-heated doesn't affect the surface roughness value of casting parts. Roughness value for casting was affect by different type of casting process. In addition, die casting process is noted for good surface finishes at around 1 μm.

4.5 THE EFFECT OF DIMENSIONS AND THICKNESS ON THE CASTINGS PARTS BY DIFFERENT PREHEATED MOULD TEMPERATURE

For second experiments, it was proposed to investigate the effect to the dimensions and thickness on castings part of different pre-heated mold temperature. For these experiments, 3 measurements were done at 3 parts from three different pre-heated mold temperatures. Subsequently, 3 point from casting part was measured to obtain various dimensions of the casting parts. Each point was measured 3 times and average values were recorded as the Table 4.4 & 4.5.

The dimensions and thickness of measurement was measured by digital vernier caliper. Digital calliper was used because it is a precise instrument that can be used to measure internal and external distances accurately. Also digital calipers are easier to use as the measurement is clearly displayed and also, by pressing the inch/mm button the distance can be read as metric or imperial. Furthermore, details explanations on the measurement of dimensions and thickness casting parts were described in chapter 3. The Table 4.4 & 4.5 below shows the data of measurement dimension and thickness for different pre-heated mold temperature.

Table 4.4: Dimension (width) values of the part taken from different temperatures of the mold

Dimensions(mm)									
Width (mm)									
	150°c			200°c			350°c		
	P 1	P2	P3	P 1	P2	P3	P 1	P2	P3
Read 1	17.50	8.46	18.43	19.32	12.60	19.37	20.16	12.60	20.13
Read 2	17.58	7.98	18.49	19.40	12.55	19.33	20.24	12.55	20.16
Read 3	17.59	8.10	18.57	19.30	12.57	19.34	20.21	12.59	20.10
Average	17.55	8.18	18.49	19.34	12.57	19.34	20.20	12.55	20.13

Table 4.5: Thickness values of the part taken from different temperatures of the mold

Thickness (mm)									
	150°c			200°c			350°c		
	P 1	P2	P3	P 1	P2	P3	P 1	P2	P3
Read 1	3.32	3.25	3.37	3.39	3.40	3.40	3.47	3.53	3.6
Read 2	3.20	3.24	3.33	3.41	3.37	3.38	3.52	3.57	3.63
Read 3	3.35	3.31	3.29	3.35	3.35	3.37	3.5	3.54	3.58
Average	3.29	3.31	3.33	3.38	3.37	3.38	3.49	3.54	3.60

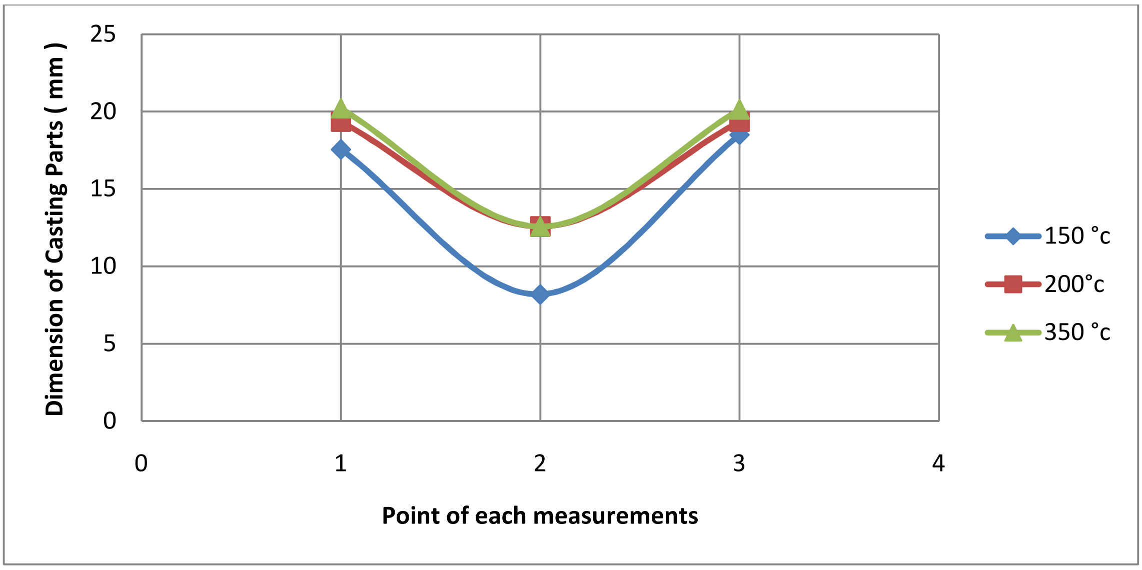


Figure 4.7: Average dimensions (mm) of casting parts taken from 3 different pre – heated mold temperature.

