UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: EFFECT OF SOLIDIFICATION TIME TO THE WALL THICKNESS CREATED ON THE SLUSH CASTING PRODUCT

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EFFECT OF SOLIDIFICATION TIME TO THE WALL THICKNESS CREATED ON THE SLUSH CASTING PRODUCT

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TENGKU AHMAD FIRDAUS BIN TENGKU ZAINAL

Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

SUPERVISOR’S AND CO-SUPERVISOR’S 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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Position:
Date:

Signature
Name of Co-Supervisor:
Position:
Date:

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 concurently submitted for award of other degree.

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Name:
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Dedicated to my beloved parents,

My siblings,

My supervisor and co-supervisor,

and all my friends

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In the name of Allah S.W.T the most gracious and merciful, first and foremost, after a year of struggle and hard work, with His will, this thesis is completed. Thanks to Allah for giving me the strength to complete this project and the strength to keep on living.

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ABSTRACT

Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods 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. After a certain time, the excess liquid will poured out, and then the solid casting is then ejected or broken out to complete the process.Casting may be used to form various materials that cold set after mixing of components (such as epoxies, concrete, plaster and clay Therefore, this study is conducted to fabricate the tool holder by using rubberwood as the material for the pattern, RTV-2 silicone rubber for the mould and polyester resin for product. The main objective of this study is to to study the effect of solidification time to the wall thickness created on the slush casting product to suit the function of product and find the optimum solidification time to achieve desire wall thickness for particular slush casting product. The study parameters are based on slush casting solidification time, which are 1, 2, 3, 4 and 5 minutes. The study output is wall thickness and digital vernier caliper is used to measure the dimension of wall thickness. Based on the measurement, only product have the value factor of safety (FOS) more than one, >1 is selected as a product. Based on the study analysis, it is discovered that the highest solidification time produce the highest wall thickness created on the product.

ABSTRAK

Proses tuangan bahan lebur ke dalam acuan atau “casting” seringkali digunakan untuk menghasilkan bentuk yang rumit memandangkan proses lain lebih sukar atau mahal dari perspektif ekonomi. Proses ini merupakan salah satu jenis proses pembuatan dimana bahan yang telah dileburkan akan dituang ke dalam acuan yang mengandungi rongga kosong mengikut bentuk yang dikehendaki, sebelum dibiarkan memejal. Selepas seketika, logam cair yang berlebihan akan dituang keluar meninggalkan bahan yang diacu. Bahan acu akhirnya diasingkan daripada acuan. Bahan acu boleh dihasilkan daripada set sejuk selepas campuran komponen seperti epoksi, konkrit, plaster dan tanah liat. Oleh itu, kajian ini dijalankan untuk menghasilkan paten penyimpan alat daripada kayu getah, acuan daripada getah silikon RTV-2 dan resin polisterin untuk produk. Matlamat utama ialah untuk mengkaji kesan masa pemejalan terhadap ketebalan dinding terbentuk pada bahan acu separa pejal untuk memenuhi fungsi produk dan menjamin masa pemejalan yang optimum. Kajian juga dilakukan untuk menentukan ketebalan dinding sesuai bagi produk acu separa pejal. Parameter kajian berdasarkan masa pemejalan bahan acu separa pejal ialah 1,2,3,4, dan 5 minit. Hasil kajian iaitu ketebalan dinding diukur menggunakan angkup vernier. Daripada ukuran, hanya produk yang mempunyai nilai faktor keselamatan (FK) lebih daripada satu, >1 dipilih sebagai produk. Berdasarkan kajian ini, masa pemejalan yang lama menghasilkan ketebalan paling tinggi terhadap produk.

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LIST OF SYMBOLS

°c	Celcious
%	Percent
cm	Centimetres
mm	Milimeter
min	Minute
kg	Kilogramme
inch	inches
N	Newton

LIST OF ABBREVIATIONS

RT	Rapid tooling
RP	Rapid prototyping
SL	Stereolithography
SLS	selective laser sintering
CAD	Computer-aided drafting
RTV	Room temperature vulcanizing
FOS	Factor of safety
Eq	Equation

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Slush casting is a manufacturing process by which a liquid material is poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solid casting is then ejected or broken out to complete the process. Casting may be used to form hot liquid metals or various materials that cold set after mixing of components.

1.2 BACKGROUND OF STUDY

Tool holders are very useful product especially in engineering field. For this study a tool holder for holding screw driver will be fabricated. The main function of tool holder is to place the screw driver according to its size and function. Firstly, the design of the tool holder is designed by using SolidWorks software and then a pattern which is made from wood is produced. Next, the pattern will be used as mould for slush casting process to produce the final part. Finally, analysis is to find the optimum time for wall thickness created in the slush casting process.

1.3 OBJECTIVES OF STUDY

(i) To study the effect of solidification time to the wall thickness created on the slush casting product.

(ii) Find the optimum solidification time to achieve desire wall thickness for particular slush casting product.

1.4 SCOPE OF PROJECT

(i) Parameter concern for slush casting process is solidification time on the wall thickness.

(ii) The prototype will be designed using Solid Works software.

(iii) The pattern is made from wood and the final part is produced by using slush casting technique.

1.5 PROBLEM STATEMENT

In slush casting method, solidification time is the one important factor that will affect the wall thickness. The wall thickness of a product that is produced by slush casting technique depends on solidification time that can be control. To produce a product, wall thickness must be suit with its function for applied load.

In this study, wall thickness of the product must be achieve value of FOS more than one to make sure the product not easily crack.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews relevant literatures on fabrication of pattern by hand works. Section 2.1 reviews on tool holder which states the important of tool holder.

2.2 TOOL HOLDER

Tool holder is a product that is used to hold tool equipment as shown in Figure 1. Actually, it is very important to avoid tool equipment from getting lost. The main function of tool holder is to place the equipment such as screw driver according to its size and function. This holder also helps mechanics especially in automotive and mechanical field to get the screw driver easily. For this study, tool holder will be designed with specific function which is to place the screw driver. This design will have three holes to place screw driver according to its size where the rod of the screw driver will be inserted into the hole. This holder is very compatible to be placed on the wall or at high place to avoid from children.

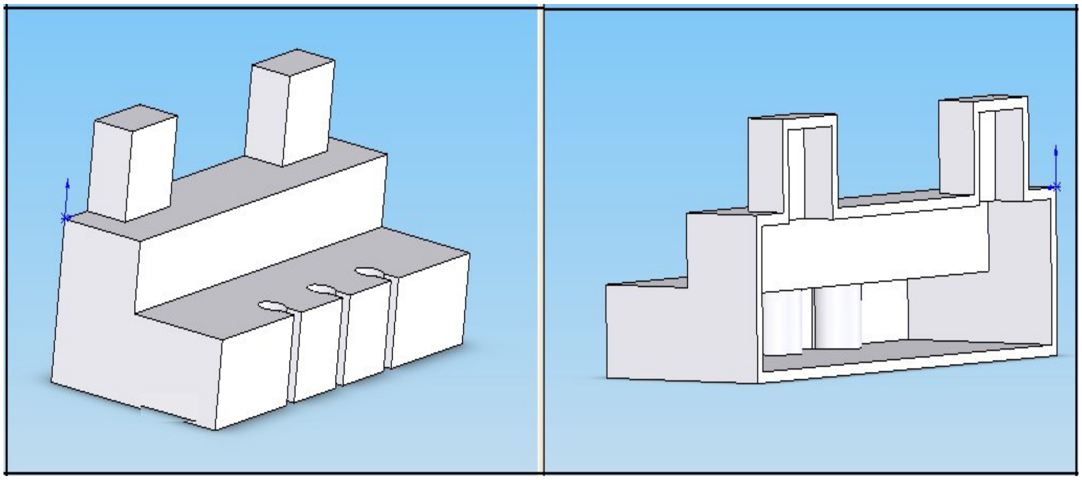

Figure 2.1: Tool holder

2.3 MANUFACTURING OF THE TOOL HOLDER

Normally, tool holder is made by plastic material. This holder is usually used in workshop, factory and other place where the place is not suitable for brittle material. That is why tool holder is made from plastic material because this will not easily crack and very light weight as compared to others material.

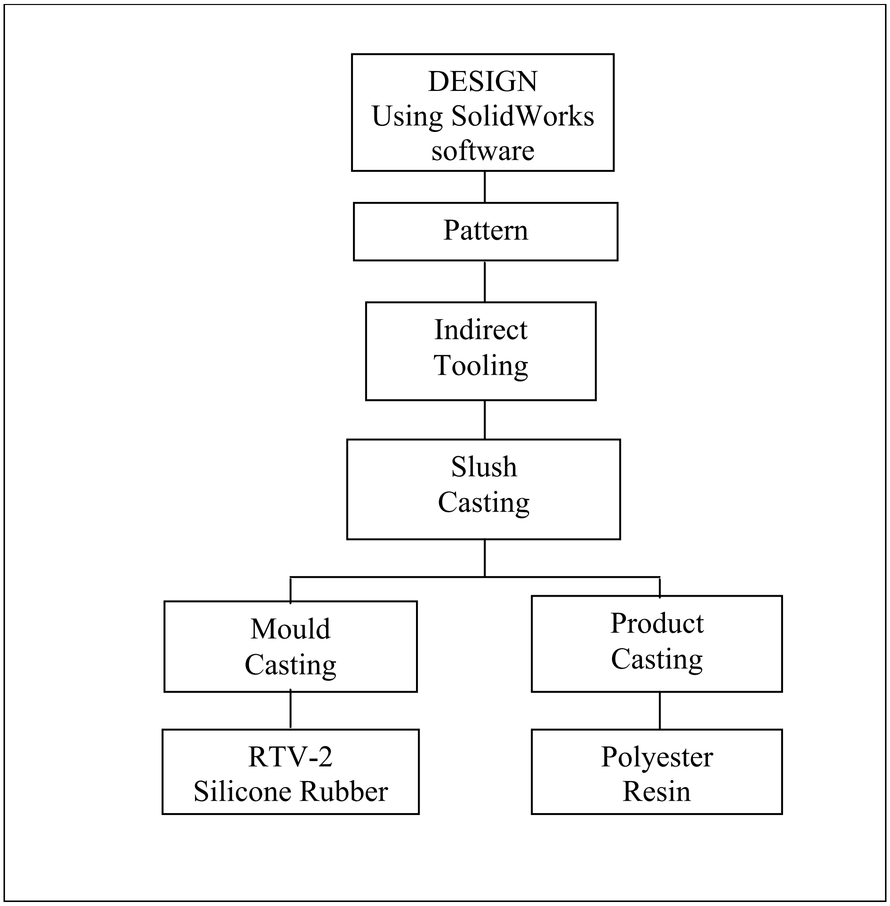

Figure 2.2: Development of Slush Casting in this Study

2.3.1 Development of Slush Casting

Figure 2.2 above shows the development of slush casting in this study. Firstly, the pattern will designed by SolidWorks software. Next, the pattern is made from wood as the material and mould will produce by using RTV-2 Silicone Rubber as the material. Finally, the final part is produced by using Polyester Resin as the material

2.4 EQUIPMENT TOOL FOR MEASUREMENT

In this study, measurement tool that will be used to measure the product is Digital Vernier Caliper, micro digital weighing machine and stop watch. Digital vernier caliper will be used to measure wall thickness while micro digital weighing machine will be used for weighing resin and silicone rubber. Stop watch will be used to record the solidification time. Details explanation of these tools will be discussed in the following section.

