DESIGN AND MANUFACTURING OF SOUVENIR PRODUCTS USING CENTRIFUGAL RUBBER MOLD CASTING

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A report submitted in fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering (BMKU)

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2025

DECLARATION

I declare that this project report entitled “DESIGN AND MANUFACTURING SOUVENIR USING CENTFIFUGAL RUBBER MOLD CASTING PROCESS” is the result of my own work except as cited in the reference.

Signature :

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Date : 9/JANUARY/2025

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

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DEDICATION

I would like to dedicate this final year project to my mother, my father, my family, my friends and to my supervisors.

ABSTRACT

Souvenirs are typically small items given, kept, or bought as mementos or reminders of a place visited. Centrifugal Rubber Mold Casting, CRMC is a casting method used to produce souvenirs or other items in precise and consistent forms. This method requires careful consideration of rotation speed parameters to ensure successful casting the complex design product. This research aims to create and analyzed complex souvenir keychain products that been selected as the study products and using the centrifugal rubber mold casting method with acrylic laser-cut master models. The casting parameters investigated included varying rotation speeds from 750 to 450 rpm, a spin time of 20 seconds, a pressure of 40 psi, and clockwise rotation (CW). Based on the results of the centrifugal rubber mold casting process, the optimal rotation speeds were determined to be 750 and 700 rpm, resulting in 100% successful cast product production. Parameters other than rotation speed were also considered to optimize the process such as the addition of runners and gates in the silicone rubber mold. The comparison of successful cast product percentages based on different base shapes revealed that each shape which are Gear based shape (KD1), Hole Gear based shape (KD2), Square based shape (KD3) and Rectangle based shape (KD4) will requires different optimal casting rotation speed. The optimal rotation speeds were found to be 700 rpm for Gear-shape (KD1) and Hole Gear-shape (KD2), 650 rpm for Square-shape (KD3), and 500 rpm for Rectangle-shape (KD4).

ABSTRAK

Cenderahati lazimnya adalah barangan kecil yang diberikan, disimpan atau dibeli sebagai kenang-kenangan atau peringatan tempat yang dilawati. “Centrifugal Rubber Mold Casting”,CRMC ialah kaedah tuangan yang digunakan untuk menghasilkan cenderahati atau barangan lain dalam bentuk yang tepat dan konsisten. Kaedah ini memerlukan pertimbangan penting terhadap parameter kelajuan putaran untuk memastikan keberhasilan produk “cast” bentuk yang kompleks berjaya. Penyelidikan ini bertujuan untuk mencipta dan menganalisis produk “keychain” cenderahati kompleks yang dipilih sebagai produk kajian dan menggunakan kaedah CRMC dengan “master model laser cutting” akrilik. Parameter tuangan yang disiasat termasuk kelajuan putaran yang berbeza-beza dari 750 hingga 450 rpm, masa putaran 20 saat, tekanan 40 psi, dan putaran mengikut arah jam (CW). Berdasarkan keputusan proses CRMC, kelajuan putaran optimum hasil kajian ialah 750 dan 700 rpm yang menghasilkan 100% pengeluaran produk “cast” yang berjaya. Parameter selain daripada kelajuan putaran juga dipertimbangkan untuk mengoptimumkan proses seperti penambahan “runners” dan “ingates” dalam “Silicone Rubber Mold”, SRM. Perbandingan peratusan produk “cast” yang berjaya berdasarkan bentuk asas yang berbeza mendedahkan bahawa setiap bentuk iaitu bentuk berasaskan Gear (KD1), bentuk berasaskan Gear Lubang (KD2), bentuk berasaskan segi empat sama (KD3) dan bentuk berasaskan segi empat tepat (KD4) akan memerlukan kelajuan putaran “casting” optimum yang berbeza. Kelajuan putaran optimum yang didapati adalah 700 rpm untuk bentuk Gear (KD1) dan bentuk Gear Lubang (KD2), 650 rpm untuk bentuk segi empat sama (KD3) dan 500 rpm untuk bentuk segi empat tepat (KD4).

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I would also, like to express my heartfelt appreciation to my family that especially to my beloved mother, Normaliza binti Nordin and my sister, Nurshafiqa Aqilla Binti Aman for their love and encouragement. I am especially grateful for their support and for always being there for me even though when I was away from home to finish my project. Their constant support has been a source of strength and motivation throughout my studies.

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LIST OF ABBEREVATIONS

CRMC	-	Centrifugal Rubber Mold Casting
CAD	-	Computer Aided Design
SLA	-	Stereolithography
LASER	-	Light Amplification by Stimulated Emission of Radiation
Nd:Yag	-	Neodymium-doped Yttrium Aluminium Garnet
HAZ	-	Heat-Affected Zone
SRM	-	Silicone Rubber Mold
Zn	-	Zinc
Al	-	Aluminium
Mg	-	Magnesium
Cu	-	Copper
HoQ	-	House of Quality
CR	-	Customer Requirement
EC	-	Engineering Characteristics
CD	-	Conceptual Design
STL	-	Standard Tessellation Language.
UV	-	Ultraviolet
DXF	-	Drawing Interchange Format
KD	-	Keychain Design
UTeM	-	Universiti Teknikal Malaysia Melaka
UII	-	Universitas Islam Indonesia

LIST OF SYMBOLS

ºC	-	Degree Celsius
cm	-	Centimeter
mm	-	Milimeter
rpm	-	Revolutions per Minute
%	-	Percentages
g	-	Gram
ml	-	Milimeter
°	-	Degree

CHAPTER 1

INTRODUCTION

1.1 Background

According to the Cambridge Dictionary in 2019, a souvenir is a product that you want to keep as a memento of a memorable visit, certain occasions, or holiday. This suggests that the main purpose of souvenirs is to act as a link or recall between the tourist's memorable moments or experiences from their time there and the locations (Collins-Kreiner & Zins, 2011). Five expressive attributes have been defined by Hume in 2014 as dimensions to categorize souvenirs into three distinct categories which are medium (materials of souvenir), maker's mark (producer or destination's mark), relational (how the souvenir relates to the destination), invitational (the story behind the souvenir design), and icon fetish (how an iconic sign or event connects with souvenir). Moreover, there are now more options for travellers to choose from in the increased souvenir industry (Li, 2020).

Traditional methods of manufacturing that are commonly used for souvenirs can restrict design complexity and flexibility. This project explores "Centrifugal Rubber Mold Casting (CRMC)" as an approach to enhancing flexibility and innovation in souvenir production. CRMC is a metal casting method used to produce souvenirs or objects in large quantities with precise and consistent shapes. The working principle of CRMC relies on centrifugal force. In this process, the mold, typically made of silicone rubber, is rotated on a spinning machine at specific parameters and the molten metal is then poured into the rotating rubber mold (Karpitschka, Weber, & Riegler, 2015). However, there is a lack of research on applying CRMC as a method in souvenir manufacture despite its potential. Existing literature primarily focuses on the technical aspects of the process for industrial applications, as evidenced, which explores optimizing casting parameters for CRMC (Yashar, 2018). This lack of intersection between these two areas creates a significant knowledge gap and the limited understanding of how to adapt CRMC for designing and manufacturing souvenirs. Therefore, to successful carrying out of the casting process using the CRMC method is crucial and requires the use of the right parameters. Cautious attention must be given to the temperature parameters of the material to be used, the rotation speed of the spin casting machine, the pressure during casting and the precision characteristics of the mold.

1.2 Statement of the Purpose

The purpose of the research to determine the optimal parameters to produce high-quality souvenirs. The CRMC process utilizes molten metal with a low melting point such as zinc alloys, lead alloys, and tin (Beznak, M, 2014). In this research a C-400 spin casting machine is utilized. The process begins with the design of souvenirs, followed by the fabrication of the product master for silicone rubber mold manufacturing later. The melted zinc alloy is used as the CRMC cast material. The research focuses on the production of souvenirs with different shapes and designs. Experimental parameters, including variations in rotation speed and rubber mold engineering are investigated to achieve the best possible results.

1.3 Problem Statement

According to Smith, 2020 the current souvenir market with mass-produced lack both quality and individuality. These common souvenirs fail to capture the unique character and essence of a travel destination, leaving tourists with unmemorable and insignificant keepsakes. Traditional manufacturing methods further exacerbate this issue by imposing limitations on design complexity, material choices, and overall aesthetic appeal.

This research aims to address these limitations by analysing the potential of Centrifugal Rubber Mold Casting (CRMC) as an innovative approach to producing high-quality personalized souvenir. CRMC offers significant advantages over traditional methods such as enhanced design flexibility, the ability to utilize a wider range of materials and the potential for superior surface finishes.

1.4 Objectives

1. Design and manufacture souvenir products using CRMC method.
2. Identify the suitable speed parameter of CRMC for the manufacture of souvenirs products.
3. Analyse the impact of CRMC speed parameters on the quality, dimensional accuracy, and surface finish of souvenir.

1.5 Scopes of Project

This section provides brief of the general steps and explanations that must performed to accomplish the objectives of the study:

1. Keychain souvenir design

Construct the souvenir design from sketch idea to CAD model using SolidWorks. The design process will include concept generation and concept screening such as "House of Quality", "Morphological Chart" and "Pugh Chart". The process then includes the design of new designs using CorelDRAW which will be explained later.

2. Keychain Souvenir Manufacturing

The suitable master model will be determined between SLA 3D printing and acrylic laser cutting for silicone rubber mold production using the vulcanization method. Furthermore, the speed parameters of CRMC methods and the most convenient keychain base shapes suitable for mass-manufacturing souvenir products will be identified and analyzed

CHAPTER 2

LITERATURE REVIEW

2.1 Keychain Souvenir

In this project, keychains have been chosen keychains as our souvenir product because, as we can see, keychain souvenirs hold a special appeal within the array of travel mementos. With their small size and ease of carrying, they make for ideal keepsakes and, therefore, perfect representations of famous landmarks, symbols of culture, or local artistry (Shen, 2022). These tiny treasures can evoke powerful memories and bring one closer to travel experiences cherished in the heart. It is found that keychain souvenirs play a dual role in life functional and sentimental. On a practical note, they act as a daily reminder of a place or event. Having them hanging with our keys ensures a constant visual stimulus that could fill us with a positive, warm feeling and nostalgia. (Havlena & Ritchie, 2010)

The market might be flooded with keychains souvenirs which are commonly recommended souvenirs when we travel (Sucahyono, 2018). This indicates that there is a potential market gap for innovation in the production of keychain souvenirs. Here is where manufacturing method like CRMC explored in the proposed project can find a place which are combining functionality with high-quality materials, uniqueness designs, and even personalized elements (Pradeep, 2021). This proves that CRMC can create keychain souvenirs which are not just practical but also have keychain essentials values as memento and has attractive design.

2.2 Design Keychain Souvenir

2.2.1 Computer Aided Design (CAD)

Computer-Aided Design (CAD) is a functional software that assists designers in the design process. The design of products is significantly facilitated by computers. Moreover, CAD also make the designers relied on hand-drawn 2D drawings to communicate design concepts before initiating the manufacturing process. With the introduction of CAD, numerous design advancements and developments in 3D model shapes have been achieved (Ramnath et al., 2020).