All casting parts were measured for dimension & thickness to investigate the effect of pre-heated mold temperature on casting parts. The results, shows in table 4.4 & 4.5, there are some discrepancies in the measurements of dimension & thickness on casting parts. The highest value of dimensions for casted material is 12.57 mm at point 2 of 350°c pre-heated mold temperature. Meanwhile, the lowest value for point 2 is 8.10 at 150°c temperatures. For dimensions on casting parts, it also found that the average dimension on casting parts for temperature 150 °c is slightly decreased compare with the other temperature. It is because temperature during pre-heated not enough for molten metal solidifies in mold cavity and caused shrinkage and misrun defects occurred on the castings part.

However, the dimensions value at 250°c and 350°c temperatures does not give too much different value on casted material. The Figure 4.8 below shows the comparison of casting parts with different pre-heated mold temperature. Based on Figure 4.8, casting parts for pre-heated temperature 200°c and 350°c has good physical condition compared with temperature 150°c.

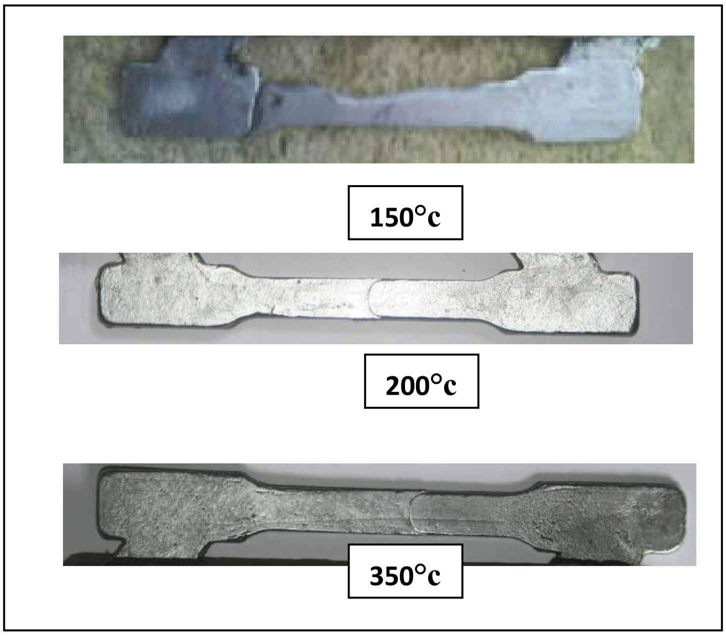
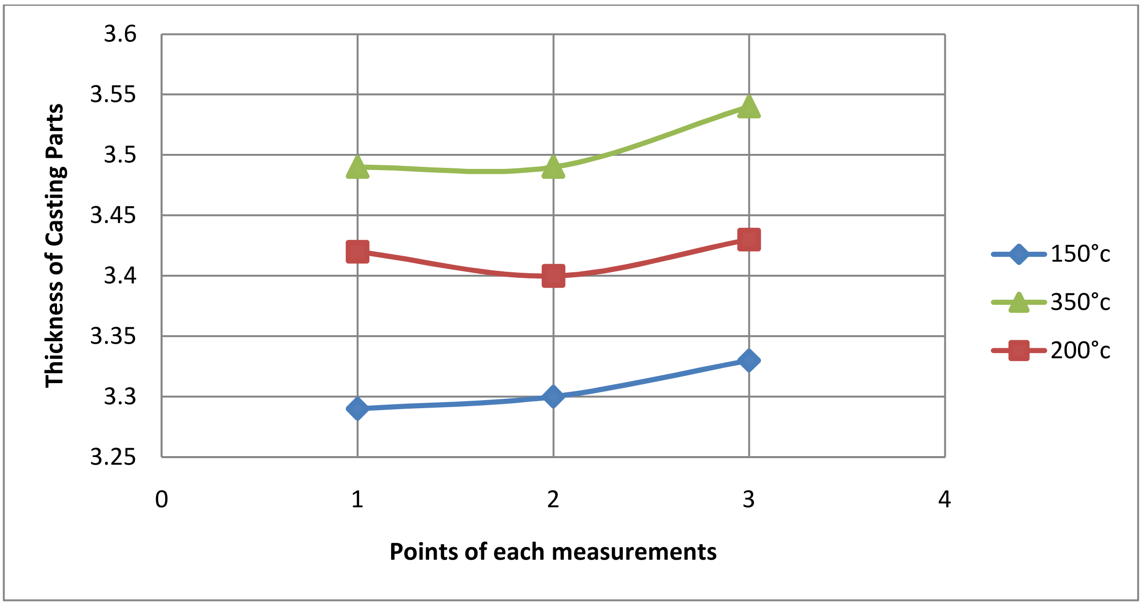


Figure 4.8: Comparison of casting parts dimension between different pre –heated mold temperature

In addition, mold cavity can't be filled up if the pre-heated mold temperature not enough and molten metal will solidifies before solidification phase. Moreover, according to (Vukota B.V 2009), The permanent mold must be pre-heated to specific temperature (depending on the metal to be cast) to ensures the mold cavity fill completely. For aluminium, the desired temperatures to pre-heated mold approximately around 300 °c -350°c, means that a half from melting temperature aluminium alloy Also, pre- heated the mold is crucial phase to drive off water, removes any residues of wax, and hardens the binder.