2.4.1 Digital Vernier Caliper

Thickness of the final product that is produced by slush casting process will be measured by digital vernier caliper Mitutoyo. These are the specification for this tool:

(i) Range: 0-6"(0-150mm).
(ii) Resolution: .0005"/0.01mm.
(iii) Accuracy: +/-0.0010".
(iv) ZERO/ABS Key: allows the display to be Zero-Set at any slider position along the scale for incremental comparison measurements.
(v) This switch will also allow return to absolute mode & display of the true position from the original point.
(vi) Maximum response speed: unlimited.
(vii) Alarm: low voltage, scale contamination, counting value composition error
(viii) Operating Temperature: 0ºC to 40ºC.
(ix) Can be hooked up to computer for data download (optional accessories required).

Figure 2.3: Digital Vernier Caliper Mitutoyo

Source: http://www.justtools.com

2.4.2 Micro Digital Weighing

In this study, micro digital weighing will be used to measure weight of material resin and silicone rubber.

Figure 2.4: Micro digital weighing

2.5 RAPID TOOLING

Rapid tooling is enabling art to production of quality parts and accelerating time to market by concentrating on the tool rather than the part (J. William, 1997). It is the ability to build prototype tools directly to prototype products from the CAD model resulting in compressed time to market solutions. The processes have been developed for generating durable injection moulds directly from computer data. These hard tooling solutions are based on sintered metal powder moulds usually infiltrated with copper. These hard tooling processes produce metal tools capable of surviving thousands of cycles. There are two types of rapid tooling processes, transfer and direct. Rapid prototyping and rapid tooling continue to have a huge impact in changing how products are designed and tested (D. King and T. Tansey, 2002). Rapid tooling (RT) processes have been developed to meet specific application and material requirements for moulding and casting. These may be forms of basic RP processes, such as stereolithography (SL) or selective laser sintering (SLS), or may be unique RP methods developed for a specific application. Typically a part made by the RP system is used as a pattern or model in these processes (J. C. Ferreira and A. Mateus, 2003).

In this study we will be indirect tooling method, is used which is silicone rubber casting technique to produce the final part of tool holder. The mould will be produced by pouring casting technique.

2.5.1 Indirect Tooling

Most rapid tooling today is indirect: RP parts are used as patterns for making molds and dies. RP models can be indirectly used in a number of manufacturing processes:

(i) Vacuum Casting: In the simplest and oldest rapid tooling technique, a RP positive pattern is suspended in a vat of liquid silicone or room temperature vulcanizing (RTV) rubber. When the rubber hardens, it is cut into two halves and the RP pattern is removed. The resulting rubber mold can be used to cast up to 20 polyurethane replicas of the original RP pattern. A more useful variant, known as the Keltool powder metal sintering process, uses the rubber molds to produce metal tools. Developed by 3M and now owned by 3D Systems, the Keltool process involves filling the rubber molds with powdered tool steel and epoxy binder. When the binder cures, the "green" metal tool is removed from the rubber mold and then sintered. At this stage the metal is only 70% dense, so it is infiltrated with copper to bring it close to its theoretical maximum density. The tools have fairly good accuracy, but their size is limited to less than 25 cm (Groover, M.P, 2002).

(ii) Sand Casting: A RP model is used as the positive pattern around which the sand mold is built. LOM models, which resemble the wooden models traditionally used for this purpose, are often used. If sealed and finished, a LOM pattern can produce about 100 sand molds (William Palm, 2002).

(iii) Investment Casting: Some RP prototypes can be used as investment casting patterns. The pattern must not expand when heated, or it will crack the ceramic shell during autoclaving. Both Stratasys and Cubital make investment casting wax for their machines. Paper LOM prototypes may also be used, as they are dimensionally stable with temperature. The paper shells burn out, leaving some ash to be removed. To counter thermal expansion in stereolithography parts, 3D Systems introduced Quick Cast, a build style featuring a solid outer skin and mostly hollow inner structure. The part collapses inward when heated. Likewise, DTM sells True form polymer, a porous substance that expands little with temperature rise, for use in its SLS machines (William Palm, 2002).

(iv) Injection molding: CEMCOM Research Associates, Inc. has developed the NCC Tooling System to make metal/ceramic composite molds for the injection molding of plastics. First, a stereolithography machine is used to make a match-plate positive pattern of the desired molding. To form the mold, the SLA pattern is plated with nickel, which is then reinforced with a stiff ceramic material. The two mold halves are separated to remove the pattern, leaving a matched die set that can produce tens of thousands of injection moldings (William Palm, 2002).

(v) Slush casting: polyester resin is poured into the mould and a desired thickness of the solidified skin is obtained. After that the remaining resin is poured out and the mold halves are then opened and the casting is removed (John Wiley and Sons, 2002).

For this study, slush casting method will be used to produce the final part by using pattern as the mould.

2.5.2 Slush Casting

Casting is a manufacturing process by which a liquid material is poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solid casting is then ejected or broken out to complete the process. Casting may be used to form hot liquid metals or various materials that cold set after mixing of components (such as epoxies, 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 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 solid casting is then ejected or broken out to complete the process (Dimov S.S, 2001).

In this study, poured casting will be use as a method to casting the model. It is simple casting processes which are poured the liquid material into the mold. Slush casting items are hollow but have an opening similar to those found in doll parts, syringe bulbs, and special containers. This casting method have two stage of process, it is divided to mould and product casting. Normally, this method is use in produce product base on plastics and rubber as the materials. Slush castings rely on liquid casting materials. However, the materials for the model casting which are compatible with materials for mould made from rubber are wax, plaster, resin, and cement and. The following section will explain more details about this process.

2.5.3 Mould Casting

Each mold making and casting compound is unique and may require special handling that differs from similar products. Mold making and casting materials must be selected concurrently. This is because some casting materials work well only in certain mold materials.

For this study, RTV-2 silicone rubber will be used as the material to produce the mould. Mold rubbers are used for numerous applications including architectural restoration, bronze art foundry and industrial foundry casting, decorative concrete and architectural precast concrete casting, plaster casting, candle mold making, rapid prototyping, decorative home décor production, stamped concrete texturing, special effects, model making and movie prop development, theme park display manufacturing.

Silicone moulding compounds offer superior ability to recreate master model detail compared to traditional cold synthetic rubber moulding material. There are two advantages of silicone moulding according to First, extremely high resolution of master model detail can be copied to the cavity mould. Secondly, back draft problems (die lock, or the inability to release the part from the mold cavity due to part geometry) are reduced (Jacobs, P. F., 1992).

Figure 2.5: Rubber Mould

Source: http://www.thecandlemaker.com

2.5.4 Product Casting

The casting technique will be used in this study is slush casting. Figure 4 show the product made from this technique. The major materials for slush casting are plastisols and organosols. Plastisols are mixtures of only finely ground plastic and plasticizers. Organosols are vinyl or polyamide dispersion in organic solvents and plasticizers. Organosols consists of 50 to 90 percent solids. The solid are tiny particles of plastic, frequently ground PVC. Organosols contain both plasticizers and varying amounts of solvents. A plastisol may convert to an organosols by adding selected solvents. The material that will be used for casting the final part for this study is polyester resin (Prof. Dr. Matthias Busse, 2002).

Figure 2.6: Slush Casting Product

Source: http://www.indiamart.com

2.6 CAUSES OF WALL THICKNESS

Basically, the main cause of wall thickness in casting is solidification time. The wall thickness builds process employed by the rotating process of the liquid at the specific time and the liquid starting gels.

2.6.1 Effect of Solidification Time and Wall Thickness

Slush casting method actually is a pouring casting, which the liquid of the resin will poured into the mould. The mould will rotate to make sure the liquid coated all the surface of the mould and the excess liquid will be poured away. This process will produce the wall on the mould surface after the certain time and liquid become solidify. The solidification time will affected the wall thickness created.

2.7 DIMENSIONS AND TOLERANCES

In addition to mechanical and physical properties, other factors that determine the performance of a manufactured product include "(John Wiley and Sons, 2002):

(i) Dimensions, linear or angular sizes of a component specified on the part drawing
(ii) Tolerances, allowable variations from the specified part dimensions that are permitted in manufacturing

2.7.1 Dimension

A dimension is "a numerical value expressed in appropriate units of measure and indicated on a drawing and in other documents along with lines, symbols, and notes to define the size or geometric characteristic, or both, of a part or part feature" "(John Wiley and Sons, 2002).

(i) Dimensions on part drawings represent nominal or basic sizes of the part and its features
(ii) The dimension indicates the part size desired by the designer, if the part could be made with no errors or variations in the fabrication process

2.7.2 Tolerances

A tolerance is "the total amount by which a specific dimension is permitted to vary. The tolerance is the difference between the maximum and minimum limits"(John Wiley and Sons, 2002)

(i) Variations occur in any manufacturing process, which are manifested as variations in part size
(ii) Tolerances are used to define the limits of the allowed variation

2.7.3 Bilateral Tolerance

Variation for bilateral are permitted in both positive and negative directions from the nominal dimension. It is possible for a bilateral tolerance to be unbalanced; for example, 2.500 +0.010, -0.005.