The increasing sophistication of CAD technology, coupled with a growing user base, has driven significant product innovations by empowering designers with greater ease in the innovation process (Murthy and Mani, 2012). As shown in Figure 2.1 below is the role of CAD in the process Product Design

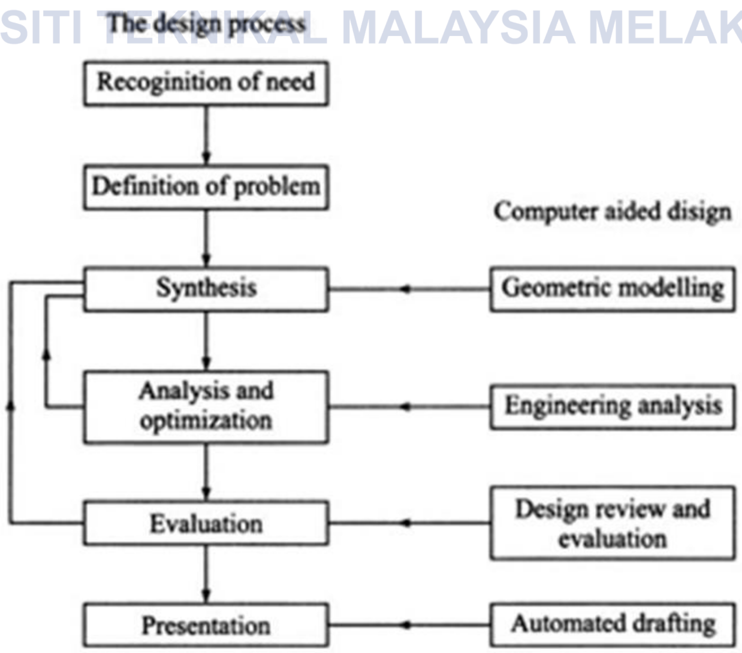


Figure 2.1:The Role of CAD in the Product Design Process (Narayan, 2008)

2.2.2 Solid Works

SolidWorks is one of the industry's leading 3D CAD tools that needs little introduction, the 3D parts are built from a series of 2D sketches and features such as extrude, revolve, fillets, cuts, and holes. It can put the parts together into assemblies and create 2D drawings from the 3D parts and assemblies.

By knowing the right information about parts function before start modelling or designing can create a model that will be easier to edit and to detail the drawings. The term design intent is a statement of how the part function, the major features of the part, and how the model reacts to modelling changes (SolidWorks Bible, 2013).

2.2.3 CorelDRAW

Akron-summit in 2019 defines CorelDraw as a vector graphics editing software developed by Corel Corporation. It is used for creating and editing digital illustrations, logos, brochures, and other design projects. The program offers many features and special effects that allow users to create designs to fit many different needs. CorelDraw is a powerful software known for its user-friendly interface and comprehensive design tools (Ekundayo, 2023).

The arrival of the digital information society has brought new opportunities for the development of apparel design. At present, the teaching content and means of the costume design profession have set up the CorelDraw software design course in different degrees and in different forms. The significance of CorelDraw in the creation of both simple and complex designs using computers. It underscores the software's versatility, user friendliness, and potential for continued growth, making it an invaluable tool for designers across various industries (Wang, 2020)

2.3 Keychain Souvenir Master Model

2.3.1 Master Model

Master model is the sculptor behind the CRMC process that will form that shapes the cavity in the mold to define the final cast product. The material used for the master model such as plastic, wood or metal depends on the complexity of the part and the production volume. But regardless of material all master models share key design principles. One important factor is shrinkage allowance. Since metal contracts as it cools from its molten state, the pattern needs to be slightly larger to compensate for this and ensure the final cast has the desired dimensions. Another crucial element is the draft angle. This slight taper on the sides of the pattern allows for easier removal from the mold without damaging the delicate mold cavity. Finally, good pattern design considers potential variations in casting dimensions. By including some extra material, the master model can account for slight inconsistencies that might arise during mold preparation or due to wear and tear on the master model itself. These considerations ensure smooth production and high-quality cast product. (Khan, 2017).

2.3.2 SLA 3D Printing

Stereolithography apparatus (SLA), an early adopted vat-based AM technique that employs photopolymerization for 3D printing. In this process, photocurable resin is solidified through photopolymerization initiated by the absorption of light (Pagac, 2021). Photopolymerization involves the use of light rays to propagate a chain polymerization process which is resulting in the photo-crosslinking of pre-existing macromolecules. A crosslinker of another component or material that links one polymer chain to another through covalent or ionic bonds. This photopolymerization process solidifies a pattern within the resin layer and providing a foundation for subsequent layers. A photoinitiator or photoinitiator system is necessary to convert photolytic energy into reactive species which are radicals or cations which drive chain growth via radical or cationic mechanisms (Bagheri, 2019).

Using a computer-controlled laser beam, a pattern is illuminated on the surface of the resin. The resin exposed to the light beam solidifies. This principle is repeatedly applied layer by layer to solidify the resin and form each layer of the product in SLA 3D printing. The thickness of each layer is controlled by the energy of the light source and the exposure time (Melchels, 2010).

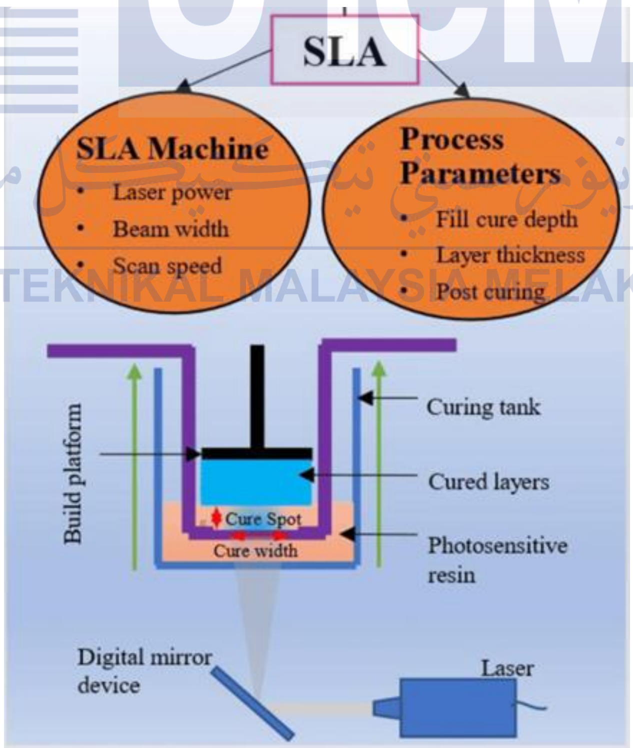


Figure 2.2: SLA 3D Printing Process Parameters (Kafle, 2021)

The major process parameters that influence the quality of SLA printed parts are fill-cure depth, layer thickness and post-curing as shown in Figure 2.2. The cure depth depends on the energy of the light being exposed to the resin. The energy is controlled by the laser power and the time the resin is being exposed to the light. The curing depth should be high enough to avoid excessive fabrication time. However, the curing depth must be low enough to avoid over polymerization resulting in the over-cured part with poor resolution (Kafle, 2021)

2.3.3 Laser Cutting

Laser cutting is a thermal, non-contact process capable of cutting complex contours on materials with a high degree of precision and accuracy. It involves the process of heating, melting, and evaporating material within a small, well-defined area and can cut almost all materials. The word "LASER" stands for "Light Amplification by Stimulated Emission of Radiation." The demand for laser cutting processes is increasing in production industries such as aerospace, automobile, shipbuilding, and nuclear industries due to the laser's ability to cut materials with attractive processing speeds, high productivity, and the ability to cut materials with complex shapes (Ranganathan, 2011).

Ahmet Hascalik mentioned that laser cutting is a non-contact operative method that does not require expensive or replaceable tools and does not exert any force that could damage the workpiece. This makes it a suitable alternative to mechanical cutting processes. Among the different types of available lasers (solid, liquid, and gaseous), solid-state lasers like Neodymium-doped Yttrium Aluminium Garnet (Nd:YAG) and gaseous carbon dioxide

(CO2) lasers are most commonly used for cutting due to their high power and suitable properties for material cutting (Arun, 2012).

Laser cutting process well-suited for various manufacturing industries to produce components in large numbers with high dimensional accuracy and surface finish. It has been stated that a high-power density beam, when focused on a spot, melts and evaporates the material within a fraction of a second. The evaporated molten material is then removed from the affected zone by a coaxial jet of assist gas, as shown in Figure 2.3.

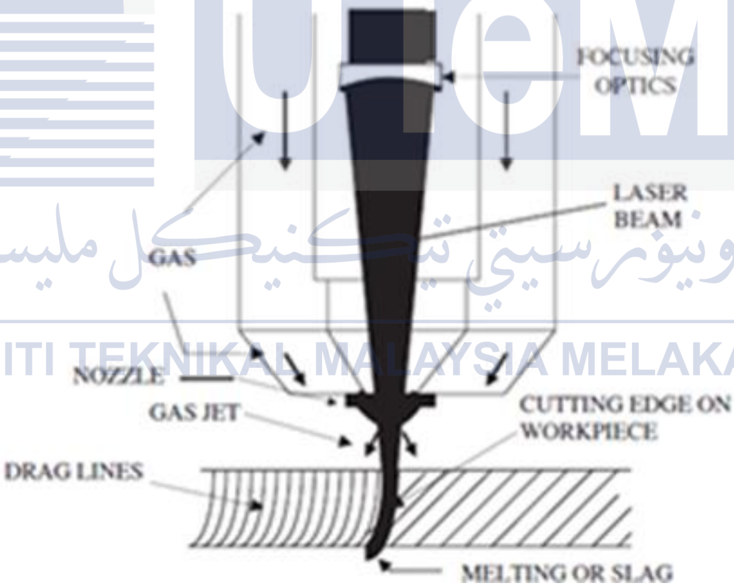


Figure 2.3: Schematic Diagram of Laser Cutting (V. Senthilkumar, 2014)

Laser cutting processes have always been a major area of research with the aim of achieving exceptionally high-quality cuts characterized by reduced surface roughness, kerf width, and heat-affected zone (HAZ). The performance of the laser cutting process is dependent on input process parameters such as laser power, cutting speed, and assist gas pressure and important performance characteristics like surface roughness, HAZ, and kerf width. Kerf as shown in Figure 2.4 refers to a groove, slit or notch where the lower and upper parts of the cut are typically not parallel which is resulting in a narrower width at the bottom than at the top. Kerf width is measured along the entire cut line that representing the difference between the starting width of the top profile and the ending width of the top profile. This principle also applies to the bottom surface (M. Sundar, 2009).

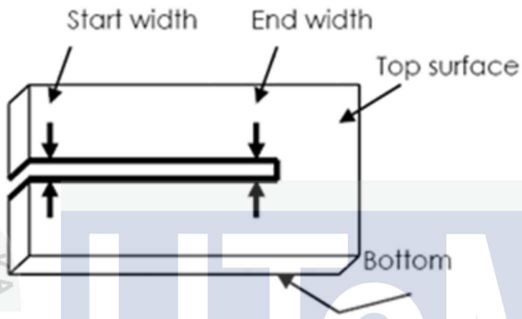


Figure 2.4: Kerf width measurements (M.Sundar, 2009)

2.4 Silicone Rubber Mold (SRM)

2.4.1 SRM

Over the past 50 years, silicone rubbers have become increasingly popular. This thermoset elastomer maintains its mechanical and electrical properties over a wide range of temperatures and is therefore a natural choice for everything from aerospace applications to medical devices (G. Koerner, 1991). Silicone rubber is a type of synthetic polymer with several advantageous properties. These properties include weather resistance, aging resistance, heat resistance, cold temperature resistance, good fire resistance, and excellent electrical insulation. (Yolanda, 2018)

Rubber molds that typically made of silicone rubber are utilized in the spin casting process as hollow master molds. The model often resembles a disc due to the working principle of spin casting, which involves rotation on a shaft. Silicone rubber is chosen for its ability to withstand high temperatures that reaching up to 500ºC. This rubber material is highly flexible, facilitating easy forming and rapid production.

The silicone rubber offers the advantage of producing molds with fine details. It also exhibits excellent chemical, physiological, and corrosion resistance. Continuous use of spin casting can cause the rubber mold to loosen. Therefore, it is recommended that the mold be allowed to rest after each use to prevent premature deterioration (Setiawan et al., 2017). Furthermore, a higher mold temperature can accelerate mold deterioration, while a low temperature can result in scrap formation if the mold material solidifies within the ingates. So, the mold temperature should be gradually increased from cold until all cavities are filled and then maintained at this temperature (LJ Barnard, 2009).