Subsequently, (Tom Clark 2008) on the other hand said that the reason mold is pre-heated is order to make the metal solidifies more slowly. By slowing down solidification and controlling metal flow through the gating system, the process is able to yield very good grain structures and mechanical properties.

Other than that, shrinkage defects also influence on changes of dimensions casting parts. (Chakrabarti 2009) founded that most aluminium alloys suffer a volumetric shrinkage of about 6% during solidification. If the solidification contraction is not compensated by supply extra metal, shrinkage defects will arise.



Figures 4.9: Average thickness (mm) of casting parts taken from 3 different pre – heated mold temperature

From table 4.5, the highest value of thickness is 3.60 mm at 350°c pre heated mold temperature meanwhile the lowest value is 3.29 at 150°c pre heated mold temperature. However the thickness value at 3 different pre-heated temperatures does not give too much different value.

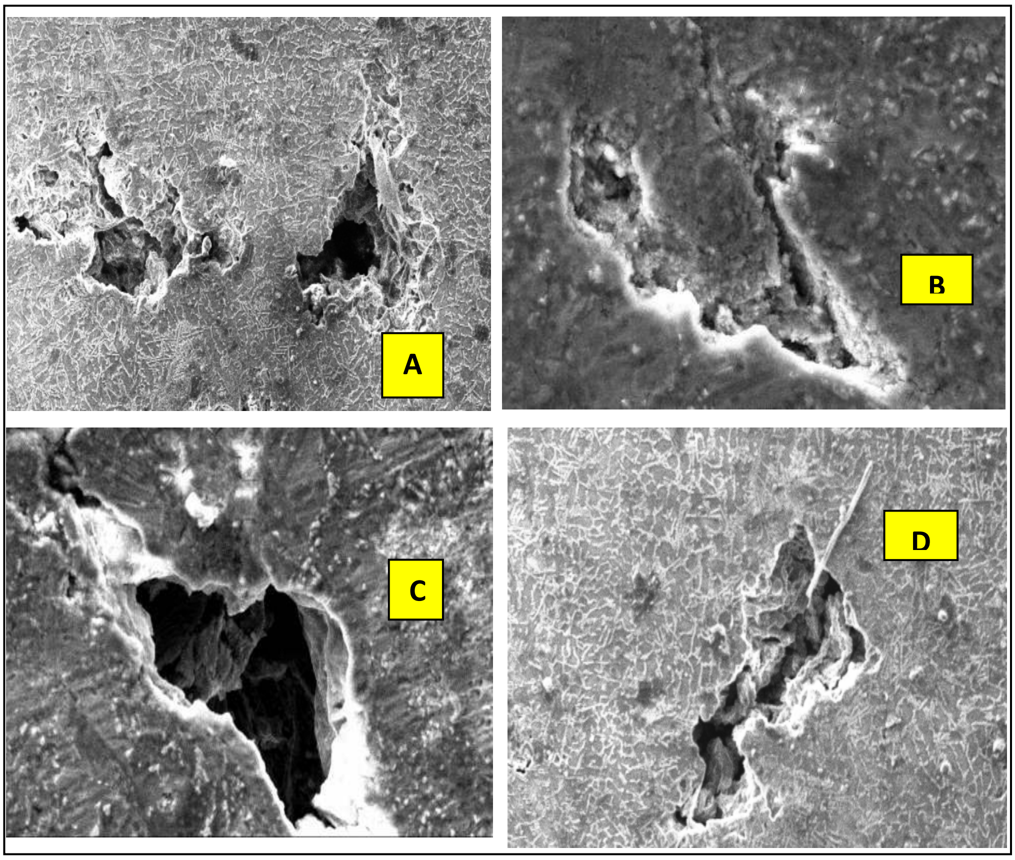
From Figure 4.9, it can be seen that the thickness values for mold temperature 150°c slightly decreased compared with other temperatures. It is because mold cavity was (aluminium) not fill completely during poured and also affects the thickness of the casting parts. Meanwhile, thickness for the temperature 200 °c & 350 °c same with actual thickness from mold. That means pre-heated mold with right temperature is crucial to ensure aluminium can fill completely without any defects from parts.

4.6 POROSITY EFFECTS ON CASTING PARTS BY DIFFERENT PRE-HEATED MOLD TEMPERATURE

Generally, they are various types of defects were observed in casting process; these defects may be related either to the metal or the mold or both. Specific defects may be encountered due to the complexity of the metal composition, casting design and casting practice (Chakrabarti, 2009) While some defects affects only the appearance of the parts made, other can have major adverse effects the structural integrity of parts.

