A STUDY ON MOLD MATERIAL AND COATING EFFECT IN SAND CASTING PROCESS

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SUPERVISOR'S AND CO-SUPERVISOR DECLARATION

We hereby declare that we have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

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

Signature
Name:
ID Number:
Date:

For my beloved parents that give a lot of support to me, my friends that fighting alongside me and my supervisor and co-supervisor that trying hard giving me ideas in completes this thesis.

Your unconditional love means the world to me….

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ABSTRACT

Surface finish is the most desired characteristics to be on product surface. This is because surface finish is a predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. In this study, the impact of mold material and coating on surface finish in sand casting was investigated. By using different kind of material to make the mold and evaluating whether coating give effect to product surface finish, the experiment had been done in 4 different tests by using sand casting process as a method to make the final product. In sand casting process, mold material and coating are two significant concerns, but they have different impact in surface finish. In producing part using sand casting, analyzing test is commonly made between these two features to get good quality surface finish. A result among these two different parameters concerns can be achieved by getting the experiment done which on the other hand, selection of better mold material and use of coating will further provide an improved solution. In this thesis, efforts towards determining good surface finish will be decide using different mold properties and coating. The quality of the surface roughness is determined by using visual and analysis. This Surface Roughness is obtained based on the analyzed using MAHR Perthometer s2. In this present work, the main objective of this study is to analyze the effect of coating between two patterns and decide which one has a better surface finish and to compare mold material whether carbon dioxide, CO_2 molding or Greensand molding with and without coating and their effect in product surface finish. The standard design approach is implemented in this experimental study where it only consists of 2 factors at one time which are coating and mold material.2 patterns and 4 final products are produced, whereby the study output is surface roughness, Ra (µm). In this study, MAHR Perthometer s2 is used to measure the surface roughness. The comparison between pattern and product will be analyzed. From the findings, it is shown that that product that used carbon dioxide CO_2 as mold material and covered with coating has the best surface finish. Based on the study analysis, it is discovered that using green sand as mold material and not using coating produces poor surface finish while carbon dioxide CO_2 with coating produces good surface finish products.

ABSTRAK

Kemasan permukaan adalah suatu ciri yang penting dalam setiap produk.ini kerana kemasan permukaan yang baik akan menjadi penanda aras prestasi bagi setiap komponen mekanikal, kerana ketidakseragaman dalam permukaan boleh terhasil dari keretakan atau pengaratan. Kesan bahan acuan dan kemasan lapisan permukaan didalam proses tuangan pasir dikaji didalam kajian ini. Dengan menggunakan bahan yang berlainan untuk membuat acuan dan penilaian ke atas kesan salutan terhadap kemasan permukaan produk, empat ujian berbeza dijalankan dengan menggunakan proses tuangan pasir sebagai kaedah untuk menghasilkan produk akhir. Didalam proses tuangan pasir, bahan acuan dan salutan menjadi dua faktor yang penting, tetapi kedua-duanya mempunyai kesan yang berbeza terhadap kemasan permukaan. Dalam pengeluaran produk akhir menggunakan tuangan pasir, ujian analisa dilakukan antara dua factor ini, untuk mendapat kemasan permukaan berkualiti baik. Dalam tesis ini, usaha-usaha ke arah menentukan kemasan permukaan yang baik akan ditentukan menggunakan acuan yang berbeza dan salutan. Kualiti kekasaran permukaan adalah dianalisi dengan menggunakan visual dan analisis. Kekasaran permukaan ini diperolehi berdasarkan analisis menggunakan mesin MAHR Perthometer s2. Dalam kajian ini, objektif utama kajian ini adalah untuk analisa kesan salutan antara dua bentuk yang sama dan memutuskan yang mana mempunyai satu kemasan permukaan lebih baik dan untuk membandingkan acuan bahan iaitu karbon dioksida, CO_2 atau greensand dengan atau tanpa salutan dan kesan mereka dalam kemasan permukaan produk. Dalam kajian ini, 2 bentuk contoh dan 4 produk akhir adalah dihasilkan, di mana output kajian adalah kekasaran permukaan, Ra (μm). Dalam kajian ini, MAHR Perthometer S2 digunakan untuk mengukur kekasaran permukaan. Perbandingan antara bentuk asal dan produk akan dianalisiskan. Daripada penemuan-penemuan sebelum ini, ia ditunjukkan bahawa produk yang menggunakan karbon dioksida CO_2 sebagai acuan bahan dan disaluti dengan salutan akan mempunyai kemasan permukaan terbaik. Berdasarkan kajian analisis, ditemui yang menggunakan pasir lembap sebagai acuan bahan dan tidak menggunakan salutan menghasilkan kemasan permukaan yang buruk manakala karbon dioksida CO_2 dengan salutan menghasilkan produk kemasan permukaan baik.

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LIST OF ABBREVIATIONS

AA	Aluminum alloy
Al	Aluminium
ASTM	American Society for Testing and Materials
CAD	Computer-aided drafting
CO_2	Linear generator

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Nowadays, surface finish of the casting product is one important thing to determine the performance of the product. It's depend on how the product being made whether using machining, casting or any other method to make the product. Although living in an age where new technologies demand exotic manufacturing techniques, most products still require traditional manufacturing processes and carry along their inherent environmental ramifications. Developing countries entering mass production, in particular, are taking on an increased environmental burden in manufacturing. Complex products like semiconductors (Williams, 2002) and cars are frequently subjected to life cycle assessments as a part of or in conjunction with environmental impact analyses. For conventional processes like sand casting, such an evaluation is uncommon. Sand casting is one of the methods that require improvement for surface finish. The design of sand molds, which produce castings with high geometric complexity and material properties, has largely been a reactive engineering endeavor. Typically, mold designs go through iterations before a final configuration is achieved. Much of this is due to the uniqueness and complexity of the process itself; and engineers in this industry are continuously gaining more insight into control of the key variables every day largely through focused experimentation and experience. An ideal situation would be to control all the key influential process variables to produce a mold design robust enough to produce castings to the required specifications.

Apart from that, different mold material and uses of coating will determine whether the final product will have good surface finish in sand casting process.

1.2 PROJECT OBJECTIVES

(i) To analyze the effect of coating between two patterns and decide which one has a better surface finish.

(ii) To compare between 2 mold materials whether carbon dioxide,CO_2 molding or Greensand molding with and without coating and their effect on product surface finish

1.3 PROJECT SCOPES

The scopes of the study include:

(i) Design a model of component part of mechanical vise using Solid Works or CAD software.

(ii) Build a prototype of component part of mechanical vise using selected polystyrene.

(iii) Compare whether coating has effect on surface finish.

(iv) To compare between 2 mold materials whether carbon dioxide,CO_2 molding or Greensand molding with and without coating and their effect on product surface finish

1.4 PROJECT BACKGROUND

Mechanical vise is a clamping device usually consists of two jaws closed or opened by a screw or lever which is used to secure a workpiece to the cross slide. In clamping workpiece, vise is important which is it always been using in some process. The surface of the workpiece that been clamped using vise depends on the surface of the vise where a good mechanical vise must have good surface so the workpiece do not damaged because of the clamp.

Using solid work software, component part of mechanical vise will be designed. Then, prototype of the component part of mechanical vise will be built by selected polystyrene using Styrofoam cutter. In this process, two parameters will be tested which are coating effect and mold material. Final product will be made using sand casting process where better surface finish of the final product will be selected between the 2 types of mold material and coating effect.

1.5 PROBLEM STATEMENT

Surface finish is the most desired characteristics to be on machined surface. It’s a predictor of the performance since irregularities may form cracks or corrosions leads to failure. Worst surface finish will effect the performance of the vise where the surface of the vise must have good surface finish to clamp the workpiece, so that the workpiece will not damaged when machining. The aim of this study is to find out the answer whether good surface finish depends on mold material, coating effect or mold design by using sand casting process.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews about literature review of some recent project or existing experiment. In this experimental study, there will be two phases. Pattern using selected polystyrene of mechanical vise being make in phase one while mold material and coating effect being investigated in phase two. In this chapter, it will explain about how the pattern being made using polystyrene, sand casting process, surface roughness and material used.

2.2 PRODUCT MEASUREMENT

Process digitizing or measuring component is very important where this process is process is aimed to find out the product dimensions. There are two types of this product measurement which are called contact method and without contact method. For this experimental study, contact method will be used in measuring the surface roughness. MAHR perthometer s2 will be used for measuring the shaft surface roughness, Ra. This machine is in high level quality, results in the nanometer range and its tolerance monitoring with optic and acoustic signaling. The ranges or resolution of this machine are ± 25 μm/0.8 nm (± 1,000 μin/0.032 μin). This machine is including with PZK drive unit with integrated datum plane for precise measurements up to 20 mm (0.787 in) tracing length (MarSurf, 2007)

Figure 2.1: MAHR Perthometer S2

Source: MarSurf (2007)

2.3 MATERIAL USED

Material that been used in this study will described with detail in below.

2.3.1 Rapid Tooling (RT)

Rapid tooling is a standardized process for building both aluminum and steel injection molds to achieve an expedited delivery. The molds can be built as prototype tools or unit tools. Prototype tools are used when the customer is only concerned with the end product which is a part that meets their specifications. Unit tools are used when the customer requires a part that not only meets the required results, but also processes similar to a production tool. Prototype tools are typically less expensive, faster to build and usually used when volumes are less than 10,000 parts, while unit tools are often used when volumes up to 50,000 or more are required. Unit tools are typically more complex but can

usually be completed within 3 - 5 weeks. Depending on the application both types of tooling can be employed to meet low volume production needs as well.
The criteria to distinguish rapid tooling from conventional tooling include:

(i) Build time is much shorter
(ii) Cost is lower
(iii) Tool life is considerably less
(iv) Tolerances are wider

2.3.2 Indirect Tooling

Indirect RT methods are alternatives to traditional mould making techniques. The aim of these RT methods is to fill the gap between RP and hard tooling by enabling the production of tools capable of short prototype runs. The broad range of indirect RT solutions makes it difficult to determine the most appreciate method for a particular project. Most rapid tooling today is indirect: RP parts are used as pattern for making moulds and dies. RP models can be indirect used in a number of manufacturing processes:

(i) Sand casting
(ii) Vacuum casting
(iii) Investment casting
(iv) Injection molding

2.4 SURFACE METROLOGY

Surface metrology is the measuring of small-scale features on surfaces, and is a branch of metrology. Surface primary form, surface waviness and surface roughness are the parameters most commonly associated with the field. It is important to many disciplines and is mostly known for the machining of precision parts and assemblies which contain mating surfaces or which must operate with high internal pressures. Surface Metrology is the study of surface geometry, also called surface texture or surface roughness. The approach is to measure and analyze the surface texture in order to be able to understand how the texture is influenced by its history, (e.g. manufacture, wear, and fracture) and how it influences its behavior (e.g. adhesion, gloss, friction).

2.4.1 Surface Roughness

Finest surface roughness is the most desired characteristic to be on machined surface. Good quality surfaces improve the fatigue strength, corrosion and wear resistance of the workpiece. The roughness of the surface can be measured by calculating the arithmetic mean value (Ra) as the best estimate for the true value of a set of experimental measurements (Alp Mithat Ozano¨zgu, 2000). In this research, there are two separate directions of surface roughness measurement taken to determine the different value from both sides. Average surface roughness on horizontal direction measurement is expected more critical than vertical direction due to the position of the lay direction. Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion.

Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application. In this project, a study of roughness parameters obtained through the use of these manufacturing processes will be made. For roughness height, it is the height of the irregularities with respect to a reference line. It is measured in millimeters or microns or micro inches. It is also known as the height of unevenness. While for roughness width, the roughness width is the distance parallel to the nominal surface between successive peaks or ridges which constitute the predominate pattern of the roughness. It is measured in millimeters.

For waviness, this refers to the irregularities which are outside the roughness width cut off values. Waviness is the widely spaced component of the surface texture. This may be the result of work piece or tool deflection during machining, vibrations or tool run out. For example, Figure 2.2 shows sandpapers of different Bgrits.

Figure 2.2: Surface roughness. These are photographs of pieces of sandpaper of varying grit painted the same shade of gray

Source: Dr. Caleb M. Li 1999

The resultant roughness produced by a machining process can be thought of as the combination of two independent quantities which are ideal roughness and normal roughness.

2.4.2 Ideal roughness

Ideal surface roughness is a function of only feed and geometry. It represents the best possible finish which can be obtained for a given tool shape and feed. It can be achieved only if the built-up-edge, chatter and inaccuracies in the machine tool movements are eliminated completely.