2.4.2 Vulcanization Process

Vulcanization is the process of chemically cross-linking rubber molecules with organic and inorganic matter through the action of heat and pressure. Bonded rubber the cross is chemically called volcanic acid (Bin Samsuri, 2010). Vulcanization also can be defined as a process which increases the retractile force and reduces the amount of permanent deformation remaining after removal of the de forming force. Thus, vulcanization increases elasticity while it decreases plasticity. It is generally accomplished by the formation of a crosslinked molecular network as shown in Figure 2.5.

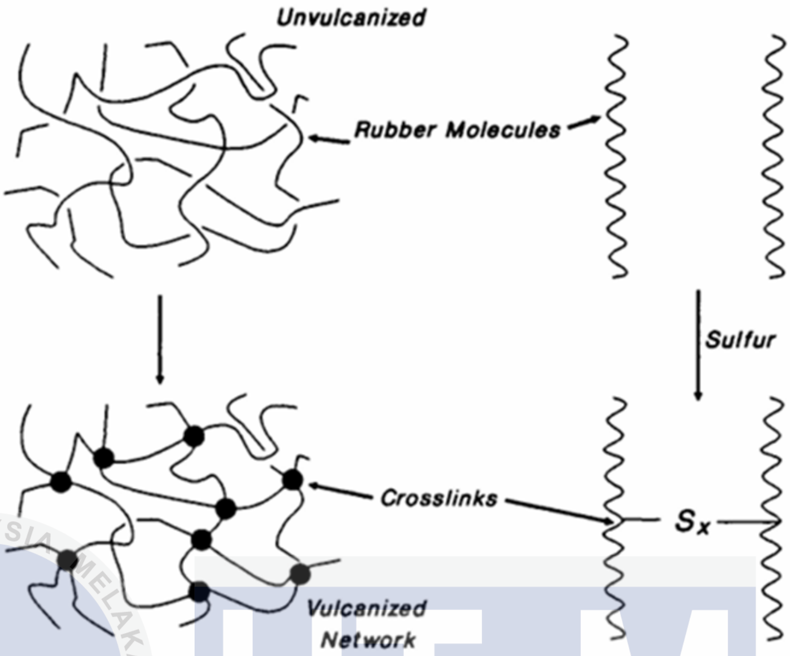


Figure 2.5: Molecular Network Formation (Aubert Y, 1994)

Vulcanization is one of the steps in making molds that aim to make cavity on the mold and rubber hardening to keep it strong and rigid during casting. The process is usually carried out by heating the rubber in a mold under pressure (Coran, 1994).

2.5 Centrifugal Rubber Mold Casting (CRMC)

2.5.1 CRMC

CRMC that also known as spin casting is a casting technique that utilizes the centrifugal forces to fill rubber molds. This technology was developed in the 1930s but was initially limited to the production of ornamental items. From the 1960s to the 1970s, spin casting emerged as a promising process to produce precise and durable metal castings. The disc-shaped mold is manually placed and clamped into the spin caster with the suitable pressure.

Once secured, the mold is rotated around the vertical axis at a specific speed that range from 100 to 1000 rpm while molten metal is poured through a sprue located at the top center of the mold as shown in Figure 2.6 below. The centrifugal force generated by the spinning action drives the molten metal into the mold cavity where it subsequently solidifies under pressure. CRMC is specifically influenced by centrifugal force, Coriolis force, and friction (Kapranos et al., 2014).

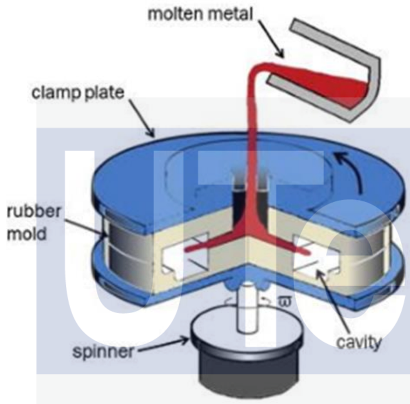


Figure 2.6: CRMC Process

Centrifugal force acts on a mass that is in circular motion. When the circular motion is uniform with constant angular speed at a fixed radius, then the magnitude of this force is defined by the Equation 1. It is a force associated with motion, specifically, rotating motion. If there is no rotating motion, so that the circular frequency term is zero, then there is no force (Victor, 2015)

$$F_C = mr\omega^2 \tag{1}$$

Where:

$F_C = Centrifugal\ Force$

$m = Mass$

$r = Radius$

$\omega = Angular\ speed$

2.5.2 CRMC Material

The selection of casting material is a critical aspect for keychain souvenirs produced using the CRMC method. The suitable metal must be identified for this manufacturing method application. After a review of relevant literature, zinc alloy was selected as the casting material. Zinc alloy is a metal alloy composed of zinc (Zn) mixed with elements such as aluminium (Al), magnesium (Mg), and copper (Cu). This material exhibits a low melting point and high fluidity, making it suitable for casting applications (Pola A et al., 2020).

Furthermore, zinc-based alloys are recognized for their excellent fluidity and sufficient strength for structural applications. It is widely utilized in die casting to produce structural shapes, electrical conduits (electrical wires and cables), and corrosion-resistant components (Kalpakjian, 2022).

2.5.3 CRMC Speed Parameter

CRMC requires retaining the mold cavity shape against gravity while avoiding longitudinal tearing and stresses during the accelerated solidification of the molten metal against the mold. Rotational speed affects grain refinement and significantly influences the metal structure. This is an important parameter for eliminating the effect of gravitational forces and maintaining the flowability of molten metal (Keerthi Prasad, 2010). The optimal rotation speed should be used to obtain the desired particle segregation within the molten metal and without encountering hot tearing. However, turbulence induced by the instability of the liquid mass at very low speeds can also be detrimental. A higher rotation speed results in a thinner particle-enriched zone (Sharma, 2020).

CHAPTER 3

METHODOLOGY

3.1 Methodology Flow Chart and Gant Chart

3.1.1 Overall Project Flow Chart

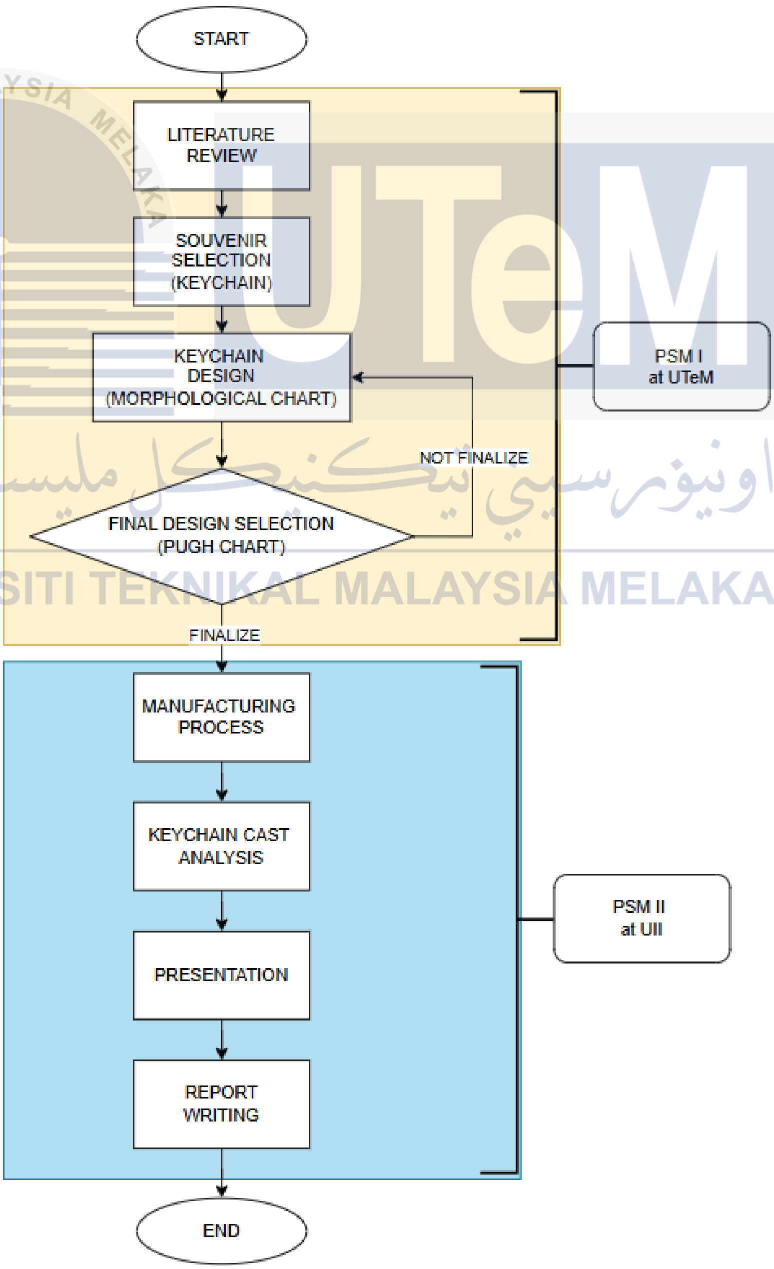


Figure 3.1: Overall Project Process Flow Chart

3.1.2 Design Process Flow Chart

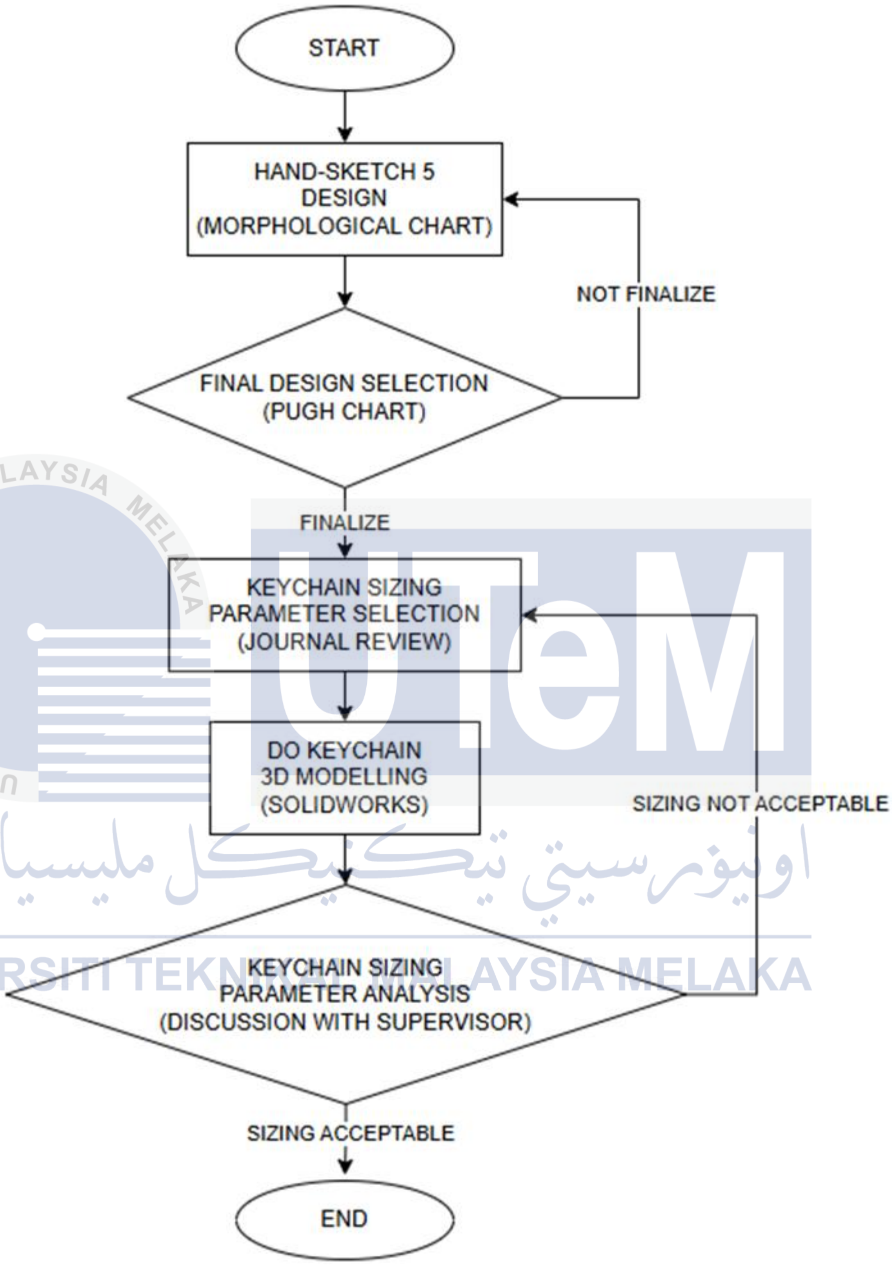


Figure 3.2: Design Process Flow Chart (PSM 1)