Porosity in casting may be caused by shrinkage or gases, or both. It is may be the most persistent and common complaint of casting users. Porosity in castings is due to bubbles being trapped during solidification. Porosity sources include entrapped air during filling, centerline shrinkage that occurs during the final solidification, blowholes from unvented cores, reactions at the mold wall, dissolved gases from melting and dross or slag containing gas porosity (Monroe, 2005).

For third experiments, the effects of porosity defects were investigated at 3 different pre-heated mold temperatures for the purposes of the present study. The experiments were performed on castings parts and cut in part with the dimension 30 mm x 25 mm x 6 mm, thus 3 sample were obtained from each different mold temperature, Subsequently, the sample were mounted, polish and etched before the specimen were examined by Scanning electron machine. Figure 4.10 shows the effects of porosity on casting parts with different mold temperature.



Figures 4.10 : SEM micrographs of porosity on casting parts with different pre- heated mold temperature (a) 150°c (b) 200 °c (c) 350°**c** (d) 150°c

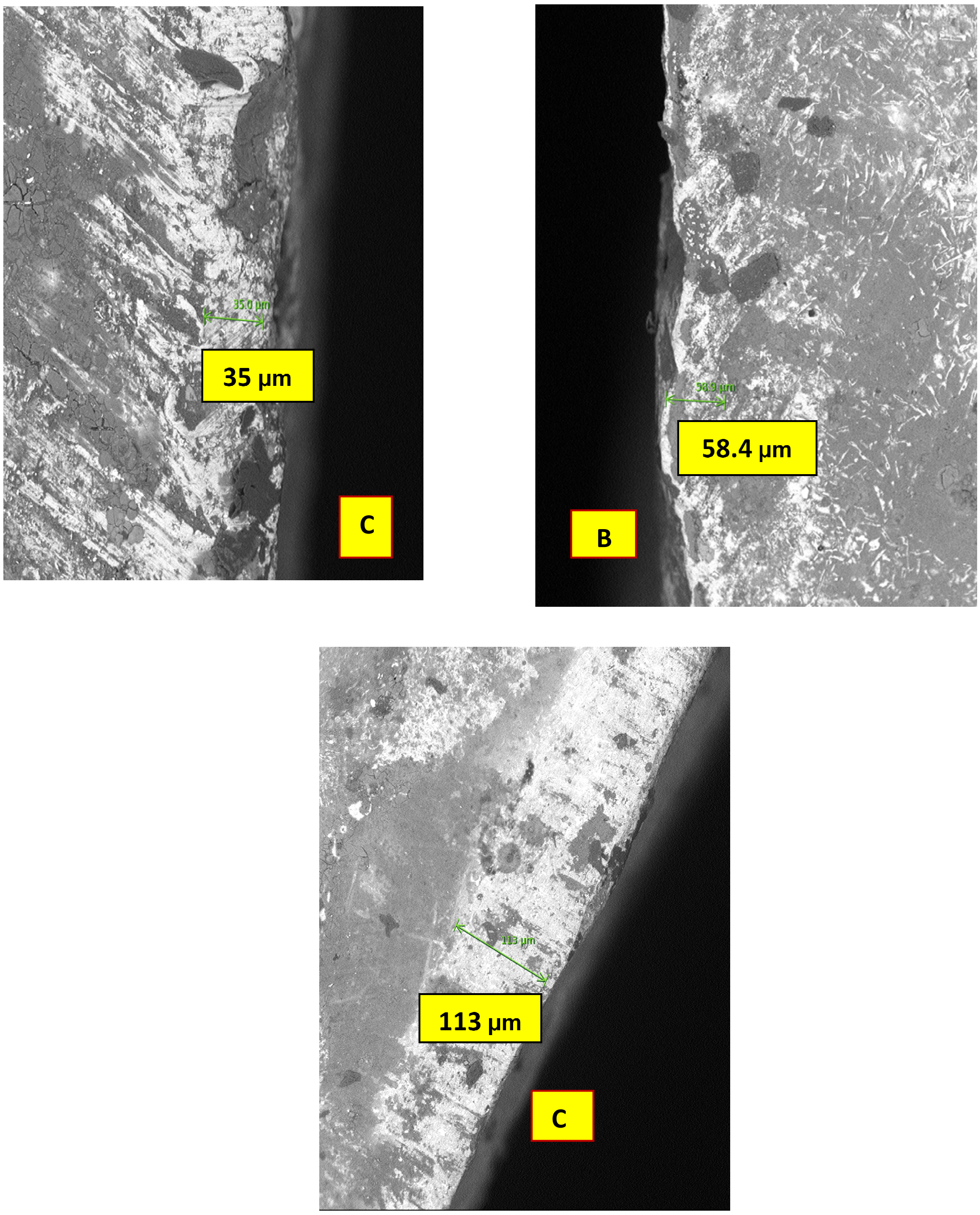
Refer from Figures 4.10, it will be shown the porosity will occurred at all temperatures. However for pre- heated 150°c mold temperature, porosity occurred more than other pre-heated temperature. It is because, the temperature of mold during pre-heated not enough and molten metal cannot fill completely and solidifies before solidifications phase. Further, not enough pre-heated temperature caused shrinkage and misrun defect and porosity will be occurred together.