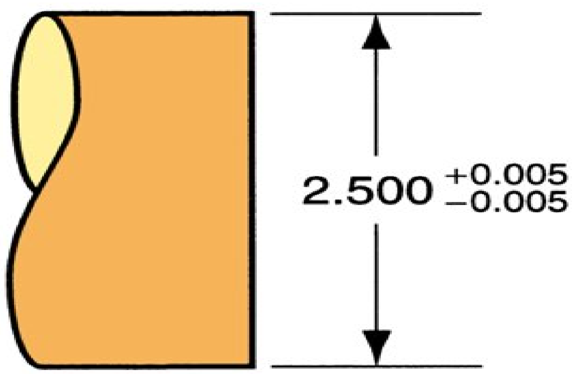

Figure 2.7: Ways to specify tolerance limits for a nominal dimension of 2.500

Source: John Wiley and Sons, 2002

2.7.4 Unilateral Tolerance

Variation for unilateral from the specified dimension is permitted in only one direction, either positive or negative, but not both

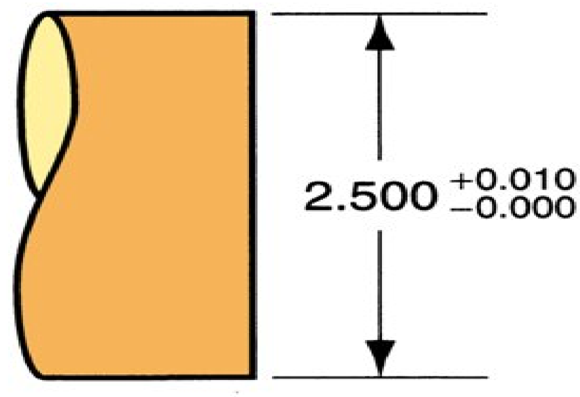

Figure 2.8: Ways to specify tolerance limits for a nominal dimension of 2.500

Source: John Wiley and Sons, 2002

2.7.5 Limit Dimensions

Permissible variation in a part feature size, consisting of the maximum and minimum dimensions allowed.

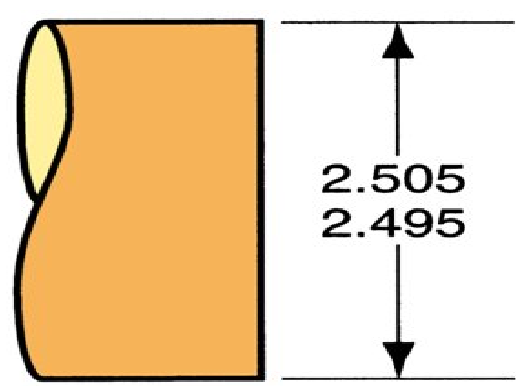

Figure 2.9: Ways to specify tolerance limits for a nominal dimension of 2.500

Source: John Wiley and Sons, 2002

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The methodology used in conducting this experimental study will be discussed in this chapter. It can be divided into five main categories as illustrated in the following figure. The categories are experimental design, data analysis, study procedures, instrumentation and materials.

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 experiment to be run repetitively in order to determine the average results from 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, combination 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 designed with parameters of study which is solidification time. Number of trial done is five for the slush casting method and the study outputs consist of wall thickness (mm).

3.3 FLOW CHART

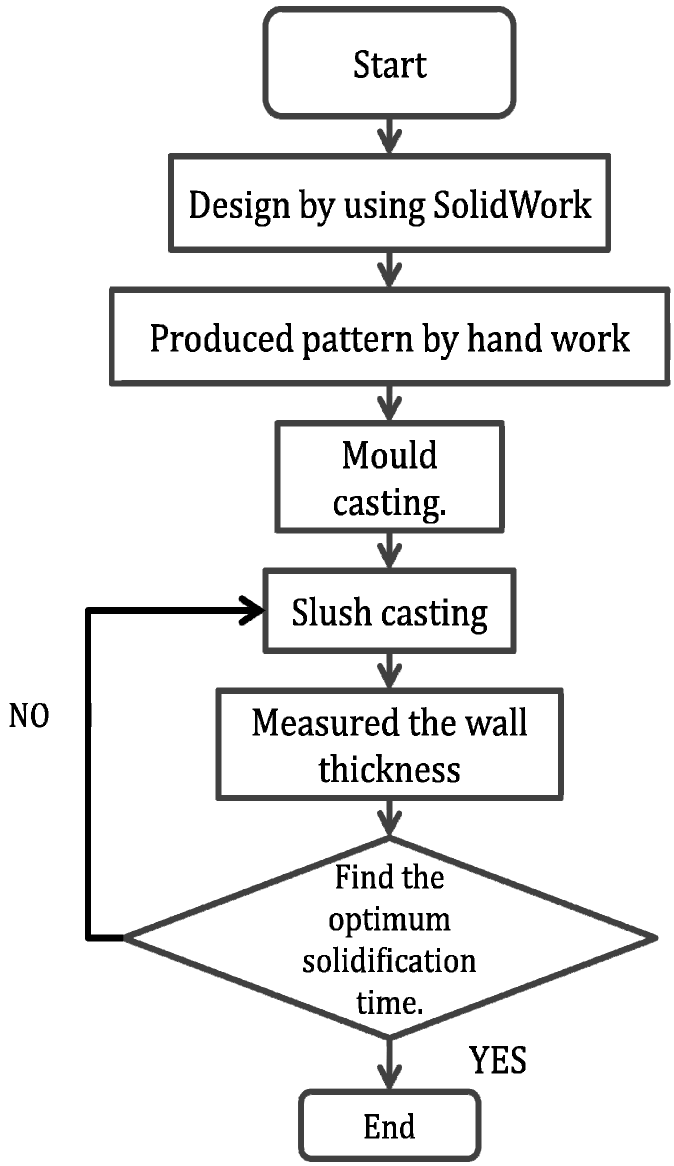

Figure 3.1: Flow Chart

3.3.1 Parameters of Study

`The parameter of study is curing time for excess liquid to poured out as shown in table 3.1. The product is produced by slush casting method.

3.3.2 Wall Thickness

In slush casting process, wall thickness depends on time taken before the excess resin is thrown away. The measurement of the thickness will be made after the liquid completely solidified. Measurements will be done by using digital vernier caliper and the collected data will be record manually into the table 2. The thickness of the wall will solidify depends on time taken for the material poured away. In this study, five different times are selected.

Table 3.1: Solidification Time

Curing time, *(minutes)*	**1**	**2**	**3**	**4**	**5**
Wall thickness, *(mm)*					

3.3.3 Number of Trials

In this study, only one trial is carried out for the pattern while five trials are conducted for the final part in order to obtain parts with different wall thickness. The pattern and final parts will produced based on the concept as shown in Figure 7.

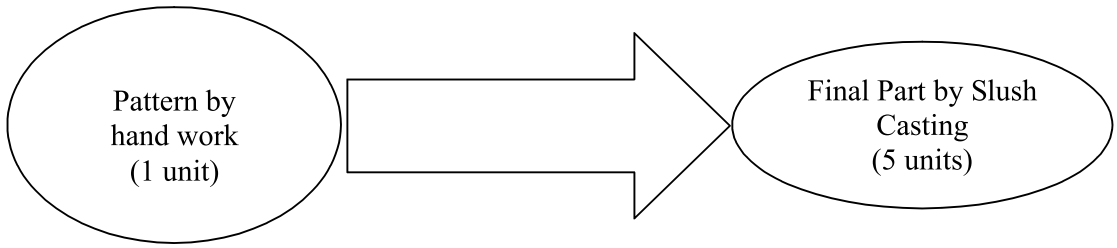

Figure 3.2: Route from Pattern to Final Parts

3.4 OUTPUT OF THE STUDY

The objectives of the experiment must be clearly and specifically defined. It is because the objectives will represent the goal of this study.

The main objective of this study is to measure the wall thickness of the produced parts. Therefore, wall thickness (*mm*) is the expected output from the experimental study.

3.5 DATA ANALYSIS

The data obtained in this experimental study is analyzed using standard design method. It is one factor at a time. This type of approach is used in this study to enable the analysis of data obtained from the set up parameters. The particular factors, which is the solidification time, is used during experimentation.

3.5.1 Mean Values

The analysis of dimensional accuracy is done by determining the mean for each part. Eq. (3.1) below represents the formulas used in this experimental data analysis.

$$\sum Mean_x = (\text{Trial } 1 + \text{Trial } 2 + \text{Trial } 3)/3 \qquad (3.1)$$

Table 3.2: Table for Wall thickness Data

Part	Curing time (minute)	Wall thickness (+/-0.0010mm)					
		A	B	C	D	E	F
Part1	1						
	Mean						
Part 2	2						
	Mean						
Part 3	3						
	Mean						
Part 4	4						
	Mean						
Part 5	5						
	Mean						

3.6 MATERIALS

Materials required for this experimental study should be determined in the first place. Silicone rubber will be used as the material for mould production whereby final part will be produced by slush casting which utilize resin as the material.