3.1.3 Manufacturing Process Flow Chart (PSM 2)

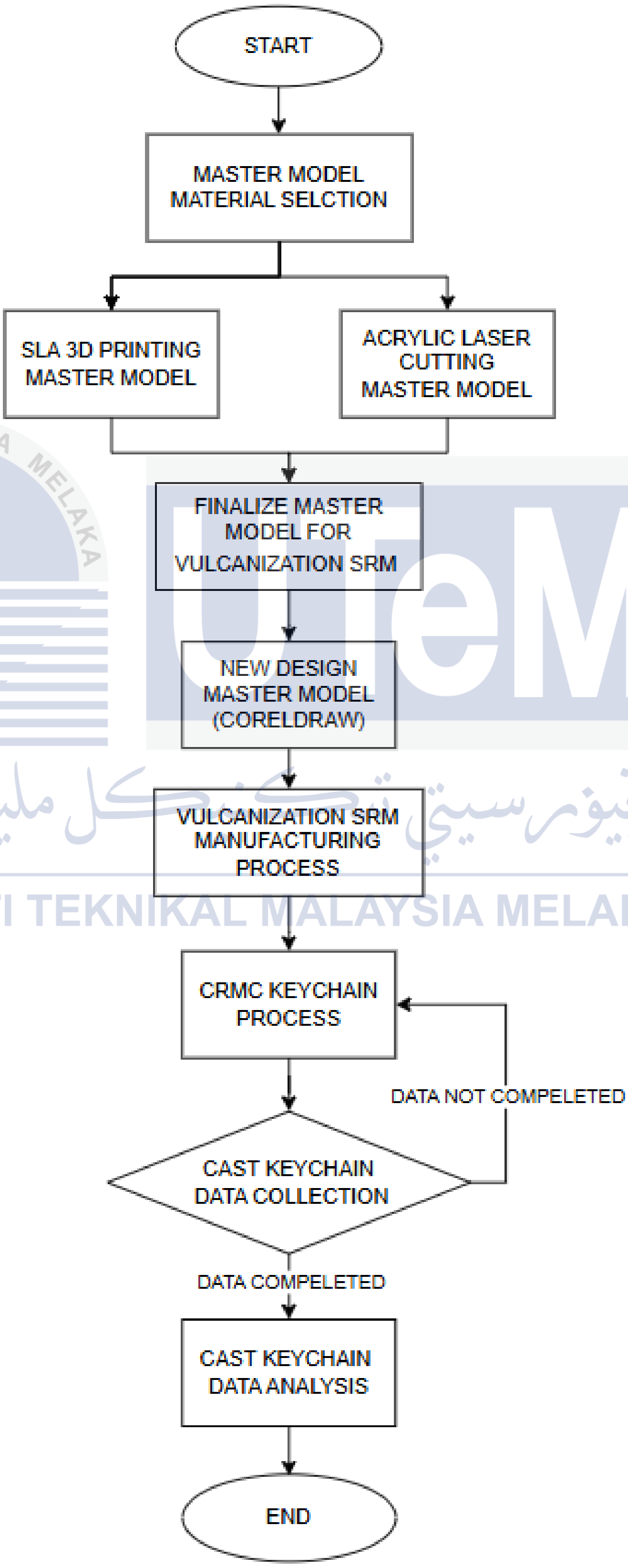


Figure 3.3: Manufacturing Process Flow Chart (PSM 2)

3.1.4 PSM 1 Gant Chart

Table 3.1: Gant Chart for PSM 1

No		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selecting PSM Title								MID SEMESTER BREAK						
2	Project Verification														
3	Determine Problem Statement and Objective														
4	Literature Review														
5	Determine Methodology														
6	PSM 1 Progress Seminar														
7	Preparation for Progress Report														
8	Designing Souvenir														
9	Final Report Preparation														
10	PSM 1 Final Report Submission														

3.1.5 PSM 2 Gant Chart

Table 3.2: Gant Chart for PSM 1

No		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Discussion with UII Supervisor																
2	Project Manufacturing Verification																
3	SLA 3D Printing Master Model Manufacturing																
4	Acrylic Laser Cutting Master Model Manufacturing																
5	Discuss Suitable Master Model																
6	Designing New Keychain Souvenir																
7	New Keychain Design Master Model Manufacturing																
8	SRM Vulcanization Manufacturing																
9	CRMC Manufacturing																
10	Analysis Keychain Cast Product																
11	Preparation for “Kolokium”																
12	Write Full PSM Final Report																
13	PSM Final Report Submission																
14	PSM Presentation at UII																

3.2 Design Specification for Keychain Souvenir

The product's design specification serves as its design guide. It describes the main features, conceptual concepts, and the method of product manufacturing. It offers all the specifications and information needed to make your product a reality as shown in Figure 3.4 below.

Material Selection

- Compatibility : Choose a material that melts well and solidifies properly during CRMC process. Common options include pewter, aluminium, copper and zinc
- Melting Point: Ensure the material's melting point is suitable for the available furnace temperature in casting setup.

Design and Part Size

- Size Limitations: CRMC process is ideal for small to medium sized parts. Consider if the keychain design falls within the range
- Design: While some design have small details, very thin sections or sharp internal coners might be difficult to cast.

Shape and Features

- Centrifugal Force: The spinning motuion during casting favors design that are flat and small
- Undercuts or Internal Features: Complex internal features that molten metal can not flow might require additional casting process

Surface Finish

- Post Process: The cast product surface finish might be slight rough. Will be deicde if surface finishing is needed for analysis cast product.
- Parting Lines: The rubber mold will leave parting lines on the keychain where the rubber mold section meet. Factor these into your design or plan for post-cast removal.

Figure 3.4: Design and Specification for Keychain Souvenir

3.3 Engineering Approach

This section will describe a framework to formulate a manufacturing strategy based on the House of Quality (HoQ). This method consists of two main phases in which Phase 1 focuses on understanding the "what" and "how" of manufacturing. The “what" translates to the customer requirement, CR like cost, quality, delivery speed, flexibility, and innovation of keychain souvenir. The "how" represents the strategic decision areas for engineer characteristics, EC keychain souvenir process, such as facilities, capacity, production technology, new product design, and control systems. A matrix is created, with CR listed as rows and decision areas as columns. The entries in this matrix detail the relationships between these two aspects. By analysing this House of Quality, the gap between what the market demands and what manufacturing currently achieves can be identified. This gap analysis allows them to develop strategic action plans to bridge that gap.

While Phase II builds HoQ, this time the "what" becomes the strategic decision areas identified in Phase I, and the "how" becomes the specific strategic manufacturing plans. In this phase, the focus shifts to ranking and prioritizing the action plans developed in Phase I.

3.3.1 Customer Requirements

Customer requirements, CR are the characteristics or specifications of an item or product that customers believe are important. Meeting these requirements increases the likelihood of customers purchasing the item or product. To determine these needs and ensure the product aligns with them, it is necessary to conduct and evaluate market research. The overview of the customer specifications for the keychain souvenir is shown in Table 3.3.

Table 3.3: CR for Keychain Souvenir

CR	Description
Uniqueness Design	The design of keychain should stand out from generic keychains.
Durability	The keychain offers long-lasting durability for the keychain
Giftable	The keychain must be suitable for gifting
Cost	The price of keychain is affordable
Safety	The keychain should have no sharp edges or protruding parts.

3.3.2 Engineering Characteristics

After identifying the customer requirements, engineering characteristics, EC to create the design must be considered to meets technical specifications and minimizes errors throughout the design and manufacturing processes. These characteristics encompass design limitations, factors, and variables identified through literature review, comparative testing against similar items and reverse engineering of existing products. Table 3.4 lists the engineering requirements for the keychain souvenir in respect to customer requirements.

Table 3.4: EC for Keychain Souvenir

Engineering Characteristics	Description
Dimension Precision	The Casting process and mold design must ensure keychain dimensions meet specifications.
Design Weight	Evenly distribute weight of keychain for balance.
Material	Choice of material that compatible with keychain souvenir and centrifugal casting
Surface Finish	Casting process parameters optimized for desired surface finish such as minimizing surface roughness.
Manufacturability	Focus on creating a repeatable process for efficiently producing keychain souvenirs using centrifugal casting

3.3.3 HOQ for Keychain Souvenir

From the Table 3.5, the main engineering characteristics to consider when designing and manufacturing the keychain souvenir are product material and keychain design dimensions. While surface finish also needs to be given fair consideration. Lastly, design weight and manufacturability can be considered of less importance than the other characteristics.

Legend	
9	Strongly Correlated
6	Moderately Correlated
3	Weakly Correlated

Table 3.5: HoQ for Keychain Souvenir

		Engineering Characteristics	Dimension Precision (mm)	Design Weight (g)	Material (n/a)	Surface Finish (n/a)	Manufacturability (n/a)
Improvement Direction			↑	↓	–	↑	↑
No.	Customer Requirement	Weight	–	–	–	–	–
1.	Uniqueness Design	5	9	3	3	3	3
2.	Durability	4	3	6	9	3	6
3.	Giftable	3	6	6	3	9	3
4.	Cost	4	3	6	9	6	9
5.	Safety	3	6	3	6	6	3
	Absolute Weight		105	78	114	96	93
	Relative Weight		21.6	16	23.5	19.8	19.1
	Rank Order		2	5	1	3	4

3.4 Benchmarking Product

The benchmark product as shown in Figure 3.5 is the basic keychain souvenir currently available in the market. The product's width and length range are 2.3-3 cm, while the thickness is around 1mm to 3mm. The product is manufactured using laser cutting. Therefore, we can determine whether CRMC is the best manufacturing method for specific sizing keychain souvenirs.

Figure 3.5: Benchmark Keychain Souvenir

3.5 Conceptual Generation

Conceptual generation is the foundation upon which successful product design is built. It's the stage where take customer needs and illustrate into souvenir product. This crucial phase carefully describes the product's design and method. Through a few rough sketches, it depicts the product's characteristics. This initial exploration helps to visualize and identify a range of potential solutions that effectively address customer needs.

The morphological chart as shown in Table 3.6 is the method to represent the desired souvenir product. It allows us to explore various approaches and combinations to achieve these characteristics. In this project, morphological chart is utilized to analyse existing keychain souvenir from the literature review. By comparing different parameters, the aim to identify the most suitable configuration for a fully optimized keychain souvenir.

Table 3.6: Morphological Chart for Keychain Souvenir

PART	OPTION 1	OPTION 2	OPTION 3	OPTION 4
OUTER SHAPE	CIRCLE	-	-	-
INNER SHAPE	SQUARE	CIRCLE	-	-
BASE DESIGN	STAR	HEART	GEAR	CROWN
KEYCHAIN ATTECHMENT	CUBE	CIRCLE	-	-

3.6 Conceptual Design

Conceptual design, CD is the initial stage where a design idea takes shape. It involves developing a framework for how this idea will be visually communicated through sketches or images. Creating successful conceptual designs requires a deep understanding of how the product will be displayed. This ensures the final design effectively meets customer needs.

In this project, morphological chart as shown in Table 3.6 has been utilized to explore all possible combinations for each part of the keychain souvenir. This systematic approach generates five concept designs which have been designated as Conceptual Design 1, Conceptual Design 2, Conceptual Design 3 Conceptual Design 4 and Conceptual Design 5.