Based on figures above, the shapes of porosity is round and (Ling, 2006) proved that porosity typically have round shapes, whereas shrinkage pores have ''crack-like'' morphologies. It is usually believed that the mechanisms of formation of gas and shrinkage porosity are distinctly different and independent, and consequently, the gas and shrinkage pores can be regarded as independent microstructural features

Most often than not, porosity occurs in castings due to solidification shrinkage and gas evolution from decreased solubility of the gas in the solid phase (Mohanty etal 1993**). (**Monroe, 2002 **)** stated that one source of porosity in castings is a failure to eliminate all the air in the mold cavity. Most often this porosity appears to be a misrun or incomplete casting. In skin forming alloys when the filling event is chaotic, air bubbles can be entrapped in the casting. Sometimes the air bubbles deflate, leaving the oxidized skin.

Subsequently, porosity caused by shrinkage or gases can be reduced or eliminated by various means such as provides adequate liquid metal to avoids cavity by shrinkage and by making the temperature gradient step. For example, mold materials that have higher thermal conductivity may be used. (Draper, 2007) reported that the porosity level of a casting decreases with an increase of the vent area for atmospheric venting. Moreover, it found that porosity decreases with increasing vent area or filling time until the vent area or filling time reaches or exceeds a critical value after which the porosity remains constant.

4.7 EFFECTS OF DEPTH THICKNESS SURFACE ON CASTED MATERIAL BY DIFFERENT COOLING MEDIUM.



Figures 4.11: Quenching effect to the thickness of casted material measured from top of the surface. a) Air b) Oil c) Water

The observations were performed to investigate the effects of cooling media to the thickness of casted material which is measured outmost surface of parts. .The casted material was immersed to fixed volume by using container to ensure the fairness in quenching. 3 cooling media which are water, oil, and air was used in these experiments. Scanning electron microscope (SEM) was used to examine the effects of thickness to the cooling media.

Based on the results from Figures 4.11, it clearly shows the cooling media by water give highest depth of hardening effects when the sample was immersed. The effect of cooling rate also depends on the surface area to thickness or surface area to volume ratio of the parts. The higher this ratio, the higher is the cooling rate. Thus, it can conclude water have the best cooling media compared with air and oil

CHAPTER 5

CONSLUCIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter will conclude the research and briefly discussed about the recommendation that can be applied for the future work. The conclusion were done according to the result obtain in Chapter 4. In order to achieve the good result in experiments and analysis of casting process, other aspects of future work also will be discussed.

5.1 CONCLUSION

After an extensive study and analysis of this present work, several conclusions could be drawn

1. The present study found that in order to achieve good quality cated material, design consideraterion for mold design considerations for mold such as gating system, fillet radius, and venting system is crucial to ensures casted material can eliminate defects. Otherwise, design considerations also influence the physical and mechanical properties of casted material.

2. The different pre-heated temperature also affects the condition & physical appearance of the casted material. Undesirable Pre-heated temperature caused many types of defects will becomes such as, shrinkage, misrun, porosity and cold shuts.

3. For surface roughness of the casting parts, the different pre-heated temperature does not affect the values of surface roughness. Surface roughness affected by types of material that will use in the mold. Generally, Permanent mold process such as die casting ,investment casting produce much better roughness values among 0.75 - 6. μm.

4. Subsequently, the values of thickness and dimensions of the casted material were slightly decreased at different pre-heated temperature. When the dimension and thickness pre-heated at 150 Celsius, the values decreased compared with other pre- heated temperature. For pre- heated temperature 200 °c and 350 °c, the values of dimension and thickness not significantly different. The appropriate pre-heated temperature is 280 °c and 350 °c for aluminium alloys to produce good casted products.

5. With different pre-heated temperature, porosity still occurred at casted material. It can conclude pre-heated temperature does not affect the porosity. Porosity occurred when shrinkage or misrun defects becomes on casted materials. Other that, porosity will occurred if a molten metal fail to eliminate all the air in the mold cavity.

5.2 RECOMMENDATIONS

In order to improve the design of mold for die casting process, horizontal mold should be designed instead of vertical mold. The purposed of design horizontal mold because horizontal can provide the velocity of the metal in the cavity not too high. Also horizontal mold can avoid turbulence flow in the cavity.

As the engineering design areas are highly developing in these day, application of design software is very useful. The Finite Element Analysis (FEA) should be widely recognizable to student as it very helpful especially in engineering design study. In casting process, FEA software is crucial to investigated, predicted and improved the molten metal flow, solidification time, heat transfer coefficients and detects some defects from casting process.