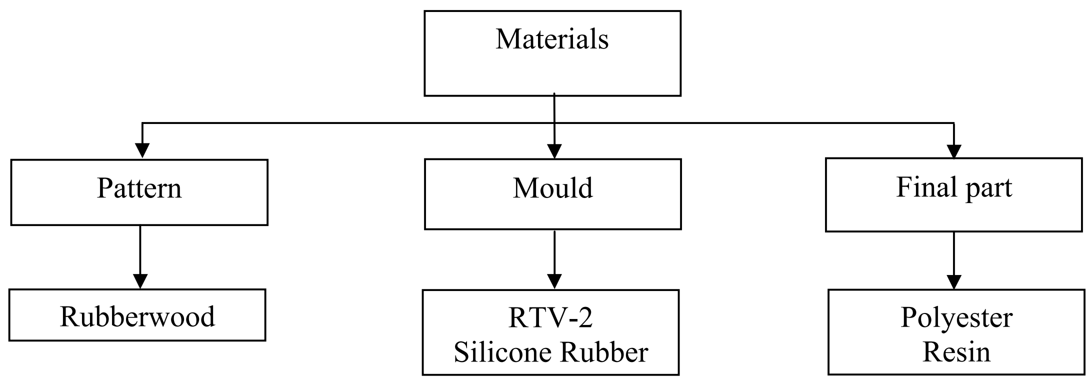

Figure 3.3: Materials Required For This Study

3.6.1 Silicone Moulding

Silicone rubber has the best release properties of all the mould rubber, which is especially an advantage when doing casting of resin. This material also exhibit very good chemical resistance and high temperature resistance (205°). The material used for this study is RTV-2 silicone rubber (Model 638#). RTV-2 silicone rubbers are generally named as two-part room temperature sulfurated silicone rubber, which features an exceptional fluidity and good operability. When mixed with 2-3% curing agent, they can still be operated within 30 minutes, but will be formed after 2-3 hours. The combination of good release properties, chemical resistance and heat resistance make silicone rubber the best choice for casting of resin. The properties of this material are show in Table 3.3.

Table 3.3: Properties of Silicone Rubber

Properties of RTV-2 Silicone Rubber	
Appearance	white
Mixing proportion of curing agent(%)	2
Operating time (hours)	0.5
Curing time(hours)	2-4
Temperature resistance (c°**)**	380-400
Hardness (A°)	22-28
Viscosity (CS)	25000-30000
Tensile-strength	≥37
Tear-strength	≥28
Elongation-break (%)	≥ 540
Retractility (%)	≤0.25
Packing (kg/pail)	25,200

Source: Alexander Gibbons (2006)

3.6.2 Slush Casting

For slush casting, polyester resin is used as material for the final parts. Resin is a thin material, fast setting polymer used for casting parts for many applications. It features a simple “one to one” mix ratio. It contains no fillers, has no odor, and cures to an off-white color. Two important mechanical properties of any resin system are its tensile strength and stiffness. Polyester, vinyl ester and epoxy resin systems cured at 20°C and 80°C. Properties of this material are show in the Table 3.4.

Table 3.4: Properties of Resin

Properties	ASTM or Unit	ECTFE
Mechanical Properties		
Specific Gravity	**D792**	**1.68**
Elongation %	**D638**	**200~300**
Tensile Elastic Modulus Young's Modulus (psi)	**D638**	**240,000**
Thermal Properties		
Melting Point	**°C**	**240**
	°F	**464**
Low Temperature	**°C**	**-76**
Embrittlement	**°F**	**-105**

Source: http://www.ecplaza.net

3.7 MAJOR MACHINING INSTRUMENTATION

In this study, the major machining instrument needed is a slush casting. Slush casting is used to produce the final part of tool holder.

3.7.1 Mould Casting by Silicone Rubber (Post Processing)

In this study, box for making tool holder mould is shown in the Figure 3.4. The liquid resin will be poured in this box to get the shape of the pattern. Steps for this process are outlined as follows:

(i) Make sure surface of the master must very smooth and no polishing is required. Then, apply a coat of wax release agent to all pattern surfaces. This will facilitate separation of the pattern from the completed silicone rubber mold.

(ii) Place the adjustable mold wall around the pattern keeping in mind that it should be no closer than 1/2 inch, so that the silicone mold wall will be thick enough. Use modeling clay to fill any voids where silicone rubber might leak.

(iii) Pour the silicon slowly to avoid air bubbles are left around the master walls. The mold arrangement can be tight at a slight angle if a large horizontal surface is present.

(iv) Once the curing time has elapsed, the mold will be removed.

(v) Since we made one piece of mold, cut the silicone rubber piece into two halves.

(vi) Once the cutting is complete, gently pull the two mold parts apart. Then, pull the master out of the half mold.

(vii) Apply a coat of release agent to the silicone mold to prevent the casting polymer from sticking to the silicone rubber

(viii) Now the moulds completely finish and ready for casting process.

Figure 3.4: Mould Casting

Figure 3.5: Box for Mould Casting

3.7.2 Resin Casting Process

(i) Firstly, mixed the two compound of resin. This process must be slowly to avoid the air bubble.

(ii) After that, poured the resin quickly around the mould before the resin starts to gels.

(iii) Rotating the mould to make sure the resin coat all the mould. Continue this process until 2 minutes, 4 minutes, 6 minutes, 8 minutes and 10 minutes (five product) the not solidify resin will poured out.

(iv) Normally, this material will completely solidify in 10 minutes to 30 minutes. Then, remove the mould from the solidify resin and measured the wall thickness.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this study, factors of final parts are subjected to wall thickness. The factor is curing time. The measurement is conducted more than once to ensure precision and accuracy. This chapter reviews the finding and discussion on data analysis of this experimental study.

4.2 MODEL ANALYSIS

This section reviews the analysis by using COSMOSexpress to find the critical part of the pattern and finding Factor of Safety (FOS) after load is applied. Load applied is constant where the value is 4.905N.

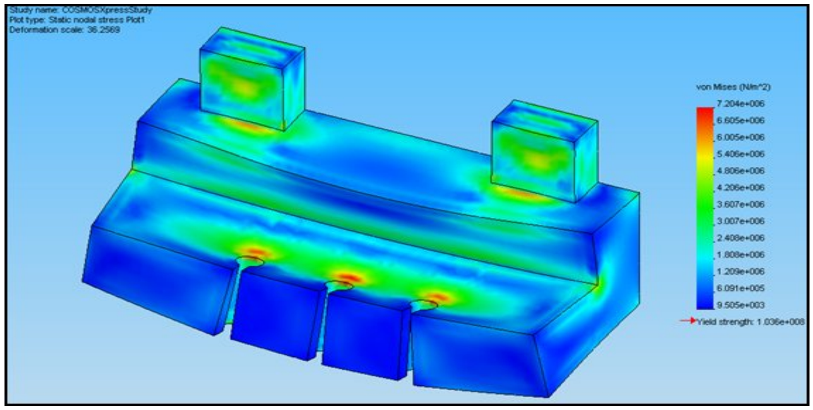

Figure 4.1: Stress Distribution for 1mm Wall Thickness

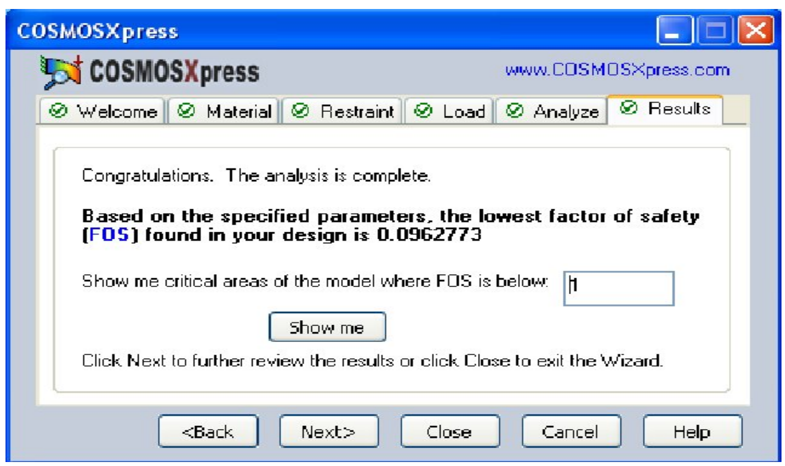

Figure 4.2: Result of FOS

Figure 4.1 and Figure 4.2 shows the analysis to find the critical part when load is applied. The minimum Factor of Safety (FOS) for product which has 1mm wall thickness is 0.0962773 when load of 4.905N is applied. Value of FOS < 1, so this pattern is not safe for holding load of 4.905N

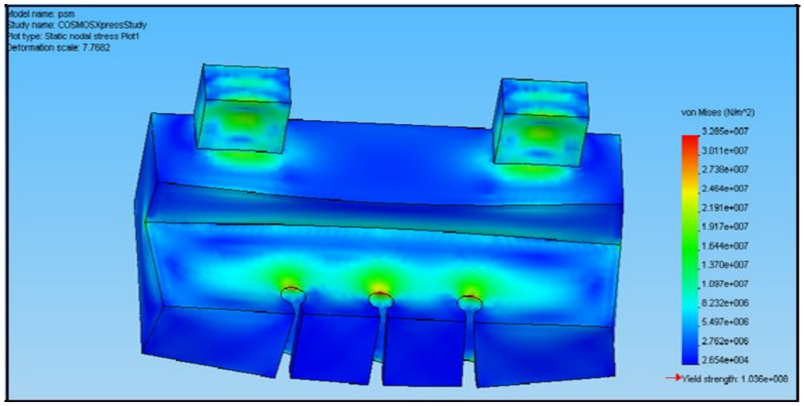

Figure 4.3: Stress Distribution for 2mm Wall Thickness

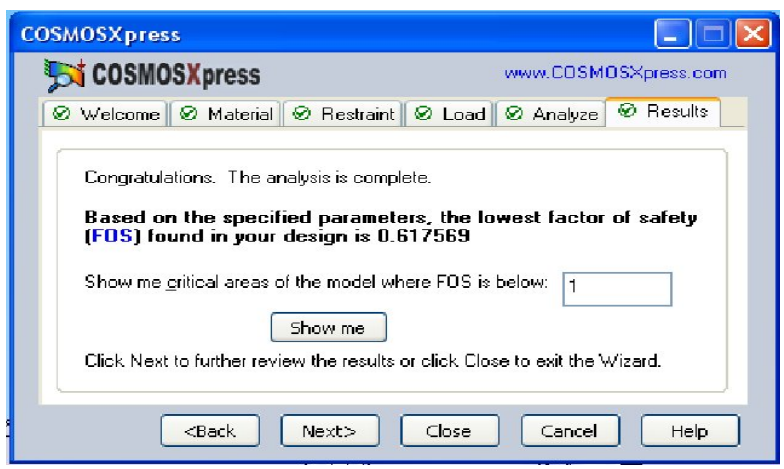

Figure 4.4: Value of FOS

Figure 4.3 and figure 4.4 shows the result of critical part when load of 4.905N is applied to the selection surface. The minimum value Factor of Safety for 2mm wall thickness is 0.61759. The value of FOS < 1, so this pattern also is not safe for holding load of 4.905N