3.6.1 Conceptual Design 1

CD 1 as shown in Figure 3.6 and Table 3.7, utilizes a circular design for the inner and square for outer shape. This circular form offers advantages in terms CRMC efficiency. While the base design maintains a simple shape, it incorporates multiple holes to enhance its visual appeal. The keyring attachment will be directly connected to the keychain itself.

Table 3.7: List of Selected Option for CD 1

Part	Option
Outer Shape	1
Inner Shape	1
Base Design	None
Keychain Attachment	None

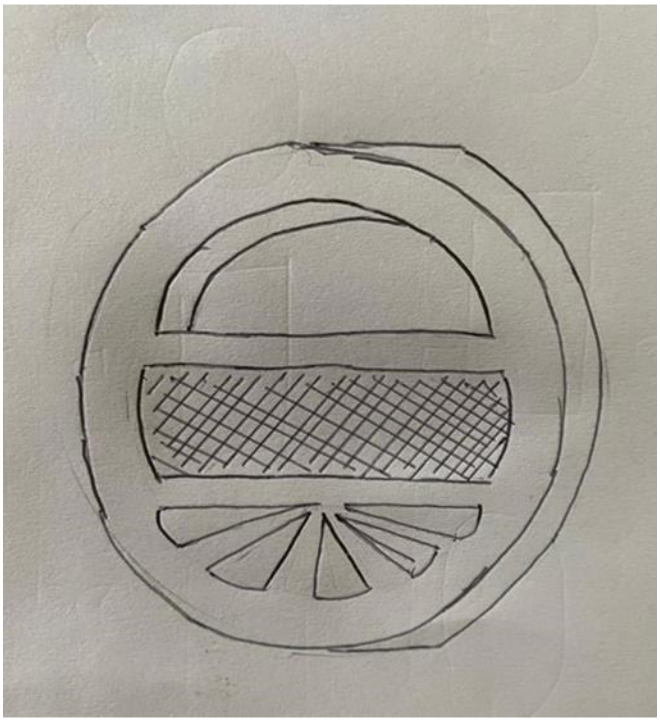


Figure 3.6: Keychain Souvenir CD 1

3.6.2 Conceptual Design 2

As shown in Figure 3.7 and Table 3.8, CD 2 utilizes a circular design for both the inner and outer shape. However, to add a touch of uniqueness, the base features a gear-shaped pattern within the circle. This design element enhances the keychain's visual appeal without compromising its suitability for centrifugal casting. The keyring attachment takes the form of a cube that is directly connected to the keychain itself.

Table 3.8: List of Selected Option for CD 2

Part	Option
Outer Shape	1
Inner Shape	2
Base Design	3
Keychain Attachment	1

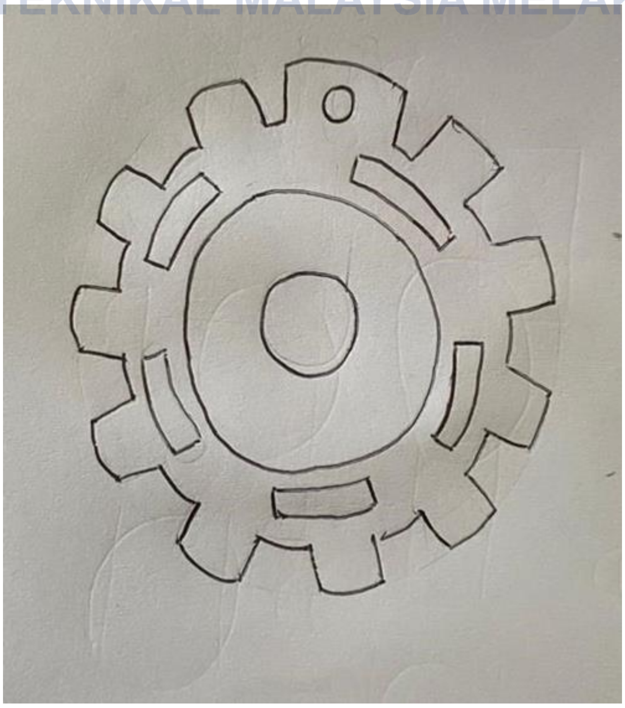


Figure 3.7: Keychain Souvenir CD 2

3.6.3 Conceptual Design 3

Just like concepts for CD 2, the CD 3 that shown in Figure 3.8 and Table 3.9 also utilizes a circular design for both the inner and outer shape. However, the base of the keychain features a unique star-shaped design for added visual interest. To ensure user safety, the sharp points of the star shape will be blunted using fillets or rounded edges. This modification maintains the aesthetic appeal of the star design while minimizing potential hazards. The keyring attachment for this concept remains a classic circular shape.

Table 3.9: List of Selected Option for CD 3

Part	Option
Outer Shape	1
Inner Shape	2
Base Design	1
Keychain Attachment	2

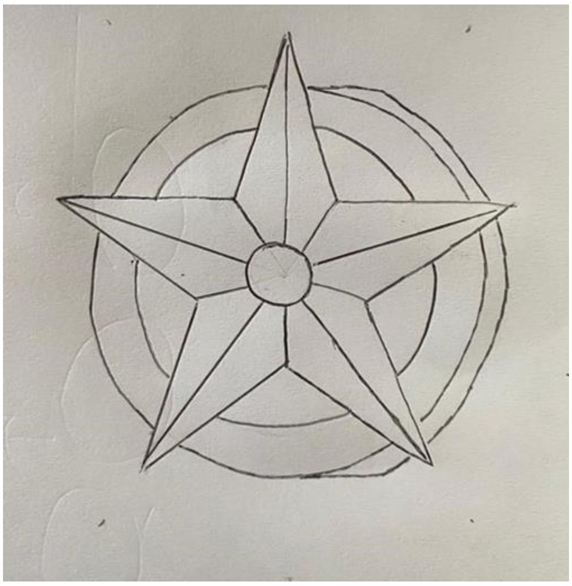


Figure 3.8: Keychain Souvenir CD 3

3.6.4 Conceptual Design 4

CD 4 as shown in Figure 3.9 and Table 3.10, slightly different from the previous circular designs. It features a circular inner shape encased within a square outer shape. This unique combination offers a visually striking appearance. The base of the keychain incorporates a heart shape, a popular design element often found in gift items. While this shape may be present in existing keychains, it adds a touch of sentimentality and gift ability to this concept. The keyring attachment for CD 4 takes the form of a cube, offering a modern and distinctive touch.

Table 3.10: List of Selected Option for CD 4

Part	Option
Outer Shape	1
Inner Shape	1
Base Design	2
Keychain Attachment	1

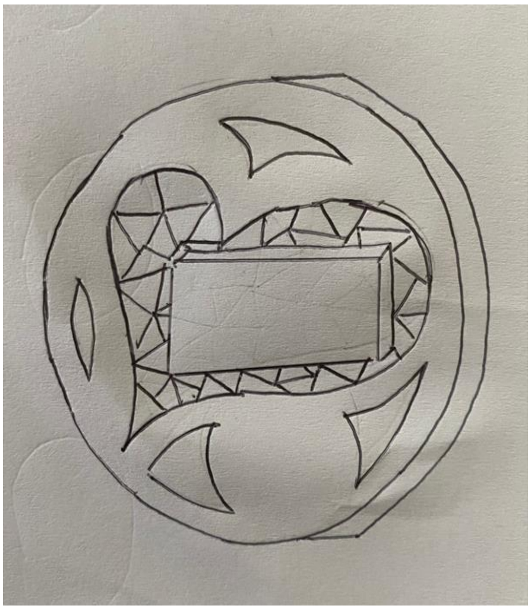


Figure 3.9: Keychain Souvenir CD 4

3.6.5 Conceptual Design 5

Concept Design 5 as shown in Figure 3.10 and Table 3.11, using a classic circular design for both the inner and outer shape. However, it adds a touch of royalty with a crown-shaped base, a unique element not commonly seen in keychains. Like CD 3, to prevent potential injury from the sharp points of the crown, it will be covered with spherical shapes, essentially blunting the edges. This modification ensures user safety without compromising the regal aesthetic of the crown design. The keyring attachment for CD 5 maintains the basic circular shape, but it will be positioned in the center of the crown for a balanced and visually pleasing look.

Table 3.11 List of Selected Option for CD 5

Part	Option
Outer Shape	1
Inner Shape	2
Base Design	4
Keychain Attachment	2

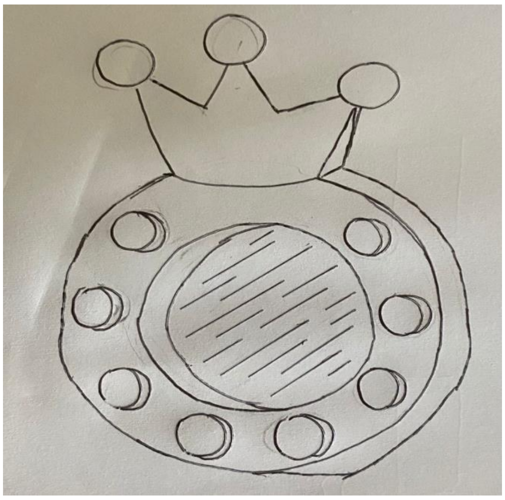


Figure 3.10: Keychain Souvenir CD 5

3.7 Concept Evaluation and Selection

The process of evaluating and selecting concepts involves a careful balancing act. It needs to consider both customer needs and other important characteristics. This evaluation is followed by comparing keychain concepts based on their advantages and disadvantages. Finally, select one or more keychain concepts for further consideration, development or analysis.

3.7.1 Concept Screening

The concept screening method serves to reduce the number of potential product concepts to a manageable quantity, allowing for further in-depth study and development. As demonstrated in Table 3.12, the Pugh chart is a valuable method for evaluating these concepts and identifying the most promising design. The left column of the chart lists the customer needs which serve as the selection criteria. By comparing these needs to each concept, the Pugh chart helps to identify the advantages and disadvantages of each option. This process involves referencing CD 1 as the DATUM and comparing CD 2, CD 3, CD 4, and CD 5 with each other to determine the three best designs for the next phase of the finalization process.

Legend	
+	Criteria scores better as compared to datum
–	Criteria do not scores better as compared to datum
S	Criteria scores same as datum

Table 3.12: Pugh Method for Keychain Souvenir

Selection Criteria	CD 1	CD 2	CD 3	CD 4	CD 5
Uniqueness Design	DATUM	+	+	S	+
Durability		-	-	+	-
Giftable		+	-	S	+
Cost		S	-	S	-
Safety		-	-	S	-
Sum of +	0	2	1	1	2
Sum of -	0	2	4	0	3
Net Score	0	0	-3	1	-1
Rank	2	2	4	1	3
Proceed	YES	YES	NO	YES	NO

3.7.2 Concept Scoring

Table 3.13 show the weight selection matrix used for concept scoring. This method represents the more advanced and detailed approach to concept screening compared to simpler techniques. Through this process, it was determined that the DATUM outscored all other concepts that advanced to the concept scoring phase.

Table 3.14 shows the importance of each requirement was determined by CR. To evaluate each concept design against these weighted requirements, the rating value was assigned to each concept according to the criteria listed in Table 14. These ratings were then multiplied by their corresponding weightings from Table 15. Finally, the scores for each design were summed, and the concept with the highest overall score was chosen as the final design.