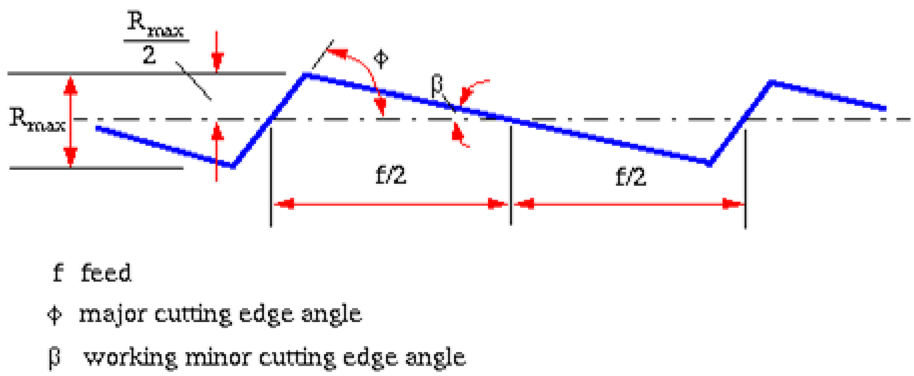

Figure 2.3: Idealized Model of Surface Roughness

Source: Dr. Mike S. Lou 1999

2.4.3 Natural Roughness

In practice, it is not usually possible to achieve conditions such as those described above, and normally the natural surface roughness forms a large proportion of the actual roughness. One of the main factors contributing to natural roughness is the occurrence of a built-up edge. Thus, larger the built up edge, the rougher would be the surface produced, and factors tending to reduce chip-tool friction and to eliminate or reduce the built-up edge would give improved surface finish.

2.4.4 Surface Texture

The terms surface finish and surface roughness are used very widely in industry and are generally used to quantify the smoothness of a surface finish. In 1947, the American Standard B46.1-1947, "Surface Texture", defined many of the concepts of surface metrology and terminology which overshadowed previous standards. A few concepts are discussed and shown as follows (Brosheer, 1948; Hommel, 1988; Olivo, 1987; ASME, 1988):

(i) Surface texture: Surface texture is the pattern of the surface which deviates from a nominal surface. The deviations may be repetitive or random and may result from roughness, waviness, lay, and flaws.

(ii) Waviness: Waviness should include all irregularities whose spacing is greater than the roughness sampling length and less than the waviness sampling length.

(iii) Lay: Lay is the direction of the predominant surface pattern, normally determined by the production method.

(iv) Flaws: Flaws are unintentional, unexpected, and unwanted interruptions in the topography typical of a part surface.

(v) Roughness sampling length: The roughness sampling length is the sampling length within which the roughness average is determined. This length is chosen, or specified, to separate the profile irregularities which are designated as roughness from those irregularities designated as waviness.

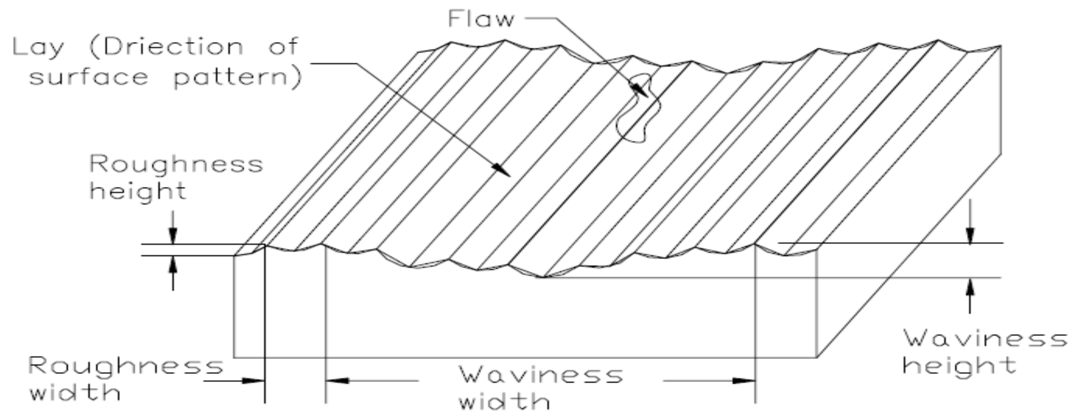

Figure 2.4: Roughness and Waviness Profile

Source: Hommel, 1988

2.4.5 Surface Finish Parameters

Surface finish could be specified in many different parameters. Due to the need for different parameters in a wide variety of machining operations, a large number of newly developed surface roughness parameters were developed. Some of the popular parameters of surface finish specification are described as follows:

i. Roughness average (Ra): This parameter is also known as the arithmetic mean roughness value, AA (arithmetic average) or CLA (center line average). Ra is universally recognized and the most used international parameter of roughness. Therefore, surface roughness average is expressed as in Eq. (2.1)

$$R_a = \frac{1}{L}\int_0^L |Y(x)| dx \tag{2.1}$$

Where Ra = the arithmetic average deviation from the mean line

L = the sampling length

y = the ordinate of the profile curve

It is the arithmetic mean of the departure of the roughness profile from the mean line.

ii. Root-mean-square (rms) roughness (Rq): This is the root-mean-square parameter corresponding to Ra is expressed as in Eq. (2.2)

$$R_q = \sqrt{\left[\frac{1}{L}\int_0^L (Y(x))^2 dx\right]} \tag{2.2}$$

iii. Maximum peak-to-valley roughness height (Ry or Rmax): This is the distance between two lines parallel to the mean line that contacts the extreme upper and lower points on the profile within the roughness sampling length. Since Ra and Rq are the most widely used surface parameters in industry, Ra was selected to express the surface roughness in this study.

2.5 SAND CASTING

Sand Casting is a process used to make many metal copies from a master part. Almost any metal can be cast, but zinc, aluminum, brass, bronze and iron are the most commonly used materials. Sand casting is an ancient art that is still widely used today. For sand casting process, the need is a work space, preferably outside and clears of anything combustible. The process starts by making a master part. The master part is called a “pattern”. A pattern is typically made of wood, but can be made of almost any durable material. The pattern is placed in a 2 part box, called a “flask”, and is covered on all sides by special sand. The flask is split in two so it can be opened and the pattern removed from the sand. After the pattern is removed, a cavity is left in the sand that can be filled with molten metal, producing a copy of the original pattern. After the molten metal cools the part is “shaken out” of the sand, cleaned of clinging sand, and finished as needed. (Metal Casting Zone, 2009). There are few basic Requirements for metal casting:

(i) A mold cavity
(ii) Melting process
(iii) Pouring technique
(iv) Solidification process
(v) Removal of casting
(vi) Finishing draft allowance

Sand Casting is the most important and mostly used casting technique. To perform sand casting we have to form a pattern (a full sized model of the part), enlarged to account for shrinkage and machining allowances in the final casting.

The cavity in the sand is formed by using a pattern (an approximate duplicate of the real part). Materials used to make patterns include wood, plastics, aluminum, fiberglass, cast iron and some other metals. Wood is a common pattern material because it is easily worked into shape. Its disadvantages are that it tends to warp and the sand being compacted around it abrades it, thus limiting the number of times it can be reused (used for a small number casting). Metal patterns are more expensive to make, but they last much longer. For example aluminum is the most common metal to be used if" many castings are to be made by the same pattern. So selection of the appropriate pattern material depends to a large extent on the total quality of castings to be made. The size of the pattern depends upon the shrinkage during cooling and the finishing allowance (Stephanie Dalquist, 2004).

The cavity is contained in an aggregate housed in a box called the flask. Core is a sand shape inserted into the mold to produce the internal features of the part such as holes or internal passages. Cores are placed in the cavity to form holes of the desired shapes. Core print is the region added to the pattern, core, or mold that is used to locate and support the core within the mold. A riser is an extra void created in the mold to contain excessive molten material. The purpose of this is feed the molten metal to the mold cavity as the molten metal solidifies and shrinks, and thereby prevents voids in the main casting.

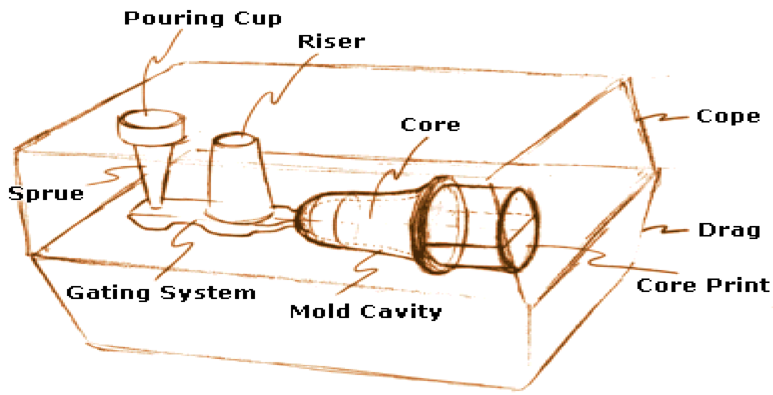

Figure 2.5: Sand Casting Diagram

Source: Stephanie Dalquist, 2005

2.5.1 Typical Components of a Two-part Sand Casting Mold

In a two-part mold, which is typical of sand castings, the upper half, including the top half of the pattern, flask, and core is called cope and the lower half is called drag. The parting line or the parting surface is line or surface that separates the cope and drag. The drag is first filled partially with sand, and the core print, the cores, and the gating system are placed near the parting line. The cope is then assembled to the drag, and the sand is poured on the cope half, covering the pattern, core and the gating system. The sand is compacted by vibration and mechanical means. Next, the cope is removed from the drag, and the pattern is carefully removed. The object is to remove the pattern without breaking the mold cavity. This is facilitated by designing a draft, a slight angular offset from the vertical to the vertical surfaces of the pattern. This is usually a minimum of 1° or 1.5 mm

(0.060 in), whichever is greater. The rougher the surface of the pattern, more draft to be provided.

2.5.2 Advantages and Disadvantages of Sand Casting

In this experimental study, sand casting been chosen to produce the product. The reason sand casting had been chose because sand casting can be used to create complex pad geometries, including goth external arid internal shapes. Some casting operations are capable of producing parts to net shape. No further manufacturing parts are needed. Besides, casting process can be performed on any metal that can be heated to the liquid state. Some casting methods are highly suited far mass production and casting is the easiest and quickest way (technique) from drawing (design) to the production.

Every casting technique has weaknesses where for sand casting also has the disadvantages. Firstly, sand casting has limitation on mechanical properties. Besides, it will provide porosity (empty spaces within the metal - reduces the strength of metal). It will also produce poor dimensional accuracy and surface finish. The worst disadvantages is hazard from sand casting can affect human health and environmental and removal of pattern of the thin and small parts is very difficult.

2.5.3 Casting Defects

There are numerous opportunities in the casting operation for different defects to appear in the cast product. Some of them are common to all casting processes:

(i) Misruns (due to rapid solidification in the runner)

(ii) Cold shuts (due to rapid solidification before complete filling of the mold)

(iii) Cold shots (due to splattered globules of metal during pouring)

(iv) Shrinkage cavity (due to lack of riser system)

(v) Micro porosity (due to localized solidification shrinkage)

(vi) Hot tearing (due to the die's prevention of contraction)

2.5.4 Patterns

Patterns in sand casting are used to form the mold cavity. One major requirement is that patterns (and therefore the mold cavity) must be oversized:

(i) To account for shrinkage in cooling and solidification
(ii) To provide enough metal for the subsequence machining operation.

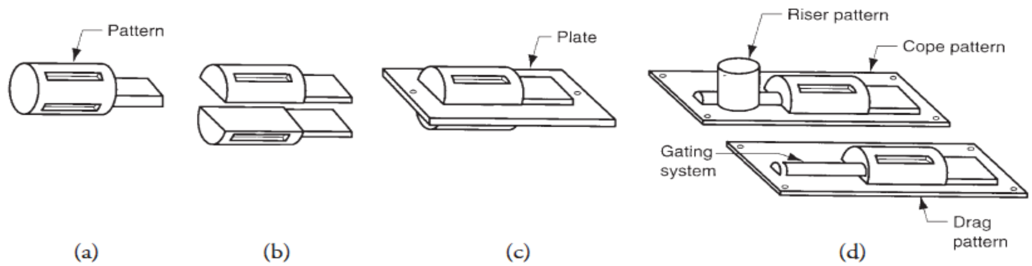

Figure 2.6: Types of Patterns Used in Sand Casting

Source: Pkwon 2004

(a) solid pattern, (b) split pattern, (c) match-plate pattern, and (d) cope-and-drag pattern

Polystyrene cutter as shown in figure 2.7 below is used to make the product pattern from selected polystyrene according to design that been designed using solidWork software for this experimental study.