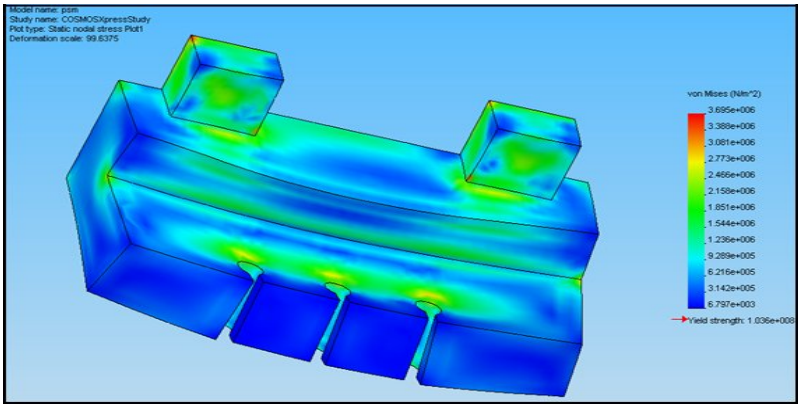

Figure 4.5: Stress Distribution for 3mm Wall Thickness

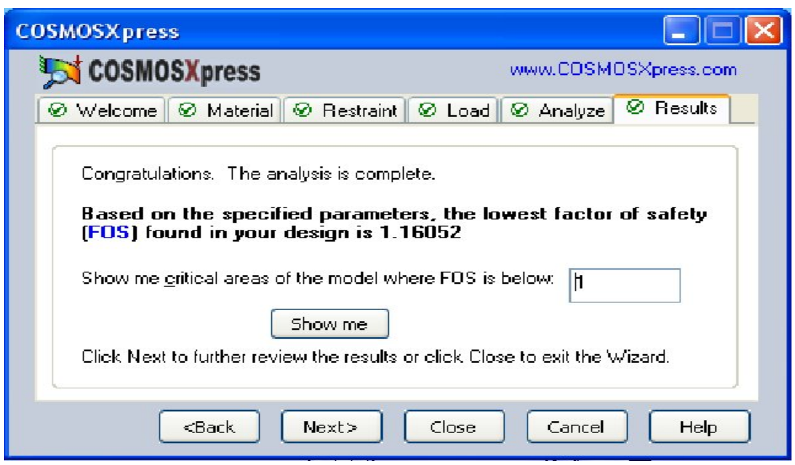

Figure 4.6: Value of FOS

Figure 4.5 and figure 4.6 shows the result from stress distribution analysis for wall thickness 3mm. The analysis shows that the minimum Factor of Safety for this pattern is 1.16052 when load applied is 4.905N. Value of FOS > 1, so this pattern is safe for hold load 4.905N

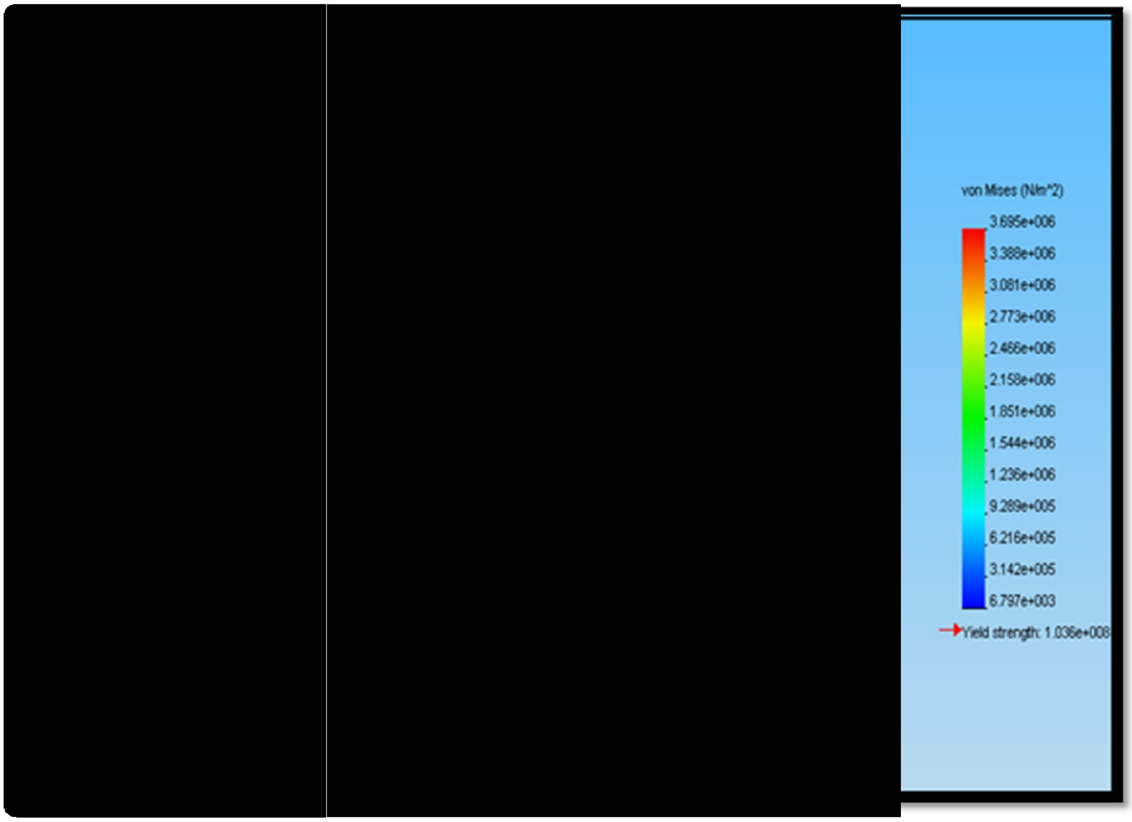

Figure 4.7: The arrow show the critical portion of this pattern

Figure 4.7 show the critical portion which have potential crack when load is applied. So, from this result the measurement portion was selected as show in figure 4.7.

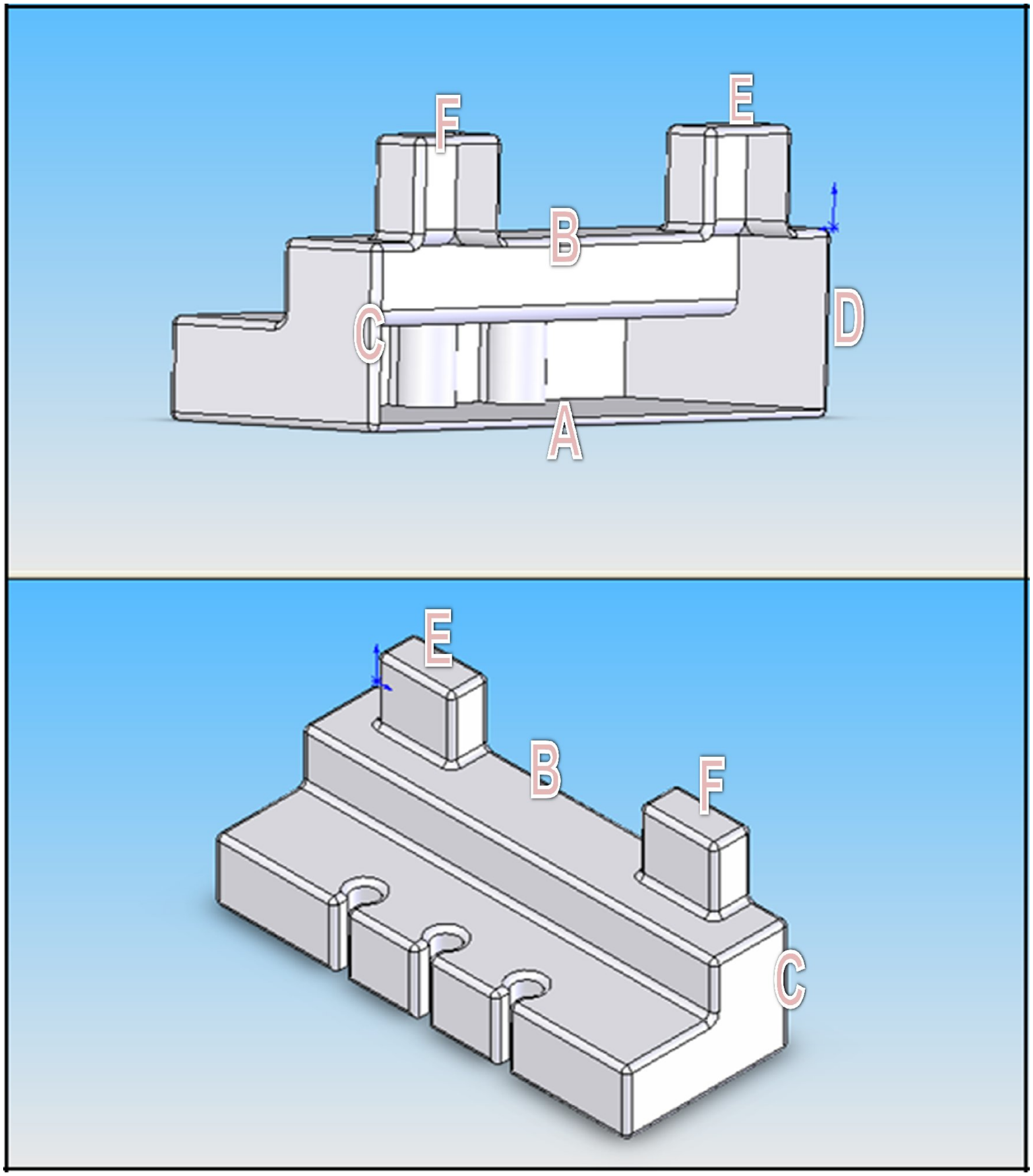

Figure 4.8: Selected Point for Wall Thickness Measurement

4.3 WALL THICKNESS (mm) OF FINAL PARTS

This section reviews the finding on the wall thickness of all final parts produced by slush casting process.