Table 3.13: Rating Scales for Weight Decision Matrix

Point Scale	Description
5	Excellent
4	Good
3	Satisfied
2	Weak
1	Poor

Table 3.14: Concept Scoring of Keychain Souvenir

		CD 1		CD 2		CD 4	
Selection Criteria	Importance Weight (%)	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Uniqueness Design	35	3	1.05	5	1.75	3	1.05
Durability	20	4	0.8	4	0.8	5	1
Giftable	15	3	0.45	5	0.9	3	0.45
Cost	15	4	0.6	3	0.45	4	0.6
Safety	15	5	0.75	3	0.45	5	0.75
Total Score			3.65		4.35		3.85
Proceed		NO		YES		NO	

3.8 3D Model Final Design

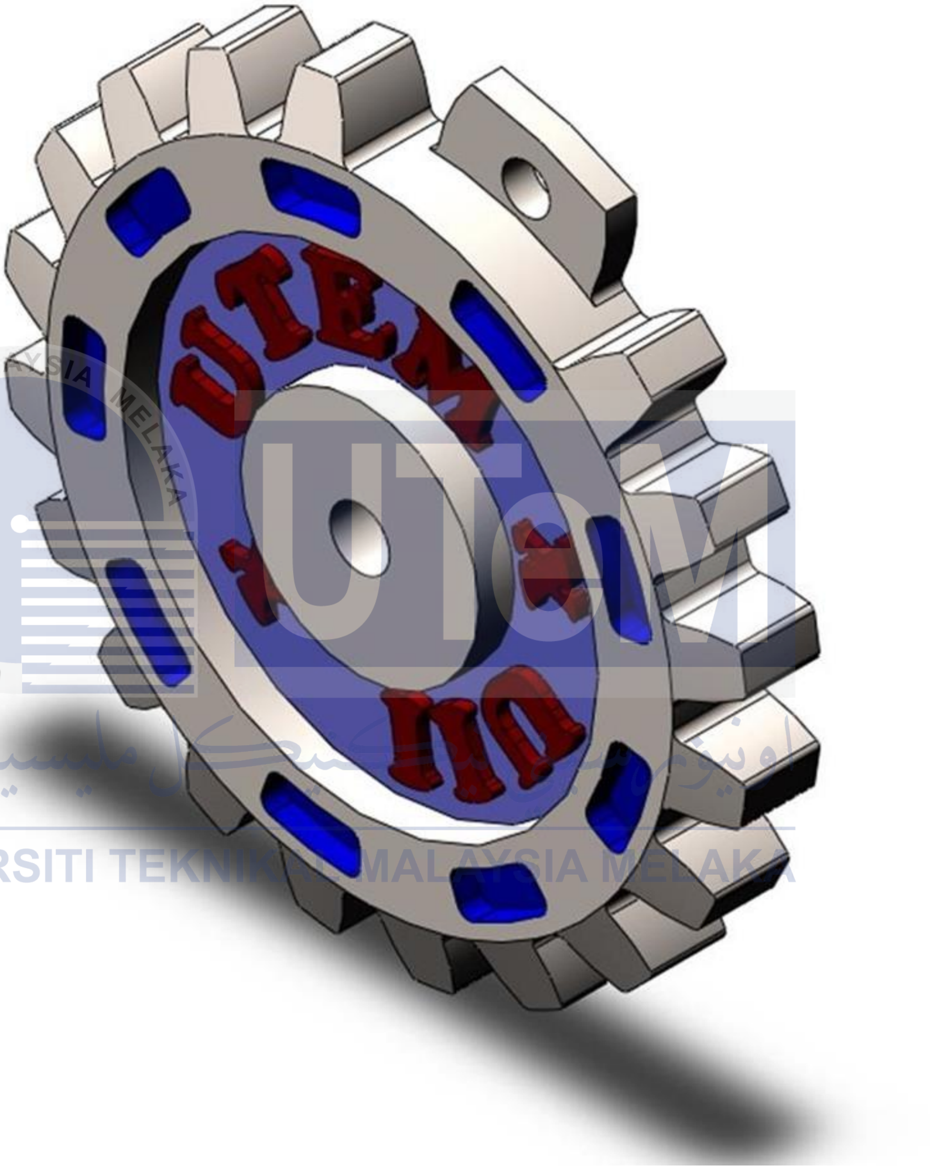


Figure 3.11: Isometric View 3D Model for Keychain Souvenir

3.9 Master Model Manufacturing

3.9.1 SLA 3D Printing Master Model

The SLA 3D printing of the master model will be utilizing resin as the material that involves three primary stages which are preparation, printing, and post-processing.

In the preparation stage, the 3D model file was converted from SolidWorks to STL format. This STL file was imported into Anycubic Photon Software. Settings such as layer height, exposure time, and support density were then adjusted. The 3D printer was cleaned of any excess resin from previous printing processes using alcohol. Figure 3.12 shows the SLA 3D Printer, tools and resin that been used.

Figure 3.12: SLA 3D Printer Resin and Machine

During the printing process, resin was poured into the printer vat and the build plate was attached to the printer platform as shown in Figure 3.13. The G-code file was loaded into the printer for initiated the printing master model job. The printing process was then initiated with default parameters.

Figure 3.13: Printer Platform Attach to SLA 3D Printer

After completion of printing, the build plate was carefully removed from the printer. The printed part was then gently pried off the build plate using a tool. The printed part was immersed in isopropyl alcohol to dissolve any uncured resin. Support structures were carefully removed using cutters or pliers, and any rough edges were sanded or filed. Then, the master model was placed in a UV curing chamber to fully harden the resin as shown in Figure 3. 14. The curing process was set to 60°C for 15 minutes. Finally, the printer was cleaned after use.

Figure 3.14: Curing Process

3.9.2 Acrylic Laser Cutting Master Model

After the completion of the SLA 3D printing master model manufacturing process, the manufacturing process for the acrylic laser cutting master model can proceed.

The laser cutting machine was set up and cleaned of any dust or debris from previous processes. Next, 3 mm thickness the acrylic sheet was then placed on the laser cutter bed to ensure it was firmly secured to prevent acrylic movement during the cutting process. The design file that been saved in DXF file was imported into the laser cutter software. Then, the cutting process parameters such as power, speed, and focus were fine-tuned to optimize the cutting and engraving process. The laser cutting process was then initiated as shown in Figure 3.15. The laser beam traced the design by engraving or cutting through the acrylic sheet. The cutting process was monitored to ensure its proper execution. Finally, the master model pieces were cleaned to remove any dust or debris.

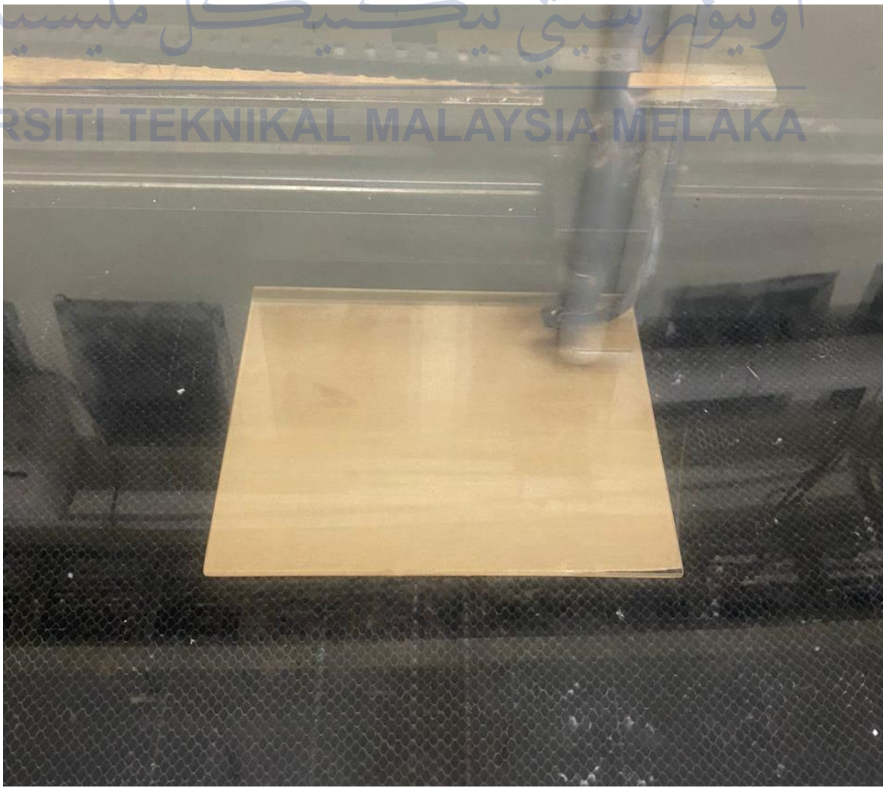


Figure 3.15: Laser Cutting Process

3.10 New Keychain Design

Following the completion of both master model manufacturing processes, an analysis and comparison of the two master models will be conducted to determine the most suitable option for proceeding with silicone rubber mold manufacturing process. The analysis and comparison will be presented in Chapter 4 which are covers the case study of the master models that been identifies acrylic laser cutting as the preferred master model for this project.

After that the multiple keychain master models will be created with incorporating various base shapes that including the circular shape as illustrated in the Morphological Chart section. This addition of new designs is essential for subsequent analysis and comparison of the cast keychain products. The new designs only need to be in 2D format to proceed with the manufacturing process since the process will utilize the acrylic laser cutting method for master model production.

3.10.1 Keychain Design 1, KD 1

As been shown in the Figure 3.16, Keychain Design 1 (KD 1) which was selected as the final design using morphological and Pugh charts in Chapter 3. The front design features the abbreviations "UTeM" (Universiti Teknikal Malaysia Melaka) and "UII" (Universitas Islam Indonesia). Conversely, the back design incorporates the full names of both universities with the text arranged along the outer circumference of the circular shape**.** The length and width of this design are 43 mm and 42 mm respectively.

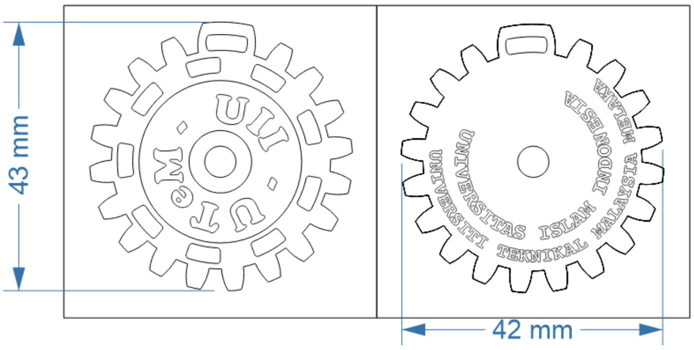


Figure 3.16: KD 1

3.10.2 Keychain Design 2, KD 2

KD 2 as shown in Figure 3.17 retains the gear shape of KD 1. The design incorporates hole features with the full names of both universities inscribed within these holes in a circular arrangement. The text size may be smaller than that of KD 1 due to space limitations. Same as KD 1, the design dimensions are 43 mm in length and 42 mm in width.

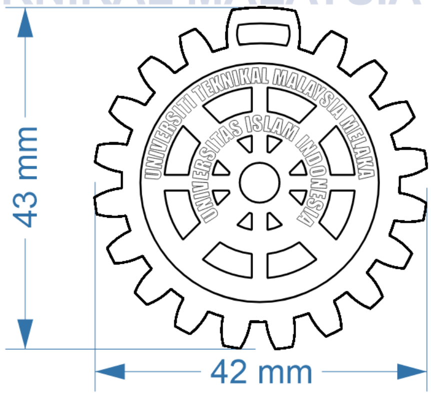


Figure 3.17: KD 2

3.10.3 Keychain Design 3, KD 3

KD 3 as shown in Figure 3.18 represents a new design featuring a square base shape. This design incorporates both front and back designs which like KD 1. The front design features the UII logo along with the university name arranged within a square line. The back design incorporates the abbreviation "UII" and a leaf motif surrounding the abbreviation. The dimensions of the design are 40 mm in length and 31 mm in width.