Figure 2.7: Cutter for Polystyrene

2.5.5 Cores

Cores serve to produce internal surfaces in castings. In some cases, they have to be supported by chaplets for more stable positioning:

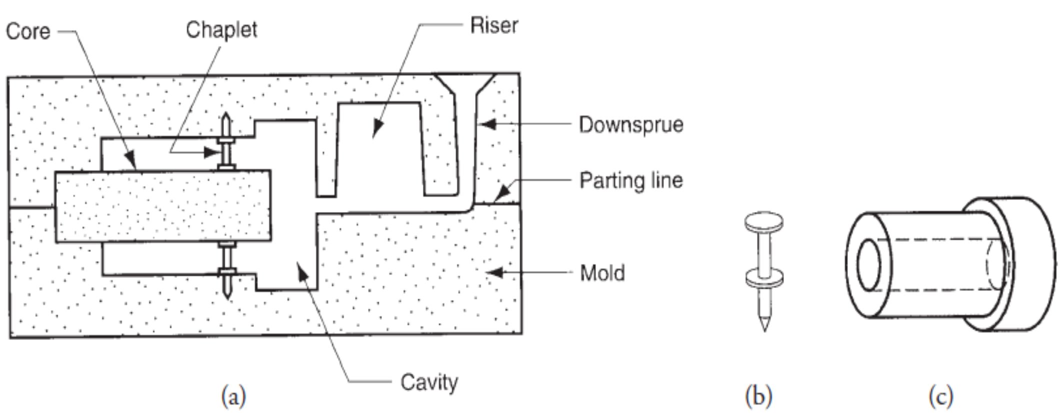

Figure 2.8 (a) Core held in place in the mold cavity by chaplets, (b) chaplet design, (c) Casting with internal cavity

Source: Valery Marinov 2007

Cores are made of foundry sand with addition of some resin for strength by means of core boxes:

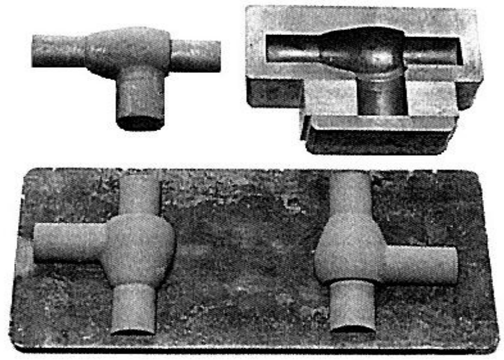

Figure 2.9: Core box, two core halves ready for baking, and the complete core made by gluing the two halves together

Source: Valery Marinov 2007

2.5.6 Foundry Sands

The typical foundry sand is a mixture of fresh and recycled sand, which contains 90% silica (SiO2), 3% water, and 7% clay. The grain size and grain shape are very important as they define the surface quality of casting and the major mold parameters such as strength and permeability: Bigger grain size results in a worse surface finish, Irregular grain shapes produce stronger mold and larger grain size ensures better permeability

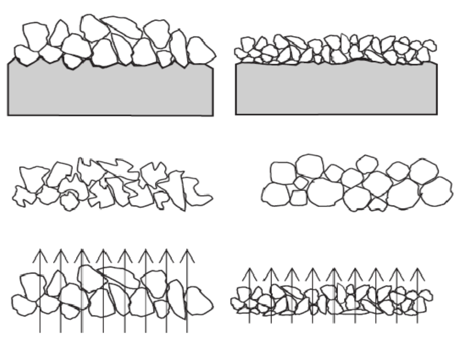

Figure 2.10: Different Grain Sizes and Shapes of Sand

Source: Valery Marinov 2007

2.6 Types of Mold Material in Sand Casting

In this experimental study, two different types of mold will be tested in order to determine which type will give better surface roughness for the final product. The types that will be tested are green sand mold and carbon dioxide, CO_2 mold.

2.6.1 Green Sand Mold

Green sand is a type of casting sand that many prefer since its ability to retain the shape of the mold is far better than normal sand. Green sand usually contains bentonite clay, sand, and water. Green sand molds can be used only once, which may be considered inefficient compared to permanent molds, but sand casting are also inexpensive and easy to make and change. While sand casting has its benefits, the use of green sand can greatly increase the likelihood of a successful casting. Green sand is not really green the color refers to the damp nature of the sand. Green sand is created by adding water and bentonite to the sand. One of the benefits of using bentonite in green sand is that it makes the sand more permeable which allows more gas to escape. Metal casters can get the bentonite from a variety of sources like home improvement stores and even from household resources. There are several recipes online for green sand but the most common method is experimentation. The best mixture of the sand, water, and bentonite is when the texture is not wet but damp and will retain its shape when molded. The type of sand that been used to make green sand depends on metal caster and the availability of the sand. Many will use sand that they found out in the wilds of nature and some will buy bags of sand like playground sand. Green sand is growing in popularity as more casters are recognizing the properties of this method. The best part about green sand casting is that is does not cost a lot of green (Metal Casting Zone, 2009)

Figure 2.11: Green Sand.

2.6.2 Carbon Dioxide (CO_2) Molding

Carbon dioxide molding is a sand casting process that employs a molding mixture of sand and liquid sodium silicate binder. The molding mixture is then hardened by blowing carbon dioxide gas through it. This method offers a great deal of advantages over other forms of sand molding. It reduces production time as well as fuel costs and reduces the number of mould boxes required for making moulds. This process also offers a great deal of accuracy in production. Carbon dioxide moulding process has many advantages over other forms of sand moulding. But it is not more economical to do than green sand moulding, but moulds can be made to much closer tolerances, which can reduce machining time of castings, this will only appeal to commercial operators, and not be of much concern to the hobby caster, where time taken to do a certain process is not important. But as green sand gets more difficult to find or make, then this form of mould and core making can be of great benefit for the hobby caster.

Carbon dioxide gas (CO_2) will allow a reduction in the number of mould boxes required for making moulds. It will make cores and moulds are gassed or hardened in situ, lessening the labor involved in mould making. Because moulds are hardened with patterns in position, a high accuracy is achieved. With careful molding practice some castings can be produced with tolerances very close to shell molding. Besides, carbon dioxide gas, CO_2 provides good dimensional tolerances through strong core and mold and it's also provides excellent casting surface finishes. Generally used for high-production runs. Next, it's accommodates a wide range of core and mold sizes. When used for making cores, the CO_2 process can be automated for long durations and speedy production runs. Also, existing pattern making equipment can be used.

2.7 COATING

Coating is a covering that is applied to an object. The aim of applying coatings is to improve surface properties of a bulk material usually referred to as a substrate. One can improve amongst others appearance, adhesion, wetability, corrosion resistance, wear resistance and scratch resistance. Coatings may be applied as liquids, gases or solids. It is well known that to increase the life of a mold and to make the removal of the casting easier, the surfaces of the mold cavity must be coated with a protective material. In the case of sand castings however it is the pattern which must be coated. Prior art coating compositions however deal primarily with mold coatings rather than pattern coatings. Hence these materials will first be considered. In this experimental study, the coating material is starch. As described, it is concerned with a method of protecting foundry molds from eroding and pitting during sand casting by preventing adherence of casting sand to surfaces of casting patterns.

High production iron foundries worldwide typically utilize silica sand for core production due to its availability and relatively low cost compared to other refractory sands. Poor refractoriness of the silica sand can lead to sand burn-in and metal penetration defects. However it is generally accepted that these defects can be overcome through the use of coatings. The typical outcome is the formation of sand expansion defects known as "veins" or "fins" (figure 2.12).

Figure 2.12: Example of Vein Defects in Cylinder Head

Source: H. Hocheng, 2001

2.7.1 The Effect of Coating on the Cooling of the Metal

Immediately after casting the temperature of the metal cools rapidly, and then adopts a comparatively lower cooling rate. The use of a core coating and the type of coating has a minor effect on this subsequent cooling rate, where no coating is used the metal temperature reaches 1100°C in 5.0 minutes, whereas with the highest insulating coating it takes 6.4 minutes (figure 2.13).

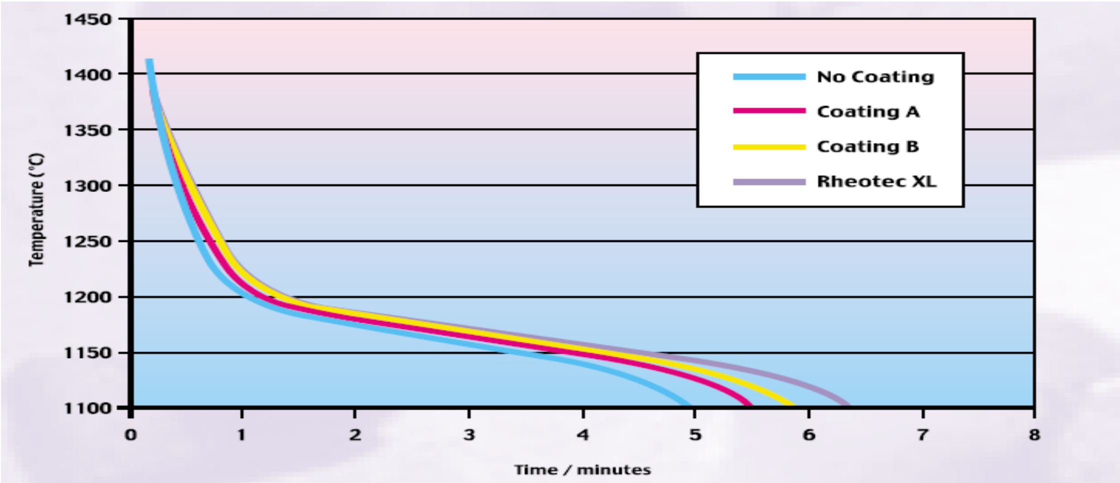

Figure 2.13: Example of Coating Effect Graph

Source: Y.H. Guu 2001

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter is discussed the ideas about the method how to implement this research. In this study, there are a few categories in this methodology process. The categories are experimental design, data analysis, study procedures, instrumentation and materials.

Selected polystyrene will be used to build the prototype or pattern of mechanical vise. There will be two prototype of mechanical vise that will be produced by considering one parameter namely surface roughness. First pattern or mechanical vise will be made without covering it with starch (coating) and the other one will be covered by starch (coating).

Figure 3.1 is an overview about the overall steps during the research. Based on the literature review, the design factor, the level of experiment, and the experiment layout using orthogonal array was developed. The significant of the factors on the performance measures (surface roughness) are studied. The study is done using surface roughness, Ra machine.

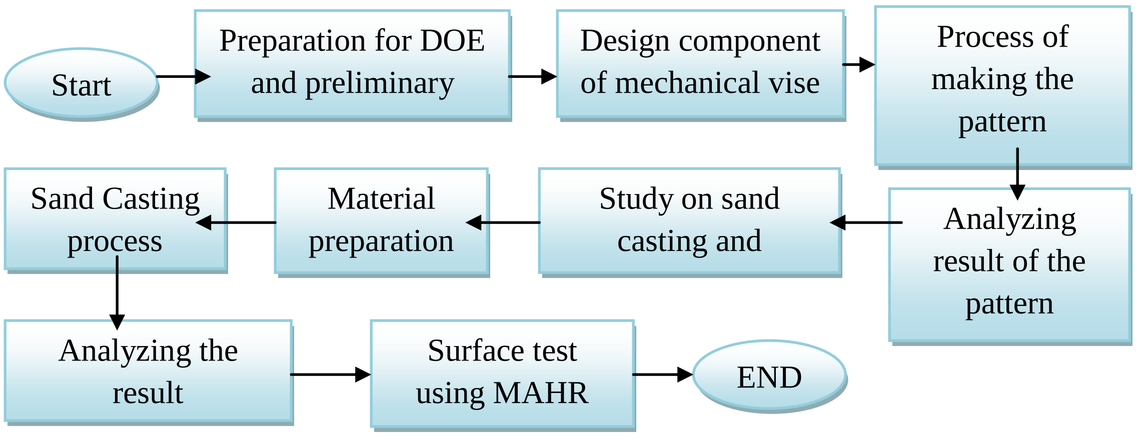

Figure 3.1: Overview Flowchart of Research Methodology

3.2 EXPERIMENTAL DESIGN

There are many types of methods in planning, conducting experiment and analyzing data from the experiments. Some of the methods require the experiment to be run repetitively in order to determine the average results from the repetitive experiments. The average value will represent the overall result of the experiment. However, this type of method only considers one experimental variable (factor) in the same experiment. It is called single factor experiment. Interaction, combinations and joint effects of various variables could not be analyzed or determined in this method. More and more experiment should be repeated if the experimenter wishes to identify the effect of other combinations. Therefore, this experimental study is designed with different types of mold material and coating effect for phase two. Experiments are conducted using a standard design with two levels of each factor. Finally, the study output and surface finish (Ra) will be derived.

Some work has been done with Design of Experiment techniques to determine the effect of process parameters on the quality of a prototype. Surface finish on prototypes is becoming more and more important with more parts being used for end purposes. Surface finish is critical not only for better functionality and look, but also for cost reduction in terms of reduced post-processing of parts (this includes sanding, filing) and overall prototyping time reduction also.

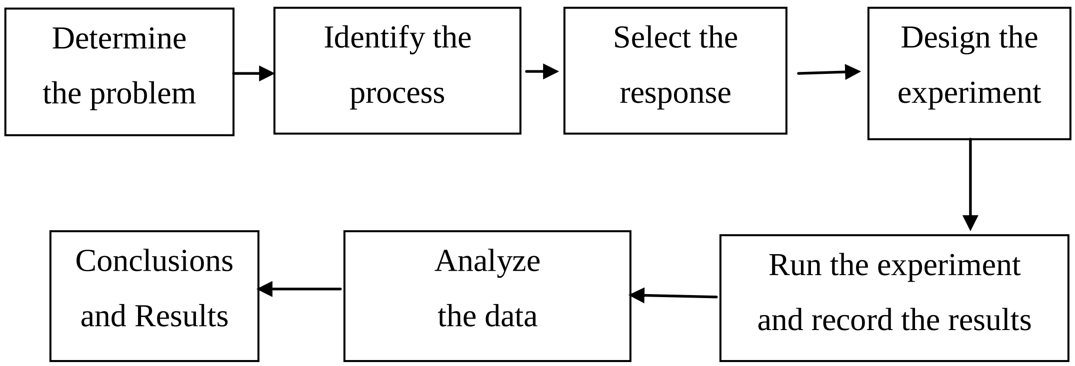

Figure 3.2: Designed Experiment Sequence

3.2.1 Parameters of Study

The factors refer to the experimental parameters that could affect the result of the product. In this study, the factors can be divided into two mainly effect of coating on pattern surface and mold materials. The pattern and final product will be examined later to estimated the surface roughness (Ra) where differences between actual pattern and real product using the sand casting process. Next, which types of mold material and coating effect will give better surface finish in sand casting process will be studied.