4.3.1 Tables and Graphical Analysis

Table 4.1 depicts the results obtained from the thickness measurement of the final parts by Digital Vernier Caliper Mitutoyo. The data is analyzed by using graphical method to select the optimum time for wall thickness created.

Figure 4.9: Part 1 with Curing Time 1 Minute

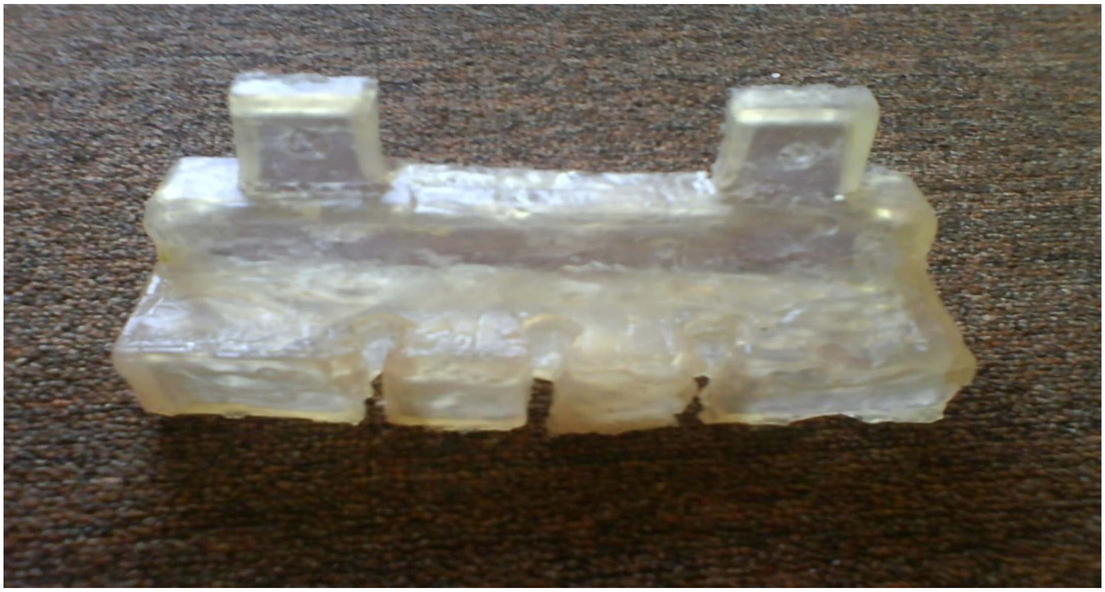

Figure 4.10: Part 2 with Curing Time 2 Minute

Figure 4.11: Part 3 with Curing Time 3 Minute

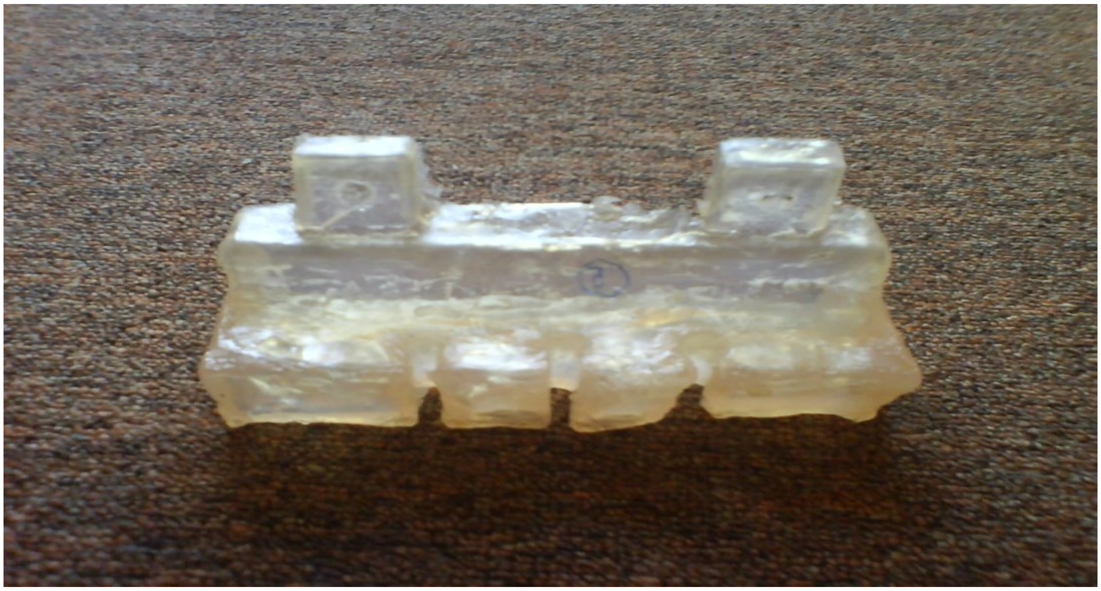

Figure 4.12: Part 4 with Curing Time 4 Minute

Figure 4.13: Part 5 with Curing Time 5 Minute

Figure 4.14: Mould Casting

Table 4.1: Wall Thickness Data

Part	Curing time (minute)	Wall thickness (**+/-0.0010**mm)					
		A	B	C	D	E	F
		1.24	1.69	2.13	2.42	2.44	2.03
Part 1	1	1.30	1.73	2.21	2.39	2.35	2.15
		1.29	1.71	2.19	2.17	2.09	2.25
	Mean	1.277	1.71	2.23	2.323	2.293	2.14
		2.26	2.35	2.24	2.34	2.58	2.61
		2.21	2.34	2.23	2.31	2.47	2.58
Part 2	2	2.32	2.29	2.28	2.33	2.52	2.63
	Mean	2.26	2.33	2.25	2.33	2.523	2.61
		2.45	2.38	2.31	2.33	2.61	2.71
		2.46	2.41	2.34	2.36	2.65	2.67
Part 3	3	2.51	2.43	2.39	2.35	2.61	2.65
	Mean	2.47	2.41	2.35	2.35	2.62	2.68
		2.68	2.70	2.51	2.54	2.71	2.74
Part 4	4	2.72	2.73	2.56	2.57	2.75	2.78
		2.66	2.75	2.49	2.55	2.74	2.75
	Mean	2.69	2.73	2.52	2.55	2.73	2.76
		2.78	2.75	2.62	2.63	2.78	2.81
Part 5	5	2.81	2.81	2.64	2.64	2.81	2.84
		2.85	2.87	2.65	2.61	2.79	2.85
	Mean	2.81	2.81	2.64	2.63	2.79	2.83

There are five critical points measured for every part, where the measurements are conducted three times each to ensure precision. Thus, there are fifteen measurements conducted for each part which later being averaged according to the five critical points. Based on the obtained values of the critical points from different time curing, the mean will be calculated later using Eq. (3.1).