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APPENDIX A

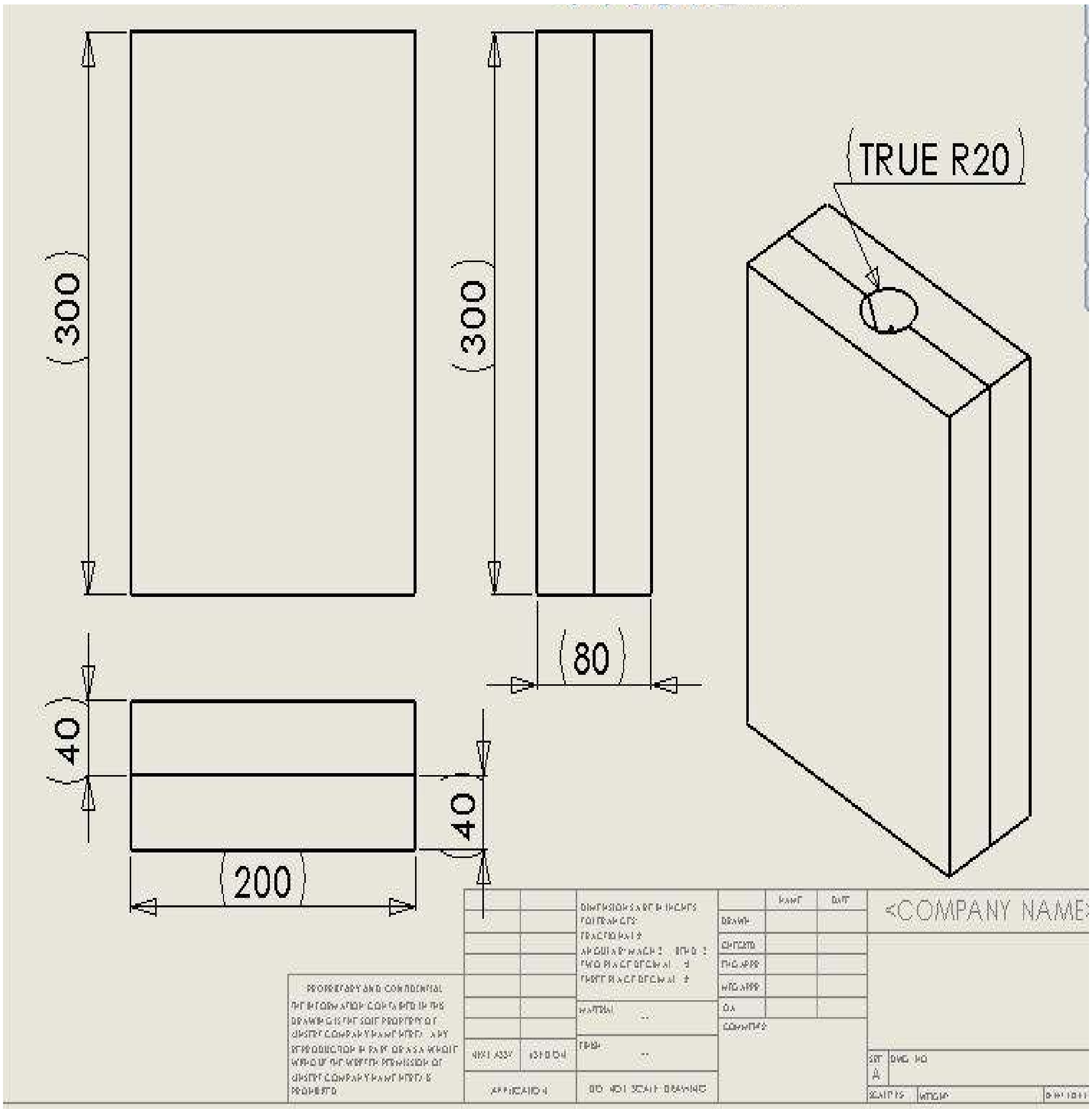


Figure 6.1 : Dimension of Mold