3.2.2 Number of trials

After selecting the parameters, the level of the parameters must be identified. Levels of the parameters refer to its varied condition during the experiment. Repetitive experiments are important to determine the average results for each factor. Table below shows the total number of trial by MAHR perthometer s2 machines that been used to analyze the surface roughness, Ra.

Table 3.1: Number of Trials by MAHR perthometer s2 (for pattern)

Part	**No. of trial**	**Surface Roughness, Ra (µm) ± 25 µm/0.8 nm**					
		A	**B**	**C**	**D**	**E**	**F**
Actual Pattern(without coating)	**1**						
	2						
	3						
	Mean						
Actual Pattern (with coating)	**1**						
	2						
	3						
	Mean						

Table 3.2: Number of Trials by MAHR perthometer s2 (Product)

Part	No. of trial	Surface Roughness, Ra (µm) ± 25 µm/0.8 nm					
		A	**B**	**C**	**D**	**E**	**F**
Carbon Dioxide(with coating)	**1**						
	2						
	3						
	Mean						
Carbon Dioxide(without coating)	**1**						
	2						
	3						
	Mean						
Green Sand (with coating)	**1**						
	2						
	3						
	Mean						
Green Sand (without coating)	**1**						
	2						
	3						
	Mean						

3.2.3 Measurement of Prototype and Product Surface Roughness Using MAHR Machine

For surface roughness measurement, the prototype pattern and final product of component mechanical vise will use MAHR perthometer S2 machine. The differences between actual between and real product will be recorded.

3.3 DESIGN STAGE

In this study, the pattern of mechanical vise been sketched and the exact dimension of the pattern will being design using solidWork. SolidWork Software is one of the latest software that can help produce engineering drawing in form 3 dimensions by better compared previous software such as AutoCAD's software and others. Figure below shows picture mechanical vise were produced use software solid work.

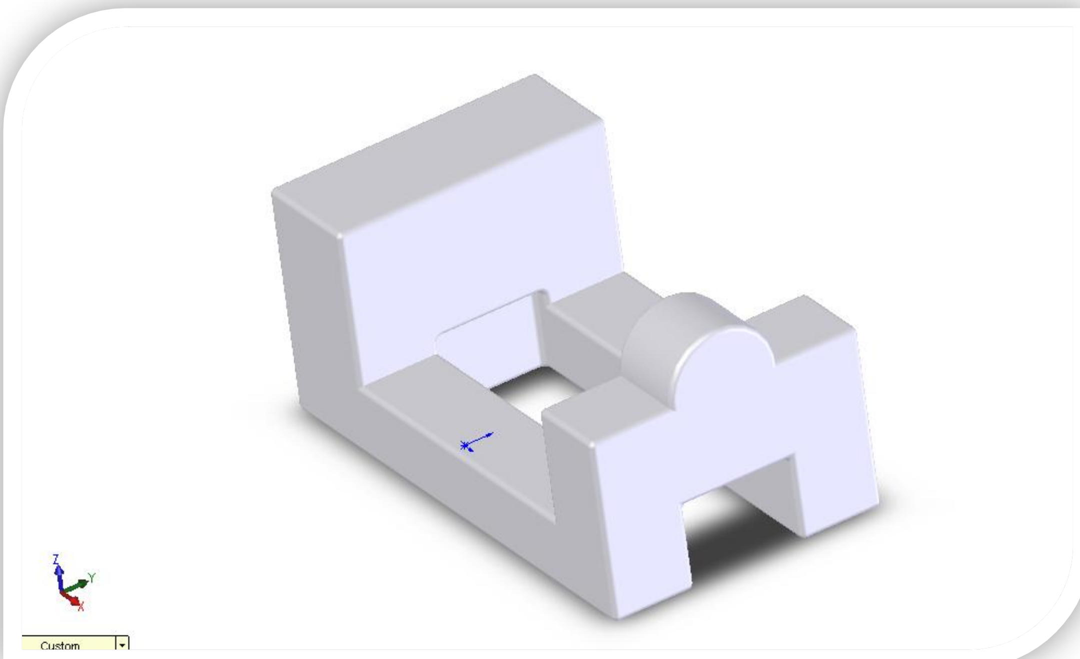

Figure 3.3: Part of Mechanical Vise Using Solidwork Software

Software solidwork can provide hybrid model for industry which is combined with feature modeling and geometric modeling. Besides that, this software is capable to provide complex form such as aerofoil and manifold which is an industrial product and this software also can be used design for installation, component, sketch, sample, jig, equipment, sheet-iron and others.

3.4 SAND CASTING

Sand casting, the most widely used casting process, utilizes expendable sand molds to form complex metal parts that can be made of nearly any alloy. Because the sand mold must be destroyed in order to remove the part, called the casting, sand casting typically has a low production rate. The sand casting process involves the use of a furnace, metal, pattern, and sand mold. The metal is melted in the furnace and then ladled and poured into the cavity of the sand mold, which is formed by the pattern. The sand mold separates along a parting line and the solidified casting can be removed. The steps in this process are described in greater detail in the next section (Valery Marinov, 2007)

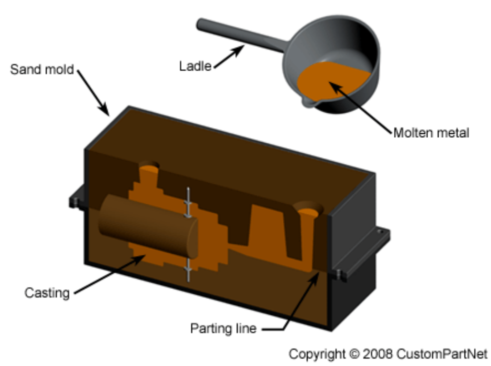

Figure 3.4: Sand Casting Overview

Source: CustomPartNet 2008

The next figure illustrates the basic production steps in sand casting:

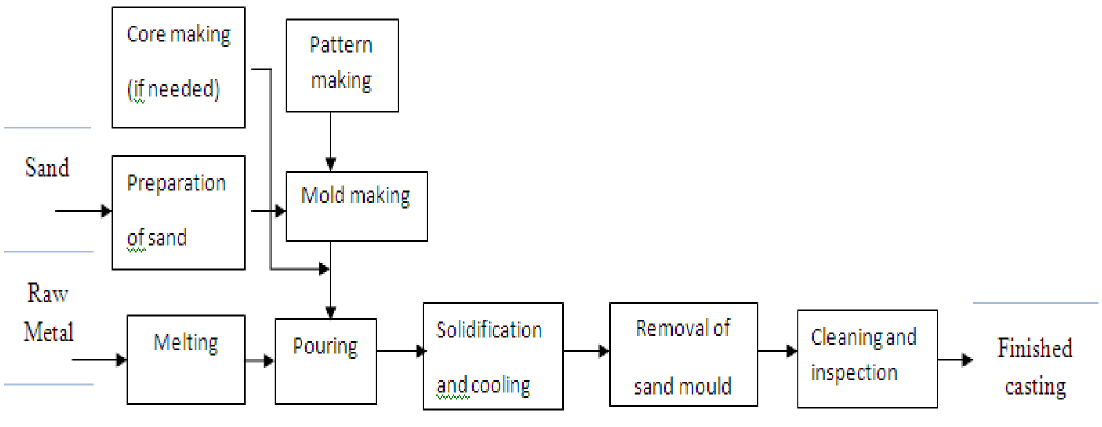

Figure 3.5: Basic Production Steps in Sand Casting

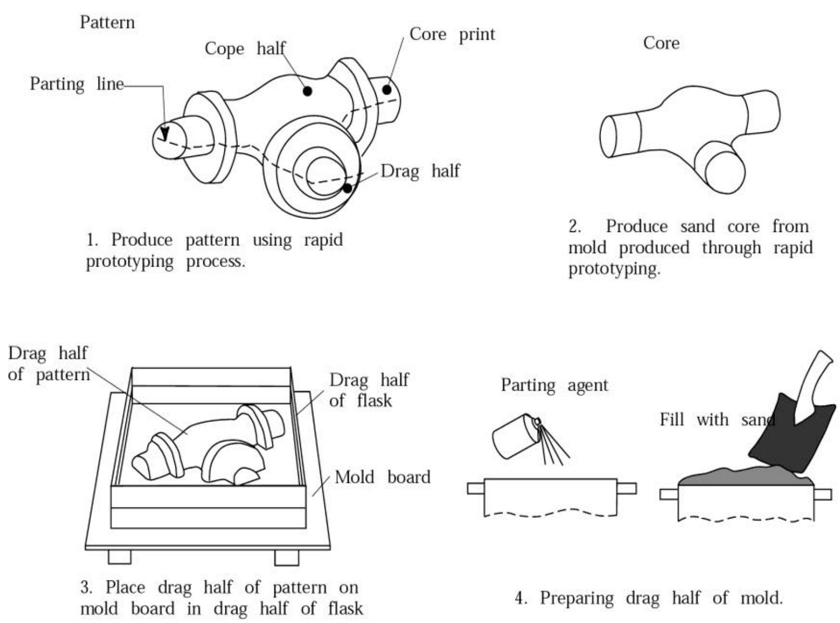

Figure 3.6: Sand Casting Using Rapid-Prototyped Patterns

Source**:** Kalpakjian, 1997

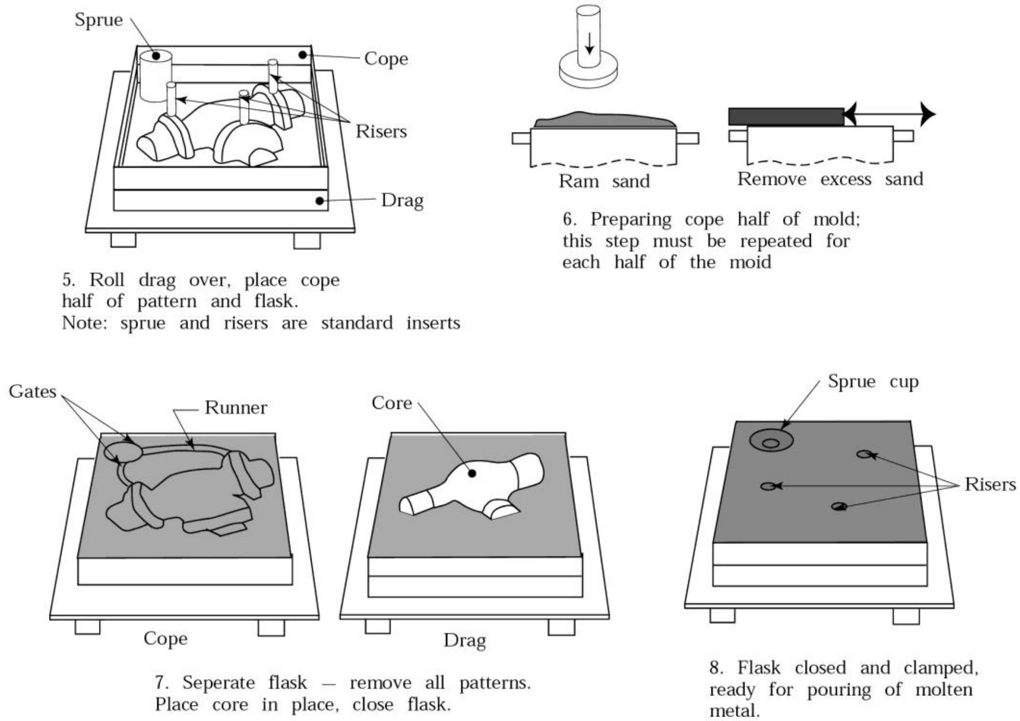

Figure 3.7: Manufacturing Steps in Sand Casting

Source: Kalpakjian 1997

Figure 3.8: Furnace in Sand Casting Machine

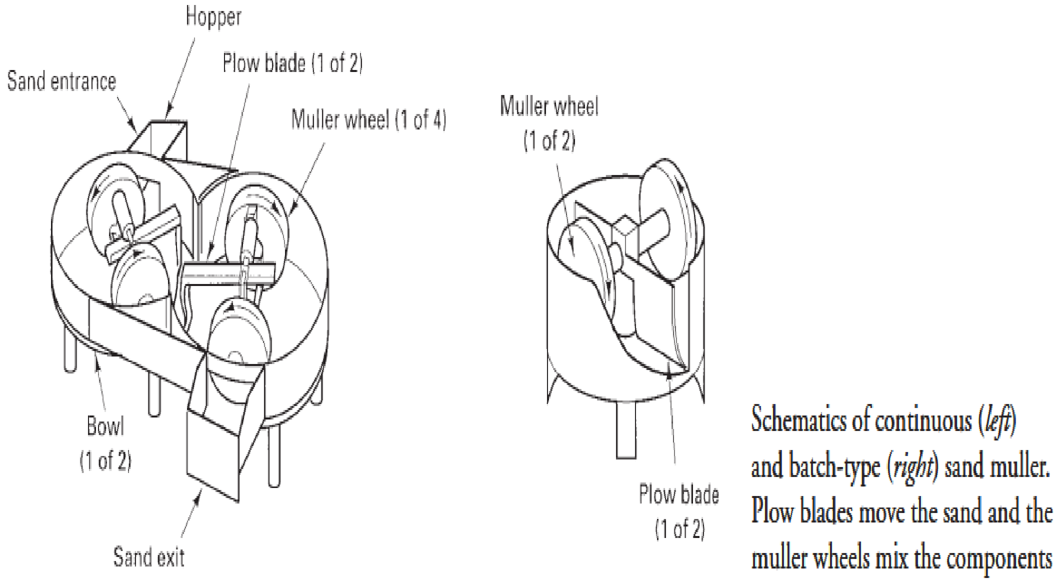

Figure 3.9: Mixing of Foundry Sands

Source: Valery Marinov 2007

Mold making is one of the processes in sand casting. This process is important in determining good surface finish. When do mold making, the packing process must be precisely and the mixture that must be follow for getting good mixture is about for each 14 kg of silica sand, 10 % of clay (bentonite) and 5 % of water must be added and to be mix for about 5 minutes. This quantity is to make sure the sand that undergo mold making not wet but damp and its shape when molded. Mold making can be making in three kinds of ways which are:

(i) Hand packing
(ii) Machine packing
(iii) Automated methods

Figure 3.10: Machine Sand Mixture Place

3.5 RAW MATERIAL IN SAND CASTING

3.5.1 Aluminium

Pure aluminium is a silvery-white metal with many desirable characteristics. The characteristics are:

(i) Non toxic, Non magnetic, Non sparking

(ii) Easily formed, machined, and cast

(iii) Alloys with small amounts of copper, magnesium, silicon, manganese, and other elements have very useful properties.