4.4 RESULT AND DISCUSSION

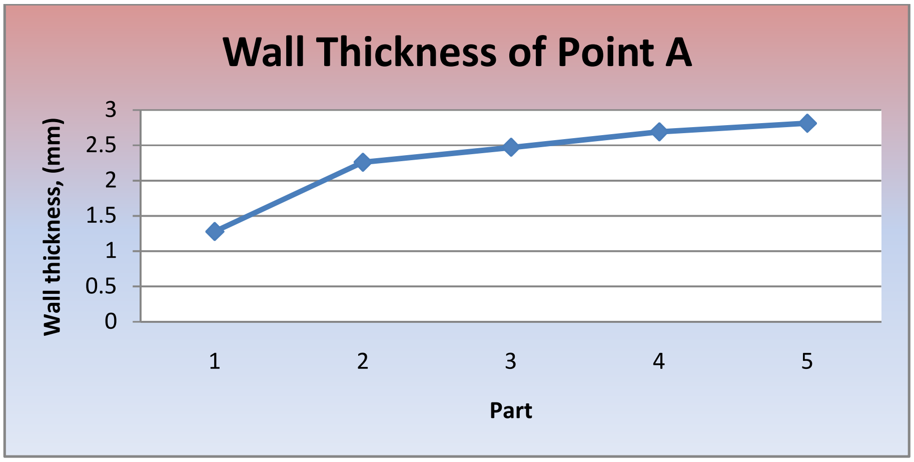

Figure 4.15: Graph for Point A

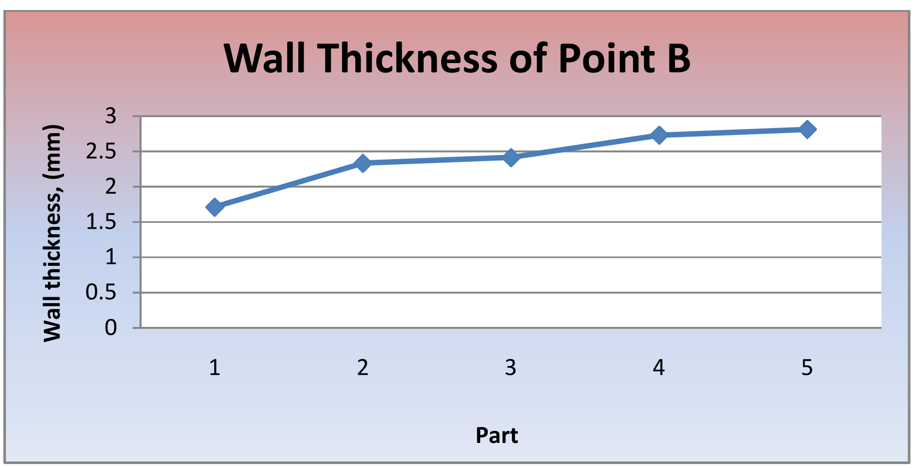

Figure 4.16: Graph for Point B

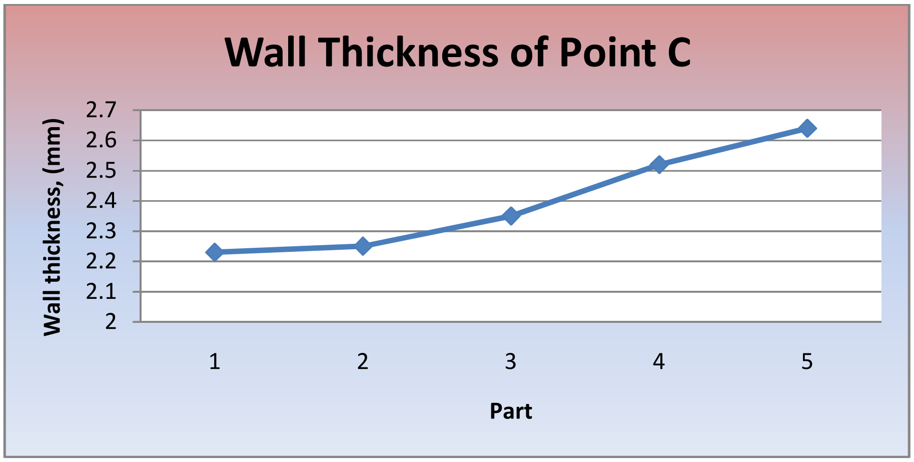

Figure 4.17: Graph for Point C

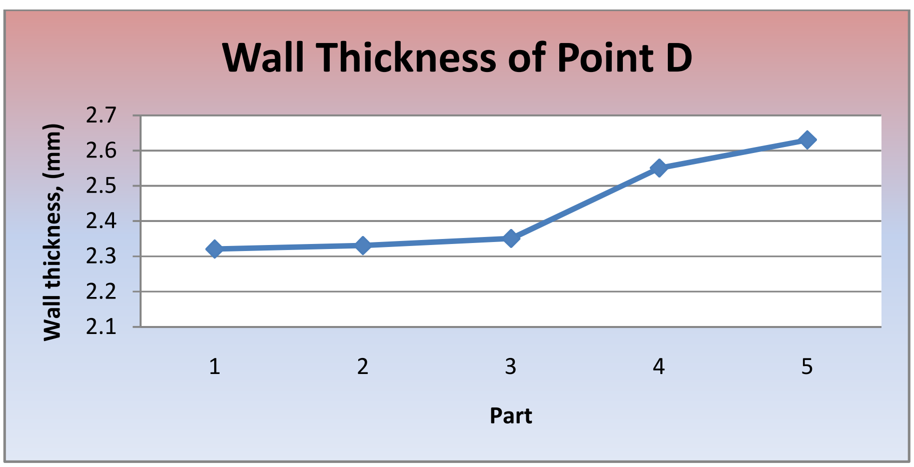

Figure 4.18: Graph for Point D

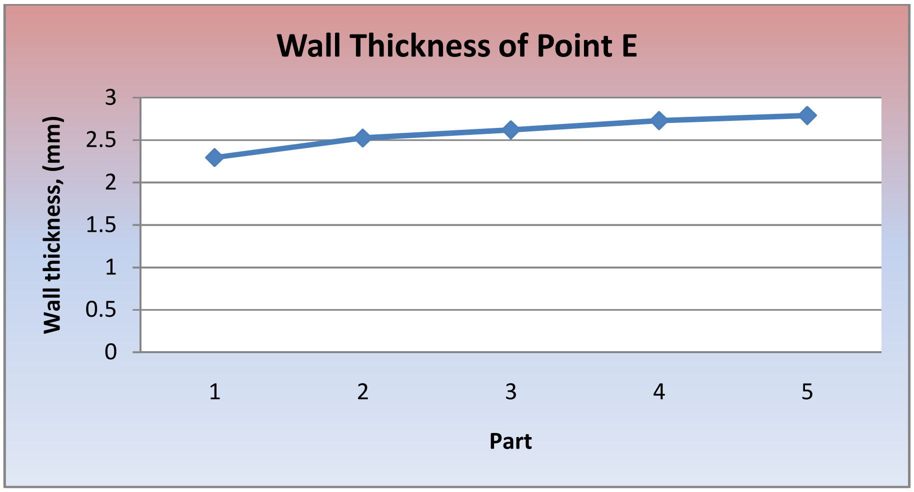

Figure 4.19: Graph for Point E

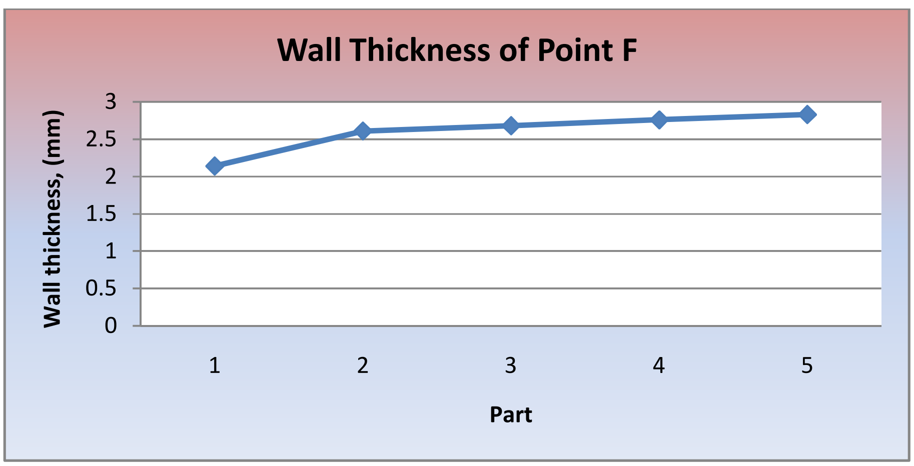

Figure 4.20: Graph for Point F

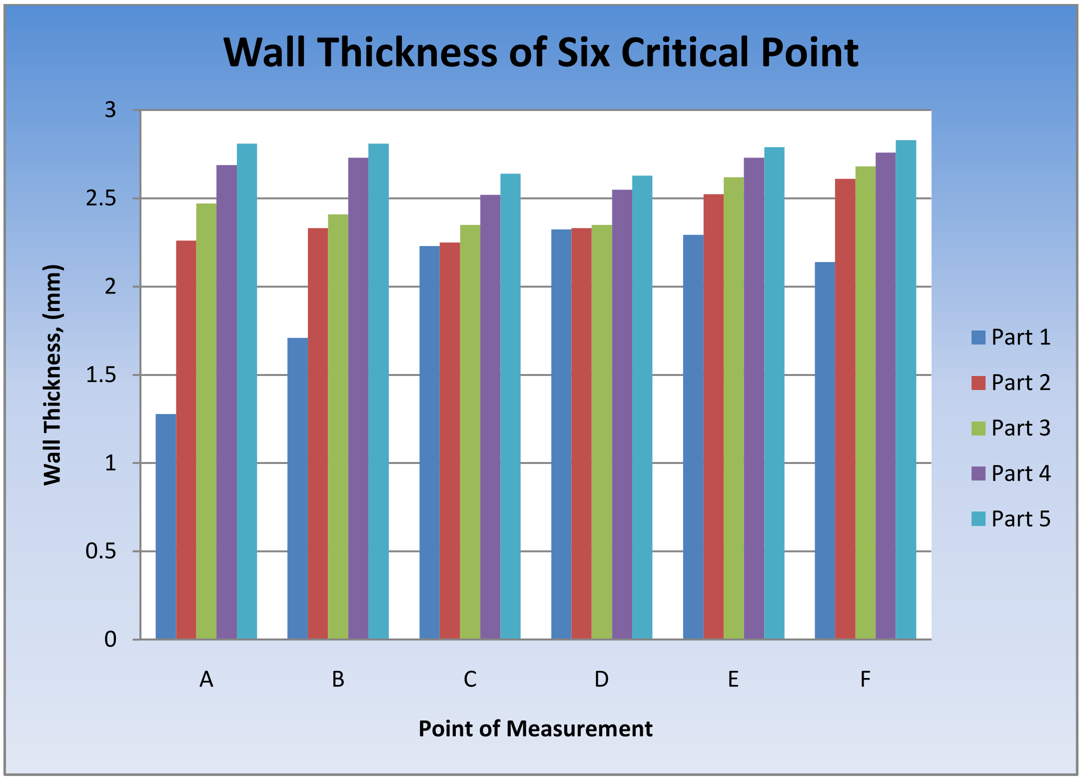

Figure 4.21: Graph for Overall Point

Based on Figure 4.21, the graph illustrates the comparison of the wall thickness of five parts at point A, B, C, D, E and F. It can be seen that there is a slight difference of wall thickness measurement between those five parts. It shows that the wall thickness increase for all point of measurement, whereby the thickness of all parts experience expansion. The highest thickness happens at section A where the thickness is from 1.277mm up 2.81mm. Although the mould and the material are same, the results displayed are not similar.

Based on this result it can be concluded that wall thickness is proportional to solidify time. This is because rate of resin to solidify depends on time before the excess liquid resin is poured out. Based on the analysis done by using COSMOSexpress (SolidWorks 2006), six points have been identified as critical part when load is applied.

4.4.1 Factors Cause the Difference of Wall Thickness

The difference of wall thickness could possibly caused by several factors. According to the result and analysis from previous sections, the material for the pattern made from wood and it has own effect on the rate of resin to solidify.

In this experimental study, one factor that could possibly cause the difference of wall thickness between parts is position of the mould. The surface of point A, B, C and D should be positioned vertically when pouring the liquid resin into the mould. Actually the liquid resin is not directly solidify after the excess material is poured out, so the liquid resin will slowly flow to the lower part until it is fully solidify. Thus, thickness of the lower part will be higher than the upper part.

The second factor which contributes to the different of wall thickness is dimension of area. As we can see, the area of point A and B is larger than area of point C, D, E and F. As a result, the wet material will be easy to flow to the lower part

The third factor is mixture of resin and its hardener which will affect the rate of resin to solidify. When the resin and hardener is not well mixed, the rate of mixture to solidify is not uniform. Hence, the liquid will not solidify uniformly throughout the whole surface and will cause the different thickness between the parts.

The fourth factor is shape of the pattern; in slush casting, sharp edge will affect wall thickness of the product. The liquid is not well hardened to the mould, thus create a thin wall at that area. This will lead to crack when the product is taken removed out from the mould or when load is applied to it.