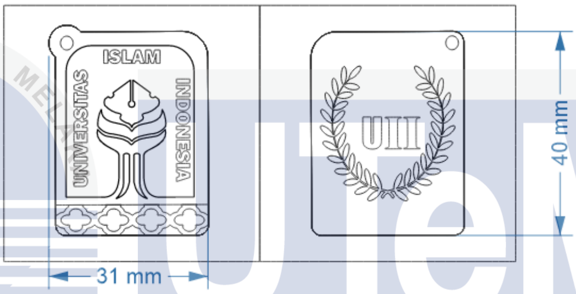


Figure 3.18: KD 3

3.10.4 Keychain Design 4, KD 4

Figure 3.19 shows the KD 4 features a rectangular base shape. The design incorporates the word "MALAYSIA" with a slight modification to the shape of the letter "Y" to distinguish it from the other letters. The length and width of the design are 63 mm and 34 mm respectively

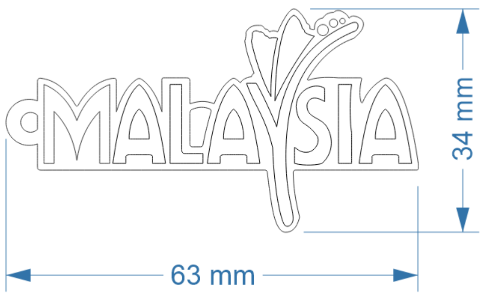


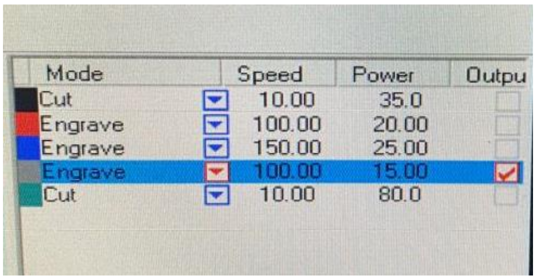
Figure 3.19: KD 4

3.11 Master Model for New Keychain Design

This section will present the engraving and cutting parameter settings within the Laser Cut 5.1 software. Each engraving depth will be designated by a different colour to facilitate the laser cutting process. The colour selection can be random as the laser engraving and cutting parameters can be adjusted. The master model will utilize two types of acrylics which are white acrylic and transparent acrylic expect KD 2 which utilizes only white acrylic. Only one type of acrylic was used because the design incorporates numerous holes and changing the type of acrylic would not have a significant effect.

3.11.1 KD 1 Master Model

The laser engraving and cutting parameters for creating the KD 1 master model are show in the Figure 3.20 and Figure 3.21 . Each engraving parameter is assigned a distinct color and utilizes varying speeds and power settings. These variations are implemented to achieve different engraving depths in the front design. The blue color is utilized for engraving the fillet gear, with a speed of 150 and a power setting of 20. The red color is utilized for engraving the area around the abbreviations, with a speed of 100 and a power setting of 25. For the words on the back design a lower engraving power of 15 is set to avoid interference with the front design engraving. The cutting power of 35 is set for both cutting processes. Initially, turquoise color is used for the cutting process to create the slot mechanism which is enabling the flipping of the model for engraving the opposite side design. Following the completion of all engraving processes for both sides, the black color is utilized for the another cutting process to obtain the gear-shaped keychain base. Figure 3.22 and Figure 3.23 show the final KD 1 master model for both types of acrylic.



Mode	Speed	Power	Outpu
Cut	10.00	35.0	
Engrave	100.00	20.00	
Engrave	150.00	25.00	
Engrave	100.00	15.00	✓
Cut	10.00	80.0	

Figure 3.20: KD 1 Laser Cutting Parameter

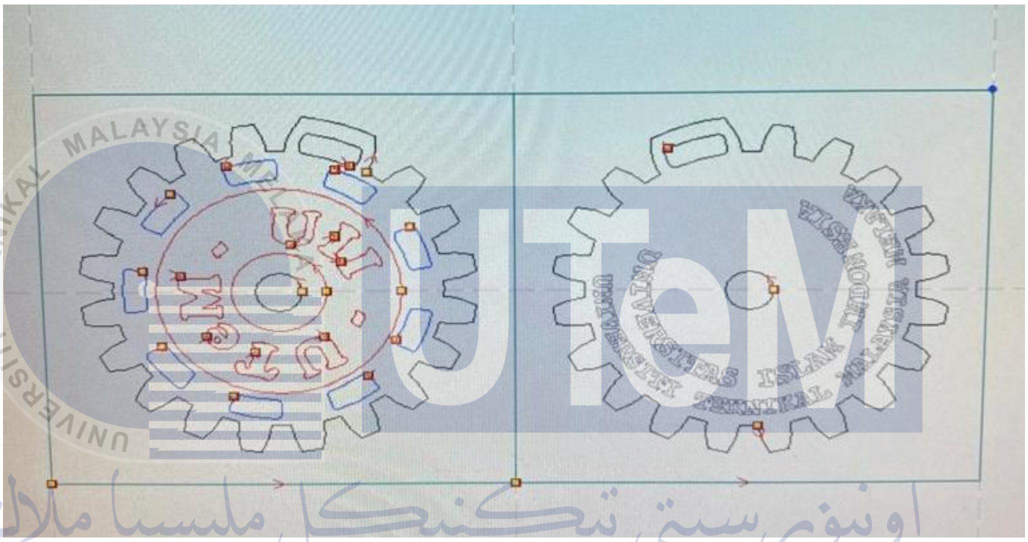


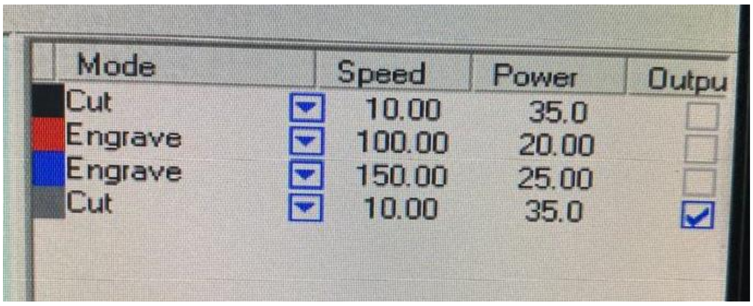
Figure 3.21: KD 1 Parameter Display in Laser Cut 5.1 Software

Figure 3.22: KD 1 Front and Back Design for White Acrylic Master Model

Figure 3.23: KD 1 Front and Back Design for Transparent Acrylic Master Model

3.11.2 KD 2 Master Model

For the KD 2 master model, two engraving parameters utilizing blue and red colours will be employed as been shown in Figure 3.24 and Figure 3.55. Blue colour will be used to engrave the inside area of the gear at a speed of 150 and a power of 25 that creating a slightly deeper engraving compared to the outer area. Red colour will be utilized to engrave the words at a speed of 100 and a power of 20. Subsequently, the cutting process will be executed using a black and grey colour setting. Figure 3.26 shows the final KD 2 master model which utilizes only one type of acrylic. Only one type of acrylic was used because the design incorporates numerous holes and changing the type of acrylic would not have a significant effect.



Mode	Speed	Power	Outpu
Cut	10.00	35.0	☐
Engrave	100.00	20.00	☐
Engrave	150.00	25.00	☐
Cut	10.00	35.0	☑

Figure 3.24: KD 2 Laser Cutting Parameter

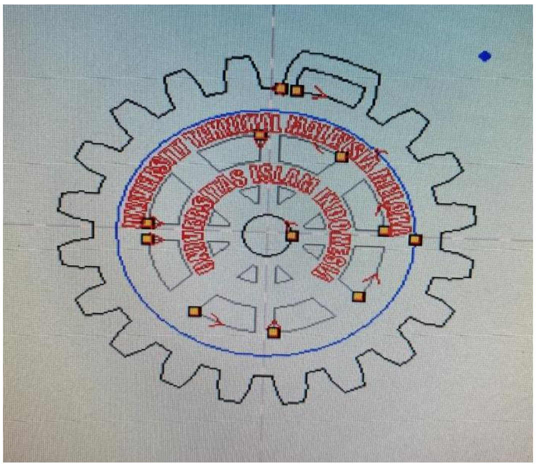


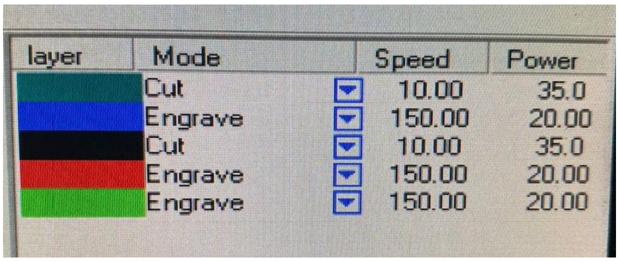
Figure 3.25: Figure 3.21: KD 2 Parameter Display in Laser Cut 5.1 Software

Figure 3.26: KD 2 White Acrylic Master Model

3.11.3 KD 3 Master Model

For KD 3, which features both front and back designs will used three engraving parameters utilizing red, blue, and green colours will be employed as been shown in Figure 3.27 and Figure 3.28. The consistent speed of 150 and a power of 20 will be applied to all engraving parameters. The cutting process will be initiated after the completion of all engraving processes in one side. Initially, the grey colour will be used to cut the slot mechanism which is enabling the flipping of the model.

Following the completion of the engraving process for both sides, black colour will be used for the final cutting process to obtain the base shape of the keychain. Figures 3.29 and Figure 3.30 shows the final KD 3 master model for both types of acrylics.



layer	Mode	Speed	Power
(teal)	Cut	10.00	35.0
(blue)	Engrave	150.00	20.00
(black)	Cut	10.00	35.0
(red)	Engrave	150.00	20.00
(green)	Engrave	150.00	20.00

Figure 3.27: KD 3 Laser Cutting Parameter

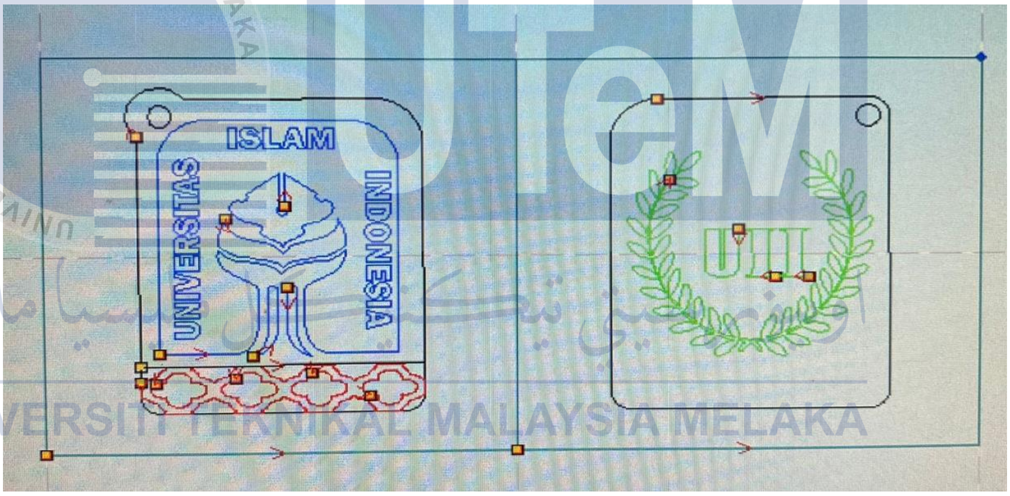


Figure 3.28: KD 3 Parameter Display in Laser Cut 5.1 Software

Figure 3.29: KD 3 Front and Back Design for White Acrylic Master Model

Figure 3.30: KD 3 Front and Back Design for Transparent Acrylic Master Model

3.11.4 KD 4 Master Model Version 1

The KD 4 master model version 1 will be utilized the transparent acrylic. As been shown in Figure 3.31, a single engraving parameter that using grey colour will be set with a speed of 150 and a power of 30. Grey colour is assigned to all lines as shown in Figure 3.32 in the design to engrave the area between the alphabets creating an extruded effect. Then, the outer lines are changed to black colour as shown in Figure 3.33 to proceed with the cutting process**.** This parameter setting will result in a uniform engraving depth around the word has been shown in Figure 3.34.