(iv) Strong. Depending on its purity, for example 99.996 per cent pure aluminium has a tensile strength of about 49 megapascals (MPa), rising to 700 MPa following alloying and suitable heat treatment.

(v) Low density, Corrosion resistant, Electricity conductor, Non-combustible

(vi) Highly reflective, Malleable

Table 3.4 are listed the materials properties of the materials used in this study

Table 3.3: Physical Properties of Aluminium

Physical Properties of Aluminium	
Density/Specific Gravity (g.cm-3 at 20°C)	2.70
Melting Point (°C)	660
Specific heat at 100 °C, cal.g-1K-1 (Jkg-1K-1)	0.2241 (938)
Latent heat of fusion, cal.g-1 (kJ.kg-1)	94.7 (397.0)
Electrical conductivity at 20°C (% of international annealed copper standard)	64.94
Thermal conductivity (cal.sec-1cm-1K-1)	0.5
Thermal emmisivity at 100°F (%)	3.0
Reflectivity for light, tungsten filament (%)	90.0

Source: Valery Marinov (2007)

These properties can be very significantly altered with the addition of small amounts of alloying materials.

3.6 TYPES OF MOLD MATERIAL

In this study, there will be tested two types of mold material which is green sand and carbon dioxide.

3.6.1 Green sand molding

There two types of sand molding use in this research are the one with silica and the other with river sand. For silica sand casting, material use are silica sand and clay that also known as bentonite. For each 14 kg of silica sand, 10 % of clay (bentonite) and 5 % of water are added to be mix for about 5 minute. After that mixed material are compacted in molding box with component part of mechanical vise pattern in it. It is also the similar method use for river sand casting which absolutely use river sand that have been sieve and clay (bentonite) to act as a binder. The ratio of mix material in this casting is for every 14 kg river sand 10 % of clay and 5 % of water are added. Then it will be mixed in mixer for about 5 minute.

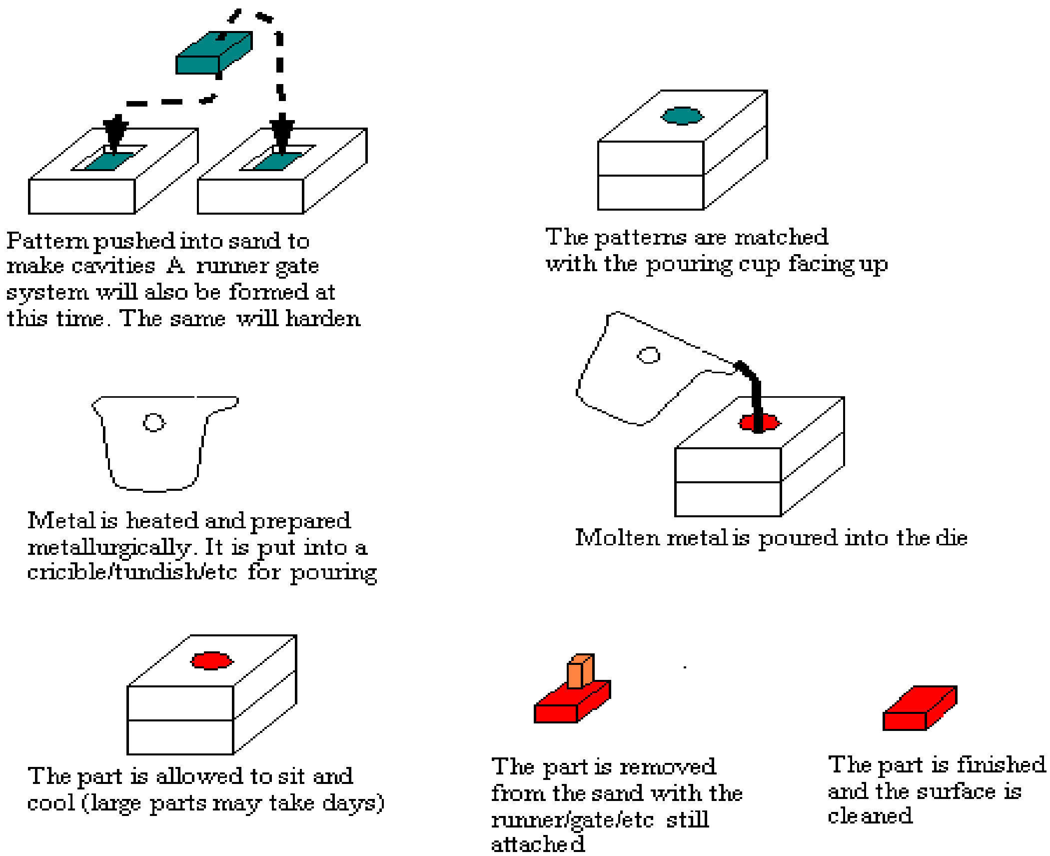

Figure 3.11: Schematic Diagram of Green Sand Casting Process

Source: Tom Clark, 2006

3.6.2 Carbon Dioxide (CO_2) Molding

In CO_2 molding, material such silica sand and sodium silicate as a binder are used. 5 % sodium silicates are mix with 14 kg of silica sand using mixer machine for about 5 minute. This mixed material are use to make mold with the desire pattern. In research, component part of mechanical vise pattern is being used. For example, Figure 3.12 shows the split dog bone pattern in the molding box.

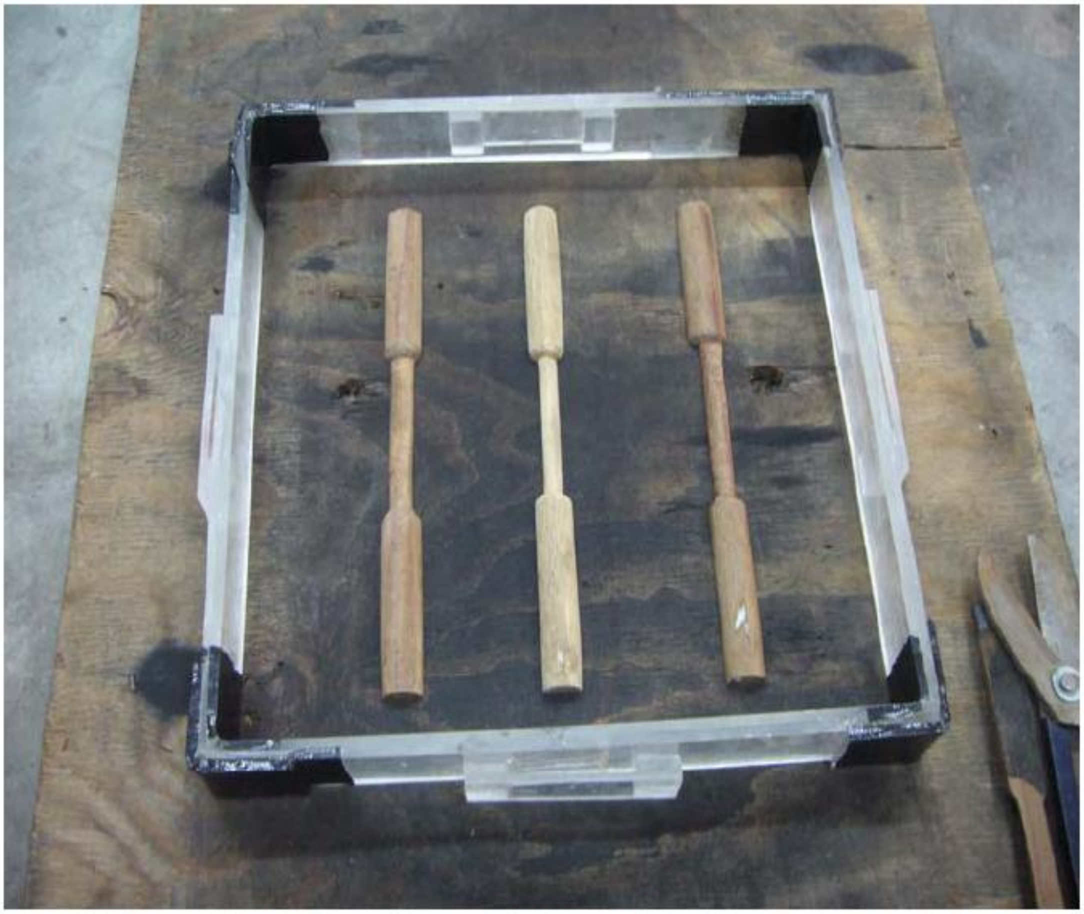

Figure 3.12: Split Dog Bone Pattern in the Molding Box.

After all the molding process is completed, CO_2 gas is sprays through the hole that have been made before. CO_2 gases cause sodium silicate to react and act as a binder in order to harden the mold. Figure 3.13 shows how CO_2 gas being spray into the mold.

Figure 3.13: CO_2 Gas Being Spray into the Mold.

3.7 PROJECT PROCESS FLOW

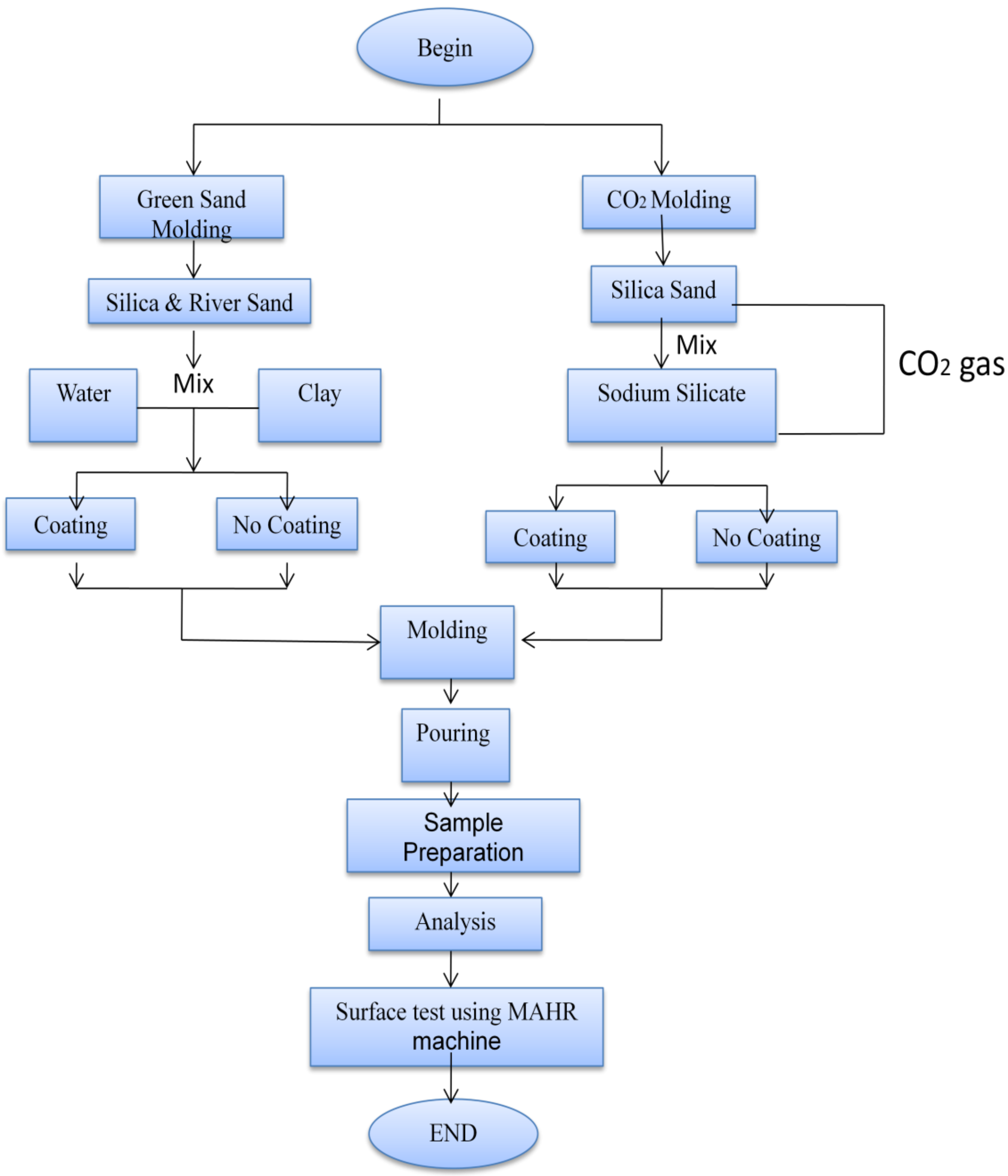

Figure 3.14: Schematic Diagram of Project Process Flow

3.8 MELTING AND POURING

Melting process of material use in this research is done using heating furnace**.** Aluminium has melting temperature about 660˚C. In a furnace material which is aluminium have to be melt above their melting temperature in order make sure that they are fully transform into liquid phase.