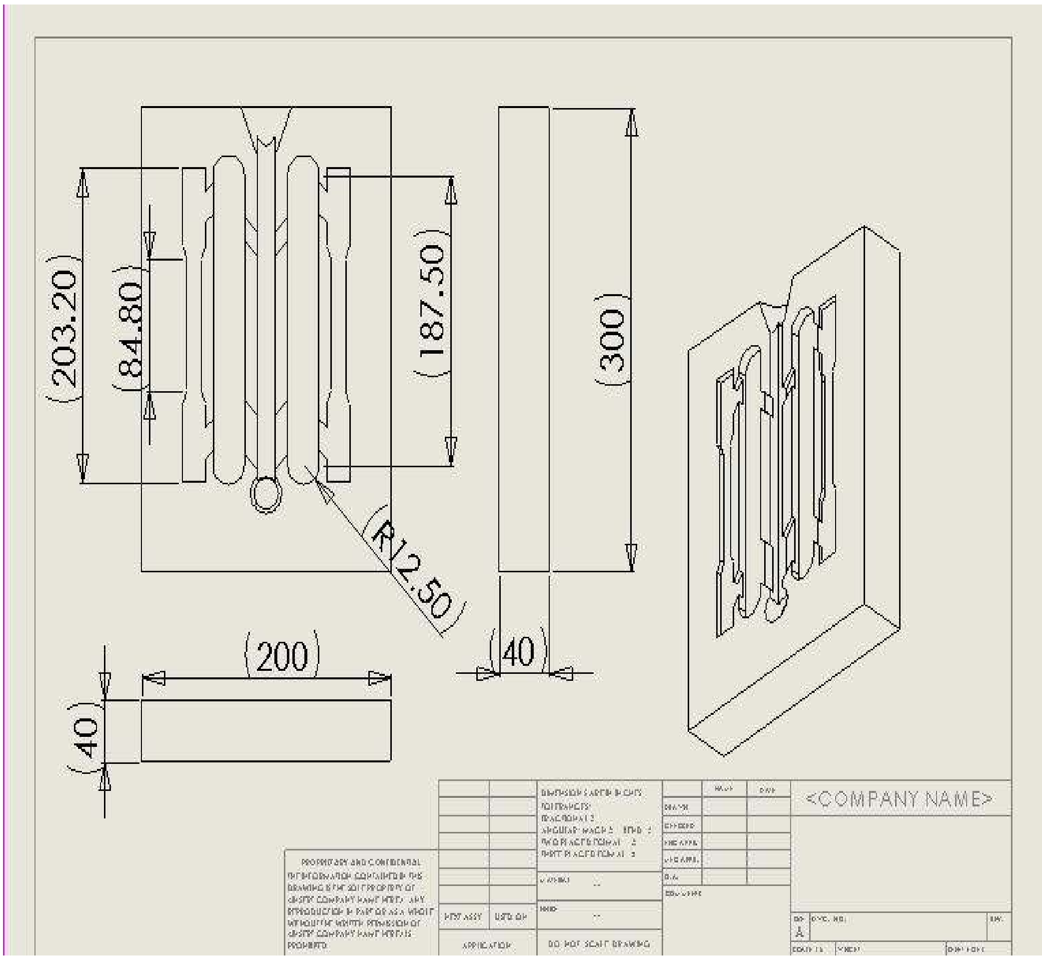


Figure 6.2 : Dimension for back side view of the Mold

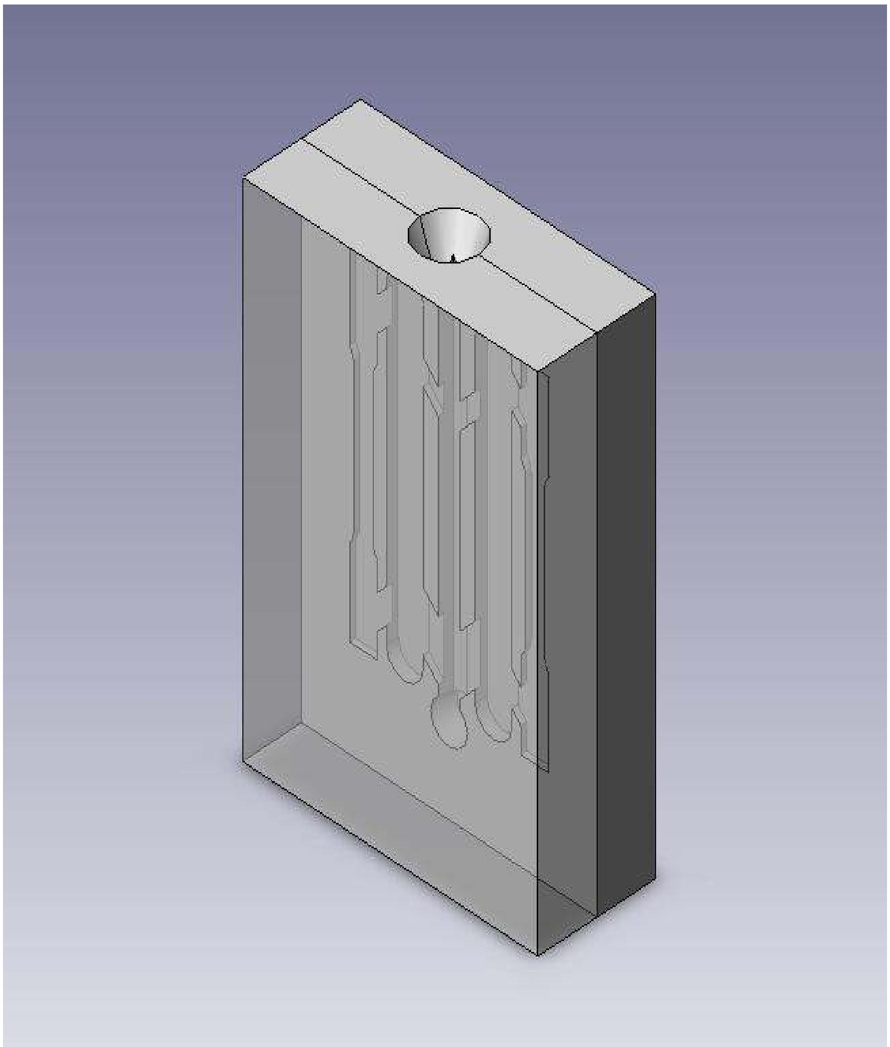
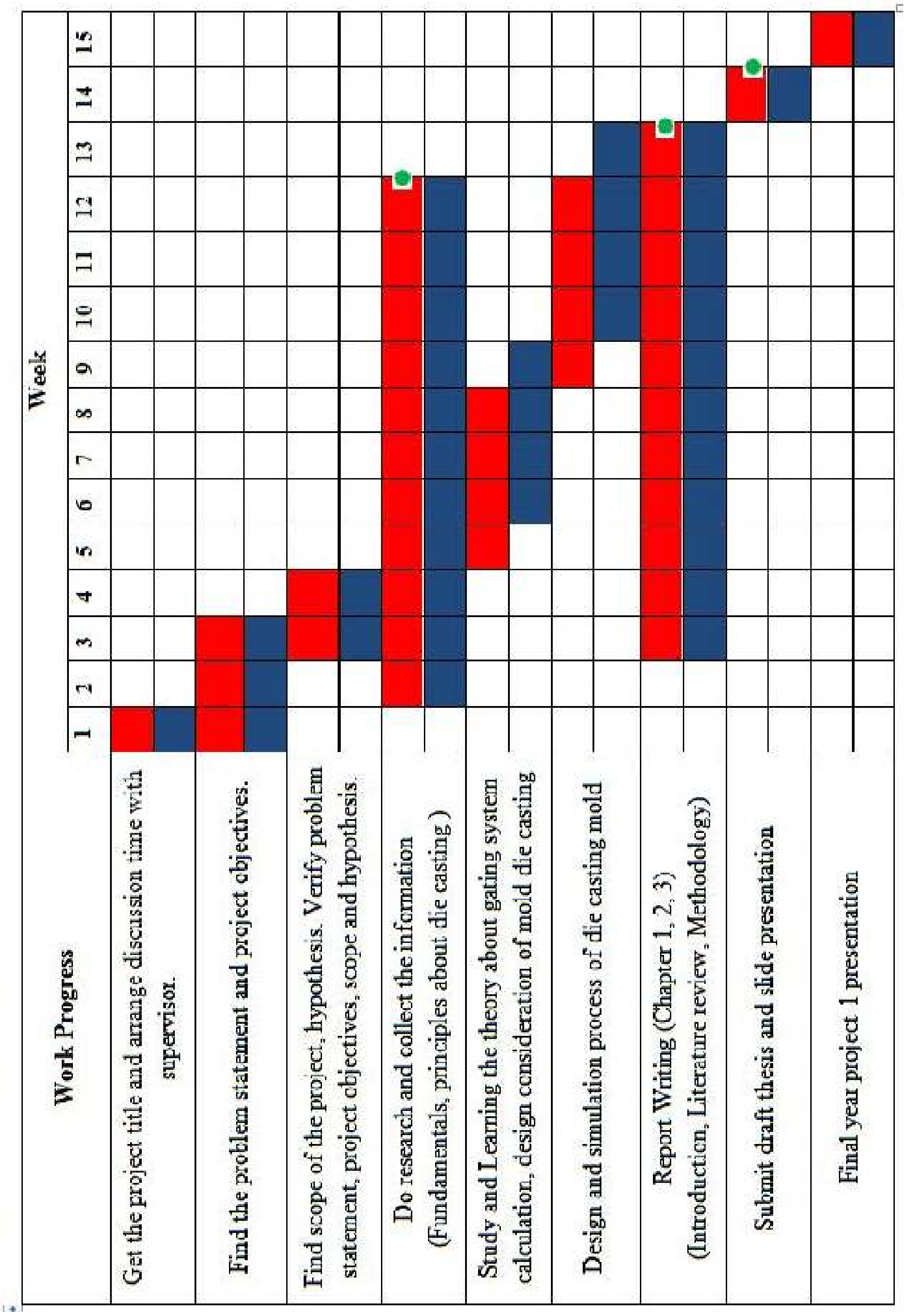


Figure 6.2: Full assembly of Mold

APPENDIX B

PROJECT PLANNING (GANTT CHART): FINAL YEAR PROJECT 1



PROJECT PLANNING (GANTT CHART): FINAL YEAR PROJECT 2