CHAPTER 5

CONCLUSION AND SUGGESTION

5.1 INTRODUCTION

This chapter reviews overall conclusion which is made based on the analysis of findings shown in the previous chapter. Section 5.1 discusses on summary of the experimental study while conclusions in section 5.2, followed by suggestions and recommendations for future works in section 5.3.

5.2 SUMMARY

This experimental study is basically an application of Rapid Tooling where the main concern is wall thickness. This study is carried out based on the standard design approach which only includes one factor at one time. The factors consist of the parameter setting, which is the solidification time on the wall thickness. The effects of this parameter setting is analyzed and discussed by using tables and graphical method to determine the best result on the final product. Pattern is made from wood which is later used to produce the RTV-2 Silicone Rubber mould. Apart from that, results from the five final parts are then compared by tables and graphical analysis is used to analyze and discuss the result.

5.3 CONCLUSIONS.

It can be concluded that the experimental study successfully fulfils the main objective which is to investigate the wall thickness of final part by Slush Casting.

Part five, which undergoes 5 minutes curing time has the highest wall thickness compared to other part with different curing time and the wall thickness (mm) of the overall part is relatively proportional to the curing time.

Based on the COSMOSexpress analysis result, part five have the highest factor of safety (FOS) followed by part four, part three, part two and part one. The wall thickness is minimum at upper part and maximum at lower part based on the position of the mould.

The position of mould also will affect the wall thickness because point A and point B is at vertical position. After the excess material is poured out, material at the higher position will flow to the lower part.

In this study, factors such as humidity of the surrounding could possibly cause the different solidify rate of the material.

5.4 SUGGESTION AND RECOMMENDATION

For future experimental works on this topic, the author would like to suggest the following recommendations.

(i) Produce the pattern by using 3D-printer with variation parameter of build orientation and layer thickness.

(ii) Produced the final parts using other material such as wax and also used another material for mould.

(iii) Include other parameter setting in study such as variation of temperature for the final part to solidify.

(iv) Add more analysis for final product such as surface roughness, Ra and dimensional accuracy, mm.

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APPENDIX A

TOOLS FOR MAKING PATTERN AND MOLD

FIGURE 6.1: Hammer

FIGURE 6.2: Saw

FIGURE 6.3: Abrasive Paper

FIGURE 6.4: Pattern after Surface Finishing Process

APPENDIX B

TOOLS USED IN PRODUCED FINAL PART

FIGURE 6.5: Cutter

FIGURE 6.6: Screw Driver

FIGURE 6.7: Resin Casting

FIGURE 6.9: Taken Out Product

APPENDIX C

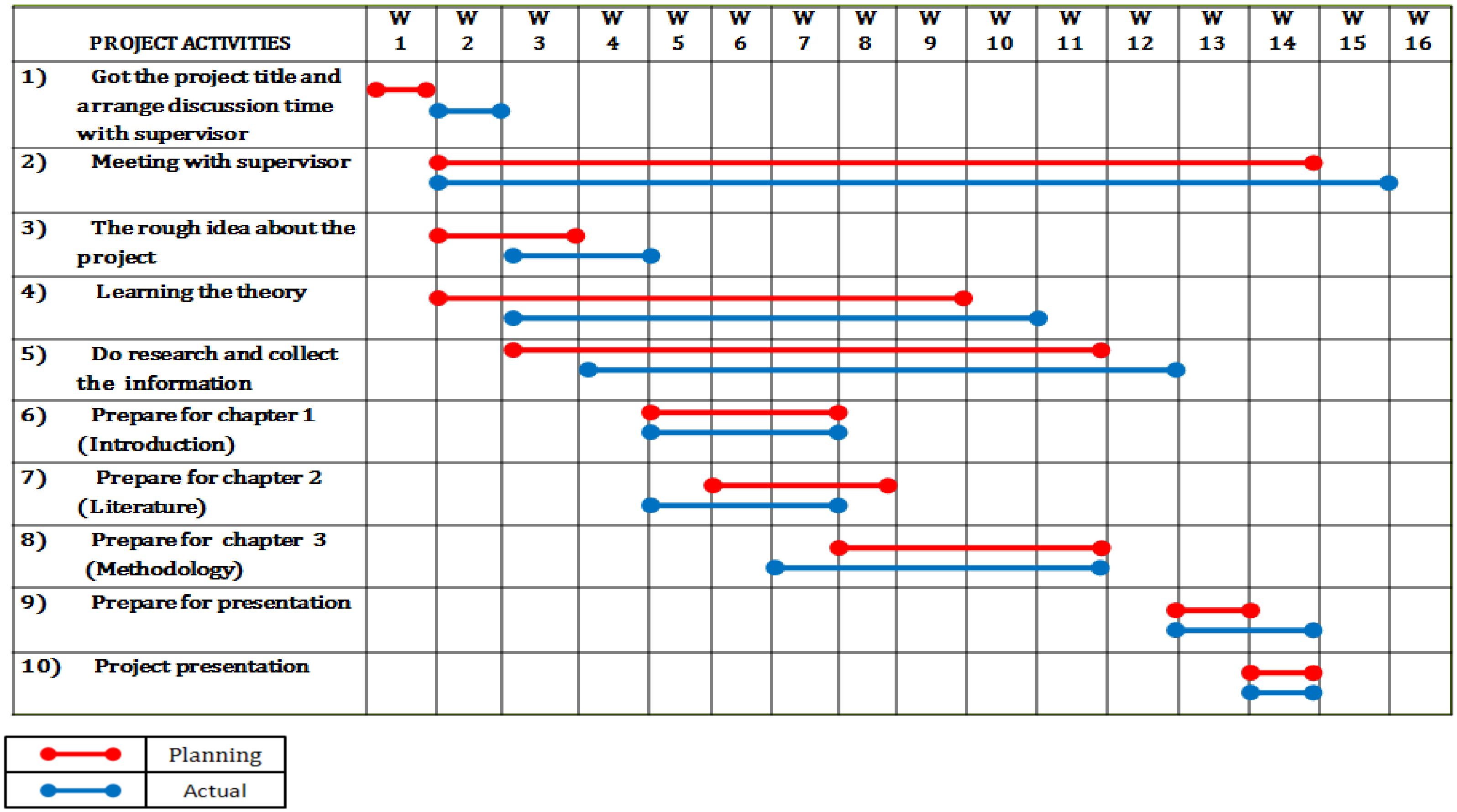

Figure 6.10: Gantt Chart for Final Year Project 1

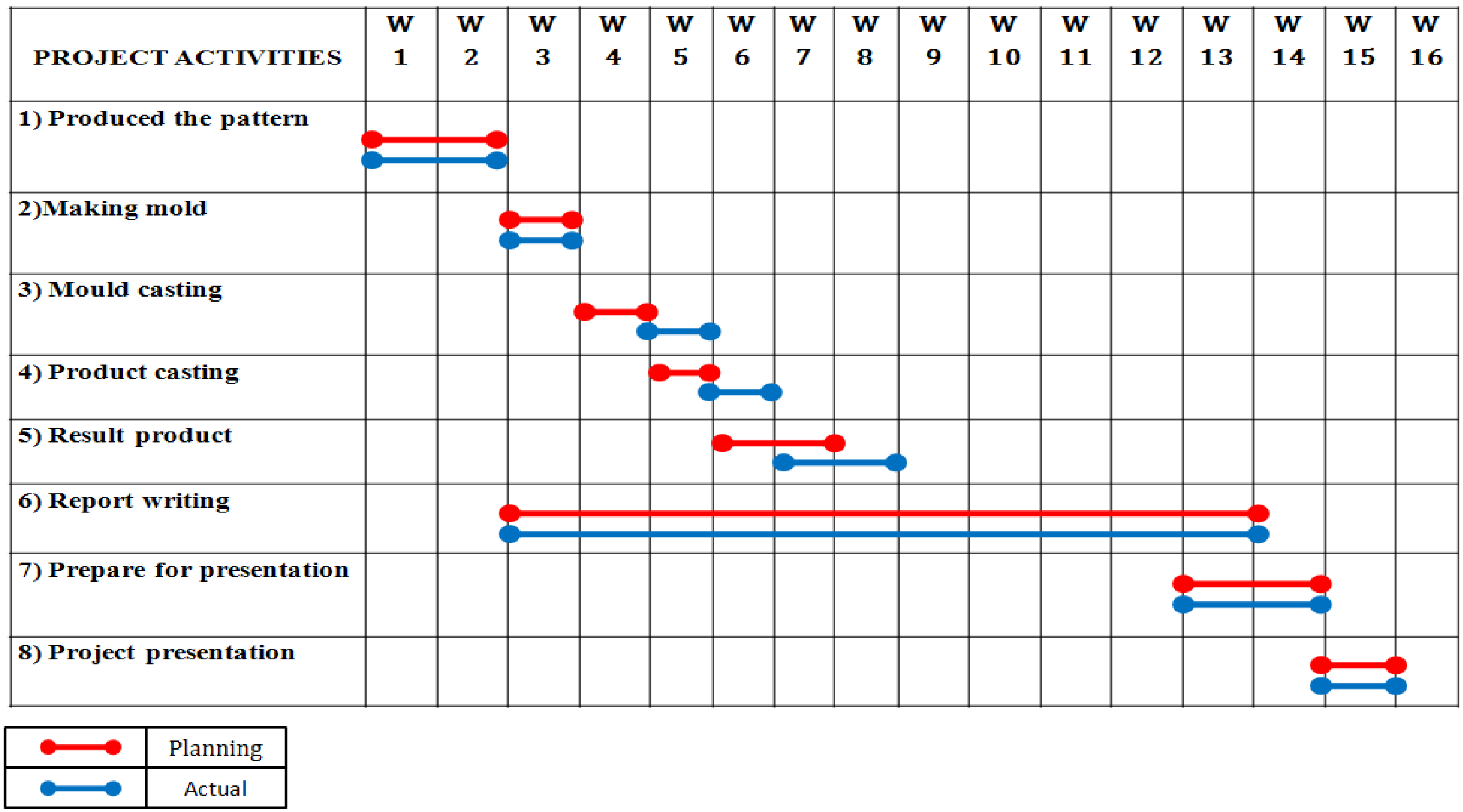

Figure 6.11: Gantt Chart for Final Year Project 2