Pouring is a process when material is fully transform into liquid phase. Pouring must be done in safe and control environment. Liquid molten metal which is being held in crucible are pour into mold using customize gripper. Figure 26 shows example of molten metal being pour into the mold using customizes gripper.

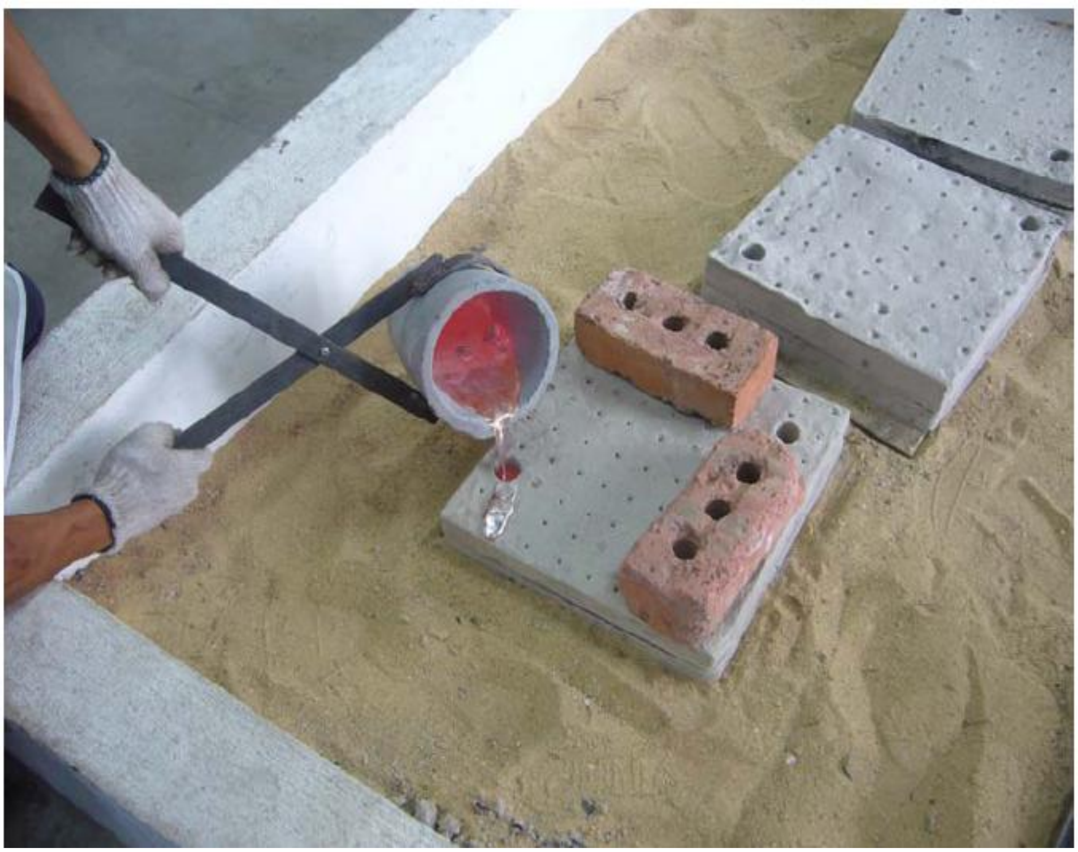

Figure 3.15: Example of Molten Metal Being Poured into Mold

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this study, the surface roughness of the pattern will be analyzed and the result of the surface finish of final parts from the sand casting is also included. The measurement is conducted more than once to ensure precision and accuracy. This chapter reviews the findings and discussion on data analysis of this experimental study.

4.2 SURFACE ROUGHNESS, (μm) OF PATTERN

This section reviews the findings on the surface finish of the original patterns which made by selected polystyrene.

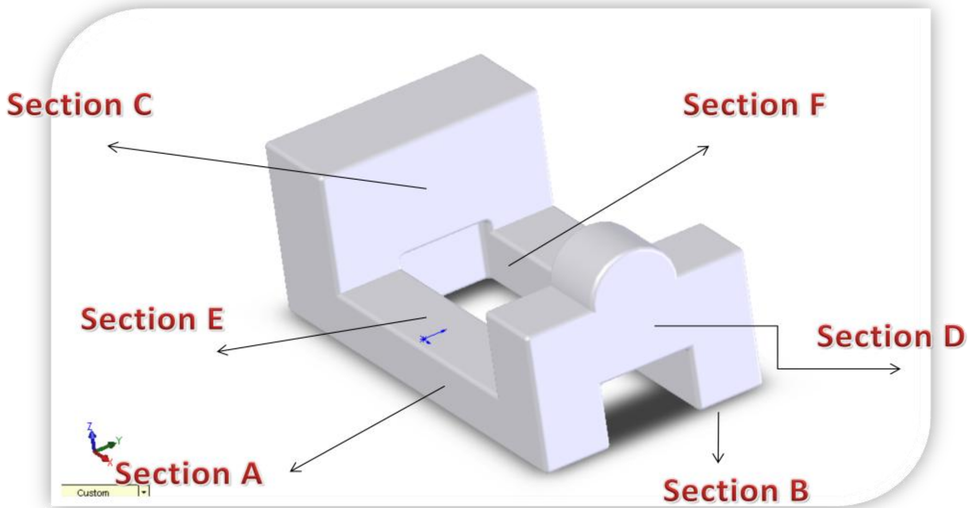

Figure 4.1: Randomly Selection Section of Mechanical Vise

4.2.1 Graphical Analysis and Discussion

Table 4.1 represent the result obtained from the surface roughness measurement by using MAHR Perthometer S2. The data is analyzed by using graphical method and will record in different kind of types. The pattern that had analyzed being divided by 2.One is original pattern made by selected polystyrene without coating and the other one is original pattern made by selected polystyrene with coating on its surface.

Table 4.1: Data Table for Pattern

Part	No. of trial	Surface Roughness, Ra (µm) ± 25 µm/0.8 nm					
		A	B	C	D	E	F
Actual Pattern (without coating)	**1**	5.326	5.926	11.460	6.430	3.024	8.648
	2	4.932	3.028	11.340	6.459	3.252	7.450
	3	5.268	4.763	11.359	6.432	2.002	6.020
	Mean	5.175	4.572	11.386	6.440	2.759	7.373
Actual Pattern (with coating)	**1**	4.206	4.246	7.608	5.376	2.882	4.147
	2	4.442	4.002	8.711	6.344	2.706	4.297
	3	4.722	3.996	5.856	6.566	2.102	4.246
	Mean	4.457	4.081	7.392	6.095	2.563	4.230

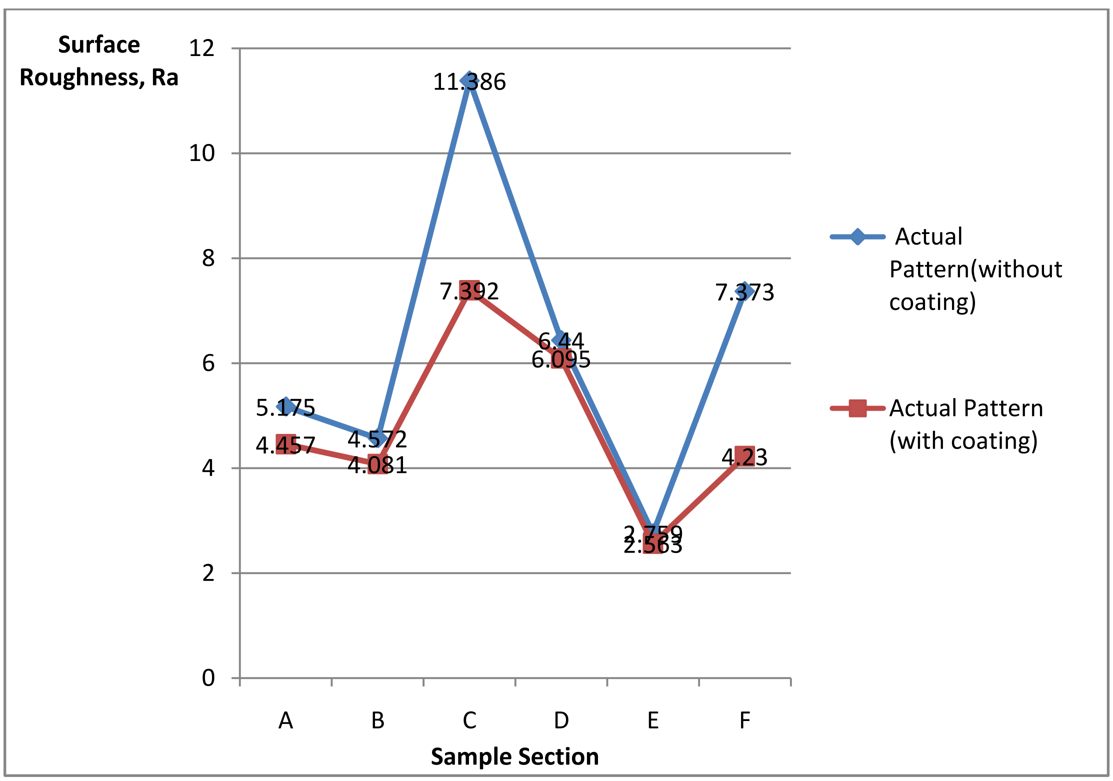

Figure 4.2: Comparison Graph between Patterns

Figure above plotted the surface roughness, Ra of the actual pattern based on 6 different sample sections. From the graph, it is shown that there exist variations in the surface roughness values for the actual pattern either for pattern with coating or without coating. The graph displayed that actual pattern without coating has higher value of surface roughness, Ra than actual pattern with coating. All section samples of the pattern that not having coating has higher value of roughness than pattern with coating. Sample section C shows largest value of surface roughness for both types of pattern either with coating or without coating.

Form analysis of the graph above, it is discovered that surface roughness of pattern without coating are high, ranging from 2.759µm up to 11.386 µm whereas the Ra values of pattern with coating only within 2.563µm to 7.392 µm. This means that, all situations above supports the facts that coating can affect the surface finish.

The coating has affect the value of surface roughness because the starch that be used for coating will covered the irregular and uneven surface on the pattern surface. This will make the measurement for determine the roughness more accurately means that the starch will make the pattern surface has better surface finish. Calculation of mean value is expressed in Eq 4.1 and calculation of variation value is expressed in Eq 4.2.

The calculation of Mean value of the roughness is based on:

$$\text{Mean} = \frac{\text{Trial } 1 + \text{Trial } 2 + \text{Trial } 3}{3} \qquad (4.1)$$

For example from result data sheet,

Type	**Surface Roughness, Ra (µm)** Part A
Actual pattern without coating	5.326
	4.932
	5.368

$$\text{Mean} = \frac{\text{Trial 1} + \text{Trial 2} + \text{Trial 3}}{3}$$

$$= \frac{5.326 + 4.932 + 5.268}{3}$$

$$= 5.175$$

The calculation of variation value of roughness is based on:

$$\text{Var.} = \left| \text{Actual Dimension} - \text{Mean Dimension} \right| \qquad (4.2)$$

For example from Mean value of part A from actual pattern and casting using carbon dioxide without coating:

Type	**Surface Roughness, Ra (μm)** Part A
Actual pattern (without coating)	5.326 4.932 5.268
Mean	5.175
Using Carbon Dioxide (without coating)	14.050 12.830 14.010
Mean	13.630

Var. = ┃Actual Roughness – Mean Roughness for final product┃

= ┃5.175 – 13.630 ┃

= ┃-8.455 ┃ = 8.455

Table 4.2: Data Distribution Between all 4 Tests with Actual Pattern

Part	Variation value(µm) ± 25 µm/0.8 nm					
	A	**B**	**C**	**D**	**E**	**F**
Carbon Dioxide (with coating)	2.760	6.721	5.568	0.345	0.196	3.143
Carbon Dioxide(without coating)	8.455	11.035	2.107	7.150	4.454	19.027
Green sand (with coating)	15.617	14.092	14.411	14.735	7.436	20.702
Green sand (without coating)	19.373	16.506	13.210	18.870	16.623	19.551

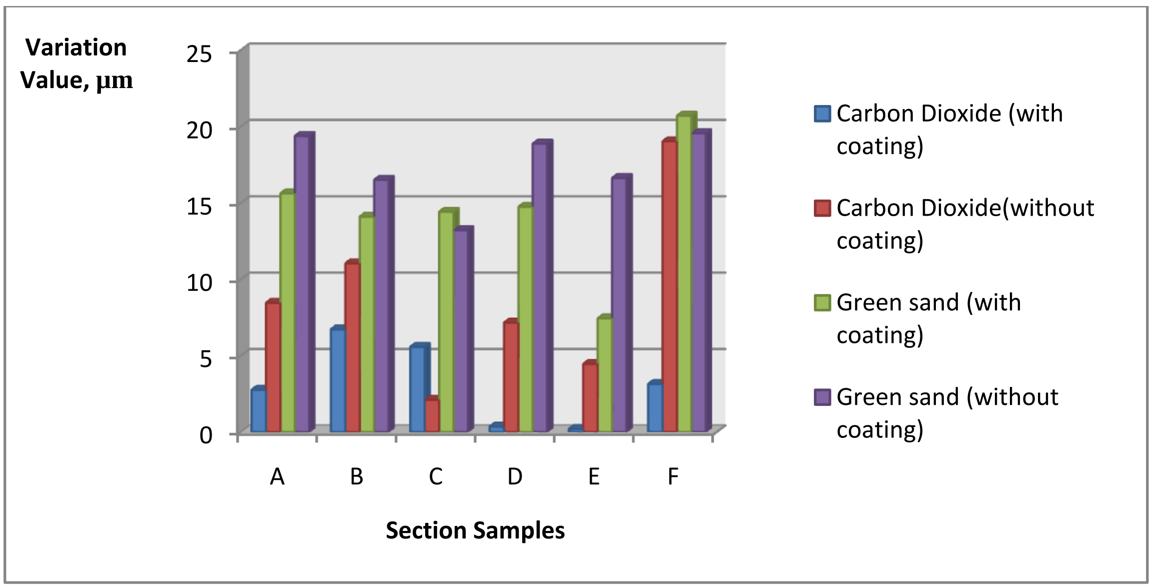

Figure 4.3: Distribution Chart between All 4 Tests

From the chart above, there are wide variations between all four tests. Carbon dioxide with coating shows almost lower value of variation between others test. The distribution of the data lies between 0.196 up to 6.721 µm while green sand without coating shows almost higher value for variation which is 13.210 µm up to 19.551 µm.

4.3 SURFACE ROUGHNESS, Ra (µm) of FINAL PRODUCT

In this section, the data of surface roughness of the finished and the final part is reviewed.

4.3.1 Graphical Analysis and Discussion

Table 4.3 displays the results obtained from the surface roughness measurement of the finished and final part. The data is analyzed by using graphical method to evaluate the resulting surface finish of the final product which is by sand casting.

Table 4.3: Table Data for Final Product

Part	**Surface Roughness, Ra (µm) ± 25 µm/0.8 nm**					
	A	**B**	**C**	**D**	**E**	**F**
Carbon Dioxide(with coating)	6.535	12.90	13.200	9.699	5.481	11.320
	7.517	9.508	12.380	10.11	5.439	11.450
	7.601	9.998	13.300	12.21	6.121	11.080
Mean	7.217	10.802	12.960	10.673	5.680	11.283
Carbon Dioxide(without coating)	14.050	19.490	13.040	12.160	7.657	26.080
	12.830	13.220	13.460	14.190	7.475	26.430
	14.010	14.110	13.980	14.420	6.507	26.690
Mean	13.630	15.607	13.493	13.590	7.213	26.400
Green Sand (with coating)	19.104	18.432	21.402	20.473	10.048	25.048
	20.005	18.204	22.112	20.998	11.114	26.884
	21.112	17.884	21.894	21.018	8.837	22.863
Mean	20.074	18.173	21.803	20.830	9.999	24.932
Green Sand (without coating)	24.843	20.482	24.210	25.064	20.089	27.014
	24.804	21.748	25.110	25.874	16.856	25.435
	23.998	21.004	24.467	24.992	21.201	28.324
Mean	24.548	21.078	24.596	25.310	19.382	26.924

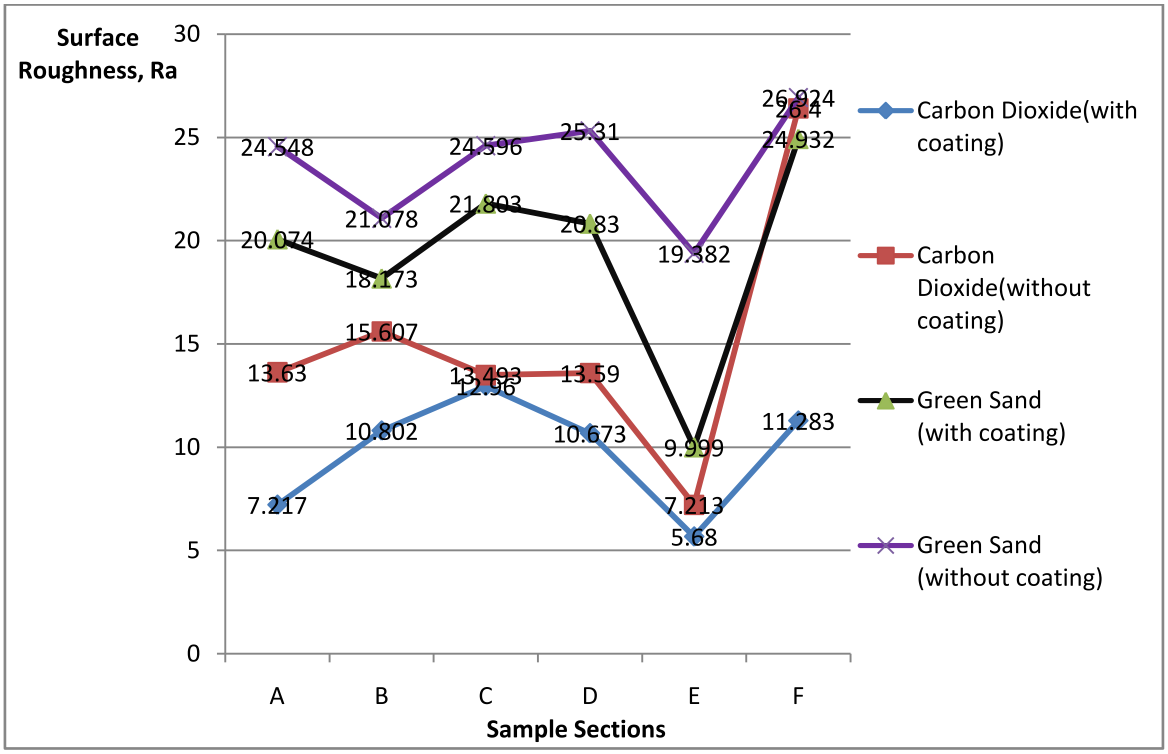

Figure 4.4: Comparison between Final Products

As shown in figure, the surface roughness, Ra of the final part is displayed in a form of line graph. From the figure, it can be seen that the surface finish of the final part is different because of different mold material and coating effect. From the graph, all types of mold material has higher value of surface roughness, Ra at section F and from all four types trial using different kind of mold material, green sand without coating has higher value of surface roughness, Ra at almost section which is for section A is 24.548 µm, section B is 21.078 µm, section C is 24.596 µm, section D is 25.310 µm, section E is 19.382 µm and lastly section F is 26.924 µm. While casting with carbon dioxide (C02) and coating displayed lower value of surface roughness, Ra which are section A is 7.217 µm, section B is10.802 µm, section C is12.960 µm, section D is10.673 µm, section E is 5.680 µm and lastly is 11.283 µm. It is argued that the product by sand casting using green sand as mold material and no coating effect will produce poor surface finish.

There are factors that can be considered as the cause of this problem. In this study, green sand and carbon dioxide will be uses as the mold material. Green sand will be mixed with bentonite and water. These two material acts as hardening agent for the green sand. This hardening agent is not good enough where the mould cannot be pack perfectly. While making mould for the pattern, the mould not compact precisely which make the surface that contact with the pattern inside the mould not flattened enough.

Apart from different kind of mold material, another factor that possibly leads to this problem poor surface finish is pouring the molten aluminium into the mould. To have better solidification of molten aluminium, the pouring must be continuously. Better solidification of molten metal will resulted in good surface finish. Besides, material shrinkage also possibly contributes to this problem. In this experiment study, the material used for the pattern is selected polystyrene. One of the properties of this polystyrene, such as elasticity could possibly have its own effect on surface finish. When the pattern being buried inside the sand and the sand being compact using compact tool will resulted of the shrinkage of the pattern. The shrinkage and expansion of the pattern could be the factor to the poor surface finish.

Besides, mold making process also has effects in poor surface finish. Not enough of one of the mixture items during mold making can lead to these problems. For each 14 kg of sand, 10 % of clay (bentonite) and 5 % of water are added. So the quantity must be precisely. Good mold must be not wet but its must damp and its can shaped when molded. Good mold can also easier the sand to be compact without having much problems and the sand can followed pattern shaped. The surface between the pattern and sand will flattened enough.

In addition, poor surface finish for greensand molding also can be caused by recycled green sand. For sand casting using green sand, the sand will be reused for another casting. In this experimental study, the molten metal had been poured into the sand so many times causing the microstructure of the sand not exactly as same as its original microstructure and had been mixed with the molten metal and affected the surface finish of the final product. This factor can caused poor surface finish to the product. While for carbon dioxide, CO_2 molding, the sand cannot be recycled. So the sand not mixed with another material that had using that sand before been used in this experimental study. So, it's has the originality microstructure of the sand which do not effect the surface finish of the final product which means providing good surface finish.

Next, the differences between these test also happened because of poor refractoriness of the silica sand can lead to sand burn-in or metal penetration defects. The used of coating can overcome the combined effects of the non-linear thermal expansion of silica sand and the low hot strength of the binder. However it is generally accepted that these defects can be overcome through the use of coatings (N. Hodgkinson, 2003)

Surface finish quality is a function of grain size and distribution. Fine grain resulted in best surface finish but reduces permeability and increase binder and or moisture demand. The purity will directly influence the property of refractoriness and affect its suitability for use with specific binder materials. Carbon dioxide molding only used silica sand which has fine grain while green sand molding has worst grain. Fine grain resulted in higher refractoriness which means the ability to withstand the melting temperature of the molten metal is high but greensand has worst grain occurring lower refractoriness. Another factor that contributes to this result is total elimination of moisture from the moulding sand (providing it has been stored correctly) which better for carbon dioxide, CO_2 molding than green sand molding (Paul Encoyand, 2001)

4.4 PICTURE OF FINAL PRODUCT USING SAND CASTING

Figure 4.5: Carbon Dioxide Sand Casting with Coating (Top View)

Figure 4.6: Carbon Dioxide Sand Casting with Coating (Bottom View)

Figure 4.7: Carbon Dioxide Sand Casting with Coating (Side View)

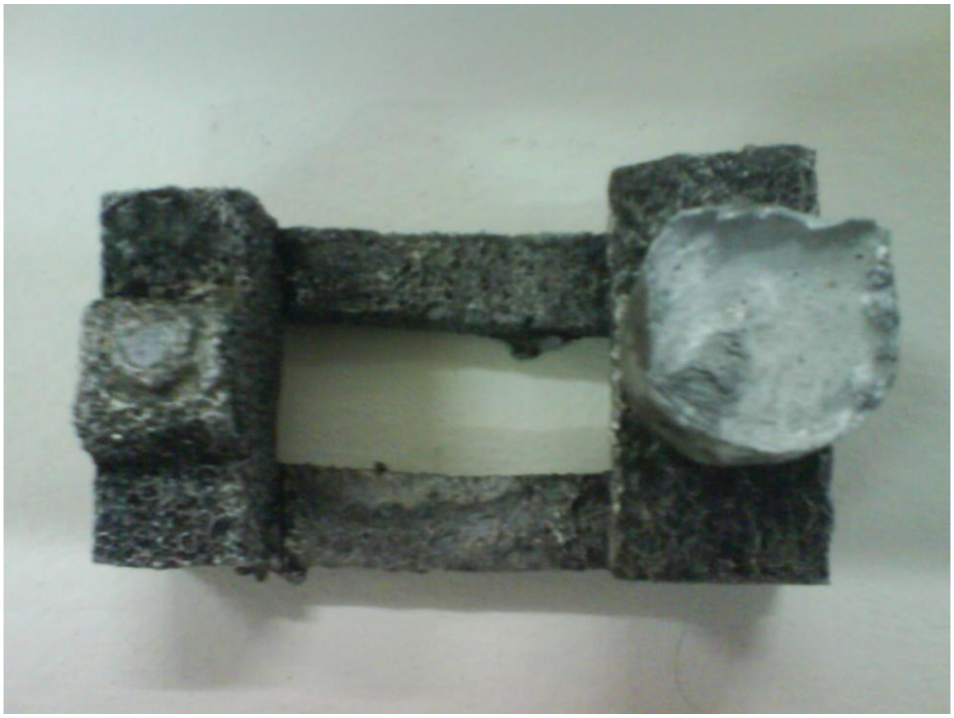

Figure 4.8: Carbon Dioxide Sand Casting without Coating (Top View)

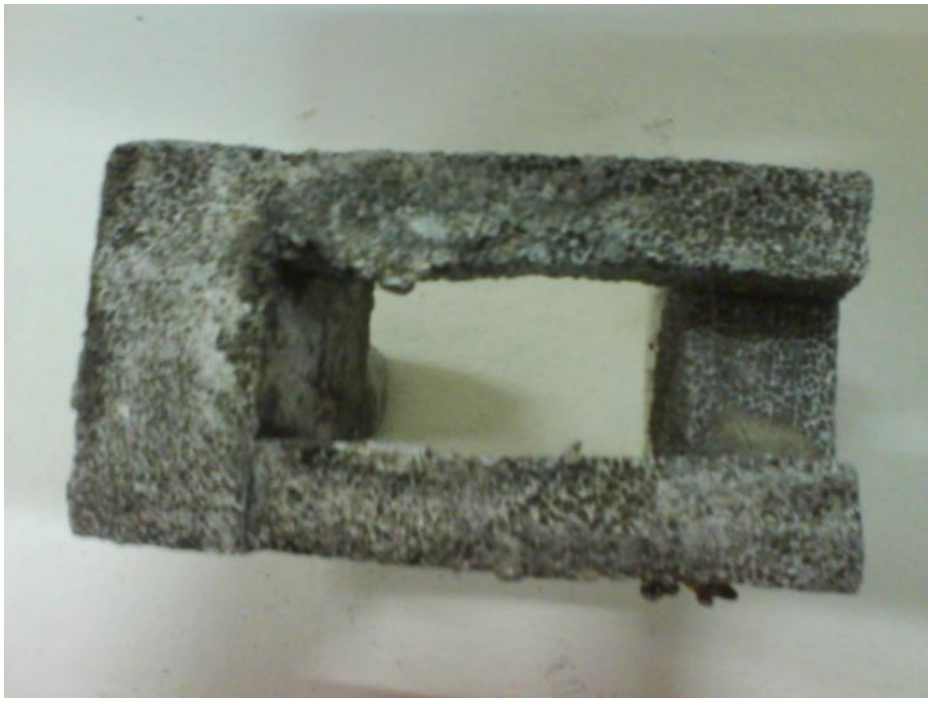

Figure 4.9: Carbon Dioxide Sand Casting without Coating (Bottom View)

Figure 4.10: Carbon Dioxide Sand Casting without Coating (Side View)

Figure 4.11: Green Sand Casting with Coating (Top View)

Figure 4.12: Green Sand Casting with Coating (Side View)

Figure 4.13: Green Sand Casting with Coating (Bottom View)

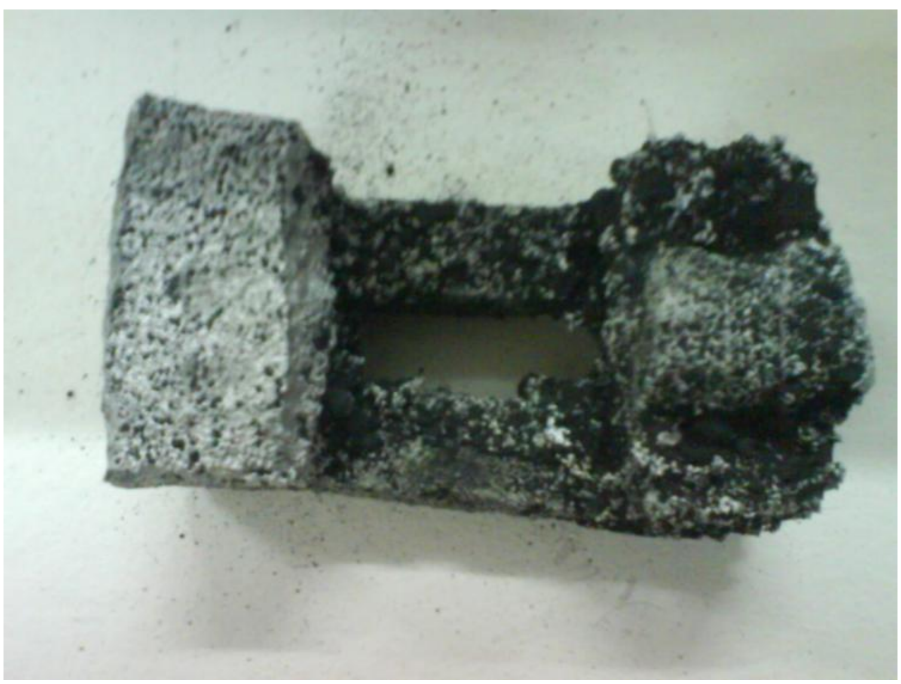

Figure 4.14: Green Sand Casting without Coating (Top View)

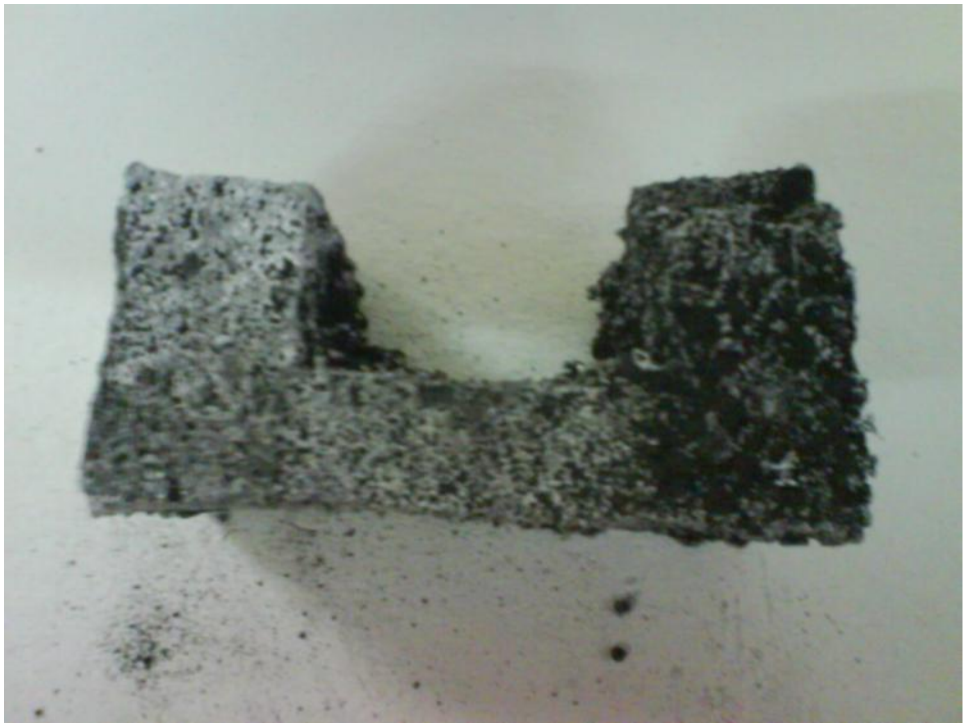

Figure 4.15: Green Sand Casting without Coating (Side View)

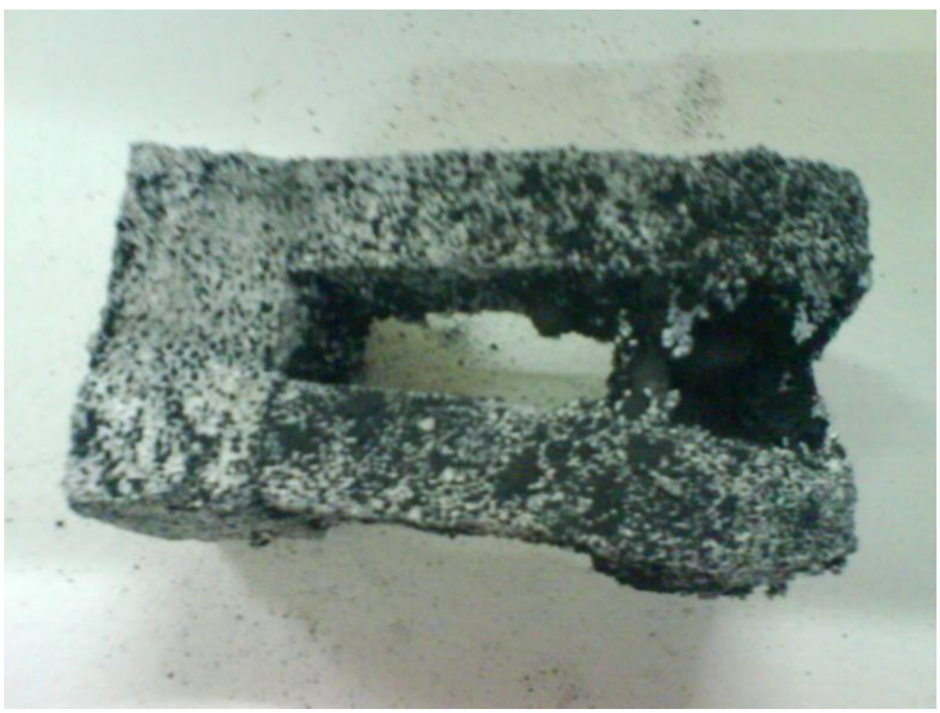

Figure 4.16: Green Sand Casting without Coating (Bottom View)

4.5 PROBLEM ENCOUNTERED

There are a few problem encountered during this experimental study. First of all, during making a pattern, the poly cutter cannot cut the polystyrene accurate enough with the dimension of the actual drawing. For sand casting process which affect the result of the final pattern. First of all, the shape of the final product did not same as pattern. Factors that contribute to this problem is when the sand being compact in the mould. The pattern is made from the selected polystyrene which is a little bit soft. When the sand being compact using human force, the pattern may be shrinkage or some part differ from its original position.

Another problem that encountered during the casting process is when using carbon dioxide as hardening agent where crack happen after molten aluminium is being pouring into the mould. After the sand being compact, carbon dioxide being inserted into the sand through the hole those has been made before. Carbon dioxide acts as hardening agent which hardening the sand. Not enough carbon dioxide for harden the sand will causes to this crack. Besides, not enough another hardening agent which is sodium silicate also can make the sand not hard enough causing the crack.

Besides, when pouring the molten aluminium which is being held in crucible are pour into mold but the capacity that one crucible to fill the molten aluminum is not enough to fill the entire mold in one pouring. So the crucible must be refill with new molten aluminium which causes the solidification time of molten aluminum not perfect causing poor surface finish to the product.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter reviews the overall conclusions which are made based on the analysis of findings shown in the previous chapters. Section 5.2 discusses on the summary of the experimental study while conclusions on section 5.3. Recommendation for future works are so included in section 5.4.

5.2 SUMMARY OF STUDY

This experimental study is basically an application of Rapid Tooling where the main concerns are the surface finish. The study is carried out based on the standard design approach which only includes two factors at one time. The factor consists of the parameter settings, which are the effect of coating and also mold material. The effects of those parameter settings are analyzed and discussed by using tables and graphical method to determine which parameter setting produces the best characteristics. Two actual patterns be build and one of the patterns will be tested with coating whether the coating will has effect to the surface roughness value. Apart from that, the both patterns will be tested during sand casting process using different kind of mold material and the best surface roughness will be analyzed. The result from the final products are then compared either from pattern with or without coating and which mold material will have better value of surface roughness, Ra, whereby tables and graphical analysis is again used to analyze and discuss the final results.

5.3 CONCLUSION

It is concluded that the experimental study successfully fulfills the main objective which is to investigate the surface finish of final products. This section reviews the conclusion drawn from this experimental study. In this experimental study, actual pattern with coating effect has almost the best surface finish in all selection section which are section A is 4.457µm, section B is 4.081 µm, section C is 7.392 µm, section D is 6.095 µm, section E is 2.563 µm, section F is 4.230 µm compared the other one actual pattern without coating effect which are section A is 5.175µm, section B is 4.572 µm, section C is 11.386 µm, section D is 6.440 µm, section E is 2.759 µm, section F is 7.373 µm. This value means that the used of coating can overcome the poor surface finish in sand casting by covering uneven and irregular surface finish of the final product.

Besides, carbon dioxide, CO_2 sand casting has the lowest value of surface roughness, Ra which means better surface finish than green sand casting. The effects of carbon dioxide, CO_2 gas which harden the sand make a huge impact in providing good surface finish fro the final product. The selection of material pattern, coating effect and material shrinkage are another possible factor that causes poor surface finish of final product in this study. Next, there exist variations in the values of surface roughness, Ra of final product even though it’s using same material for the mold which means different section of the final product will have different surface roughness value because of the ununiformly force while compacting the sand.

Lastly, the best method to have better surface finish in sand casting process is by using carbon dioxide and coating.

5.4 RECOMMENDATIONS

For future experimental works on this topic, in order to improve the study, the following recommendations being suggested.

(i) Use variety of material for the pattern or using machine to produce the pattern such as 3D printing, or using CNC machine.

(ii) Conduct a study on the best position of the parting line to plant the pattern inside the sand.

(iii) Test the mold material flowability using flowabilty test before undergo sand casting process for the final product.

(iv) Other mechanical properties, such as hardness, wear resistance, dimensional accuracy between product and pattern, microstructure of casting product can be studied for further works and application in rapid manufacturing.

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APPENDIX A

Process Flow in Sand Casting