layer	Mode	Speed	Power
	Engrave	150.00	30.00
	Cut	10.00	35.0

Figure 3.31: KD 4 Version 1 Laser Cutting Parameter

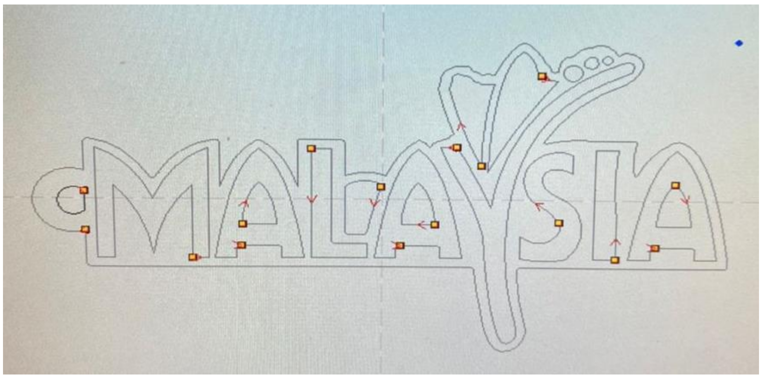


Figure 3.32: KD 4 Version 1 Engrave Display in Laser Cut 5.1 Software

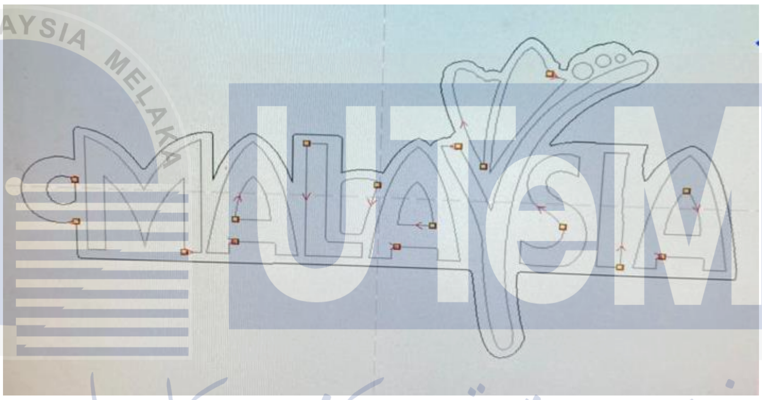
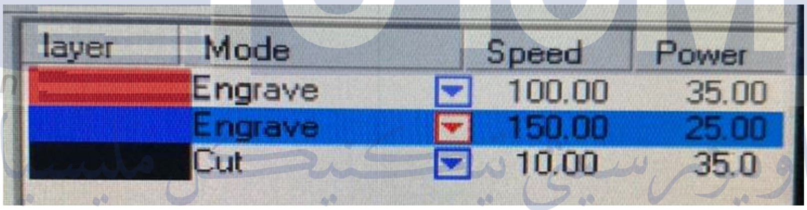


Figure 3.33: KD 4 Version 1 Cut Display in Laser Cut 5.1 Software

Figure 3.34: KD 4 Version 1 Transparent Acrylic Master Model

3.11.5 KD 4 Master Model version 2

The KD 4 Version 2 as shown in the Figure 3.35, three parameter settings are utilized which are blue and red colours for engraving and black colour for cutting. The red colour is set with a speed of 100 and a power of 35 while blue colour is set with a speed of 150 and a power of 25. The outer lines are set to blue to achieve an extruded effect for alphabets other than "A," as shown in Figure 3.36. Following the completion of the engraving process, the outer lines are changed to black colour for the cutting process as shown in Figure 3.37. Figure 3.38 shows the final master model for KD 4 Version 2 that utilizes white acrylic.



layer	Mode	Speed	Power
(red)	Engrave	100.00	35.00
(blue)	Engrave	150.00	25.00
(black)	Cut	10.00	35.0

Figure 3.35: KD 4 Version 2 Laser Cutting Parameter

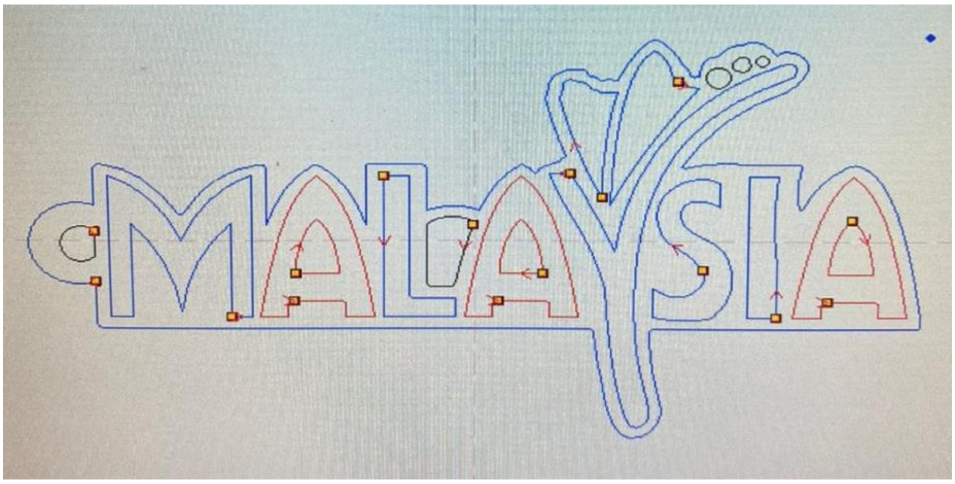


Figure 3.36: KD 4 Version 2 Engrave Display in Laser Cut 5.1 Software

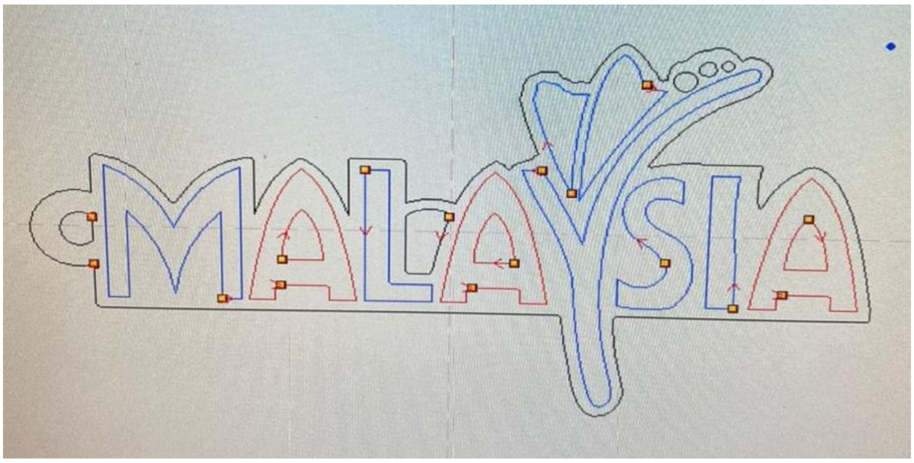


Figure 3.37: KD 4 Version 2 Cut Display in Laser Cut 5.1 Software

Figure 3.38: KD 4 Version 2 White Acrylic Master Model

3.12 SRM Manufacturing

The mold process utilizes silicone rubber in a vulcanization process using the P-400 Matic Vulcanizing Machine. Vulcanization is employed to create molds of the master models prior to casting. The vulcanization process involves pressing and heating the master product between two silicone rubbers under specific pressure, temperature, and time. This process results in the production of a reflective pattern from the master mold itself.

The molding frames were first cleaned and talc was applied to the bottom frame (1). One of the silicone rubbers was then placed on the bottom molding frame (2). The master model was positioned on top of the silicone rubber and pressed until part of its body was embedded (3). Both white acrylic and transparent acrylic master models were utilized to meet the minimum requirement of eight master models for the optimization of the vulcanization process. Next, locking pins were then attached and talc was applied to the surface of the rubber and the base of the molding place to prevent sticking (4). The top of the silicone rubber was then attached and pressed until the lock protruded on the silicone rubber. The molding frames were then closed and locked with the frame locks (5). Finally, the mold was lifted and placed in the center of the vulcanizing machine and the machine settings were then adjusted to 100 psi, 180°C, and 2 hours process time (6).

After the completion of the vulcanization process, the mold was removed from the molding frames (7). Each mold pattern was then visually inspected. Finishing process was performed using the linoleum cutter to flatten any uneven center areas and to add runners and ingates to the rubber mold (8). Runners were added based on the specific requirements of the keychain souvenir shape design (9).

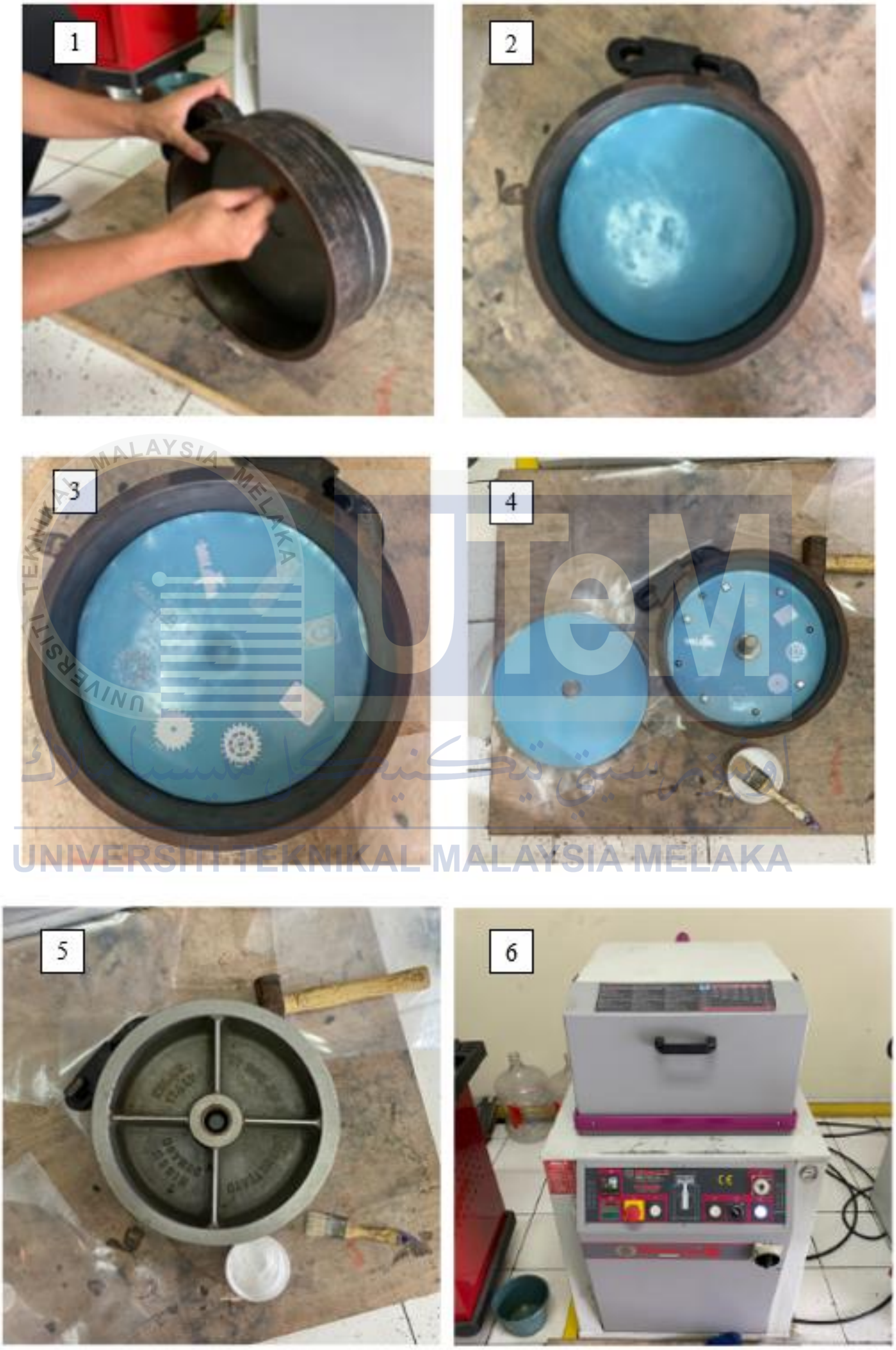


Figure 3.39: SRM Manufacturing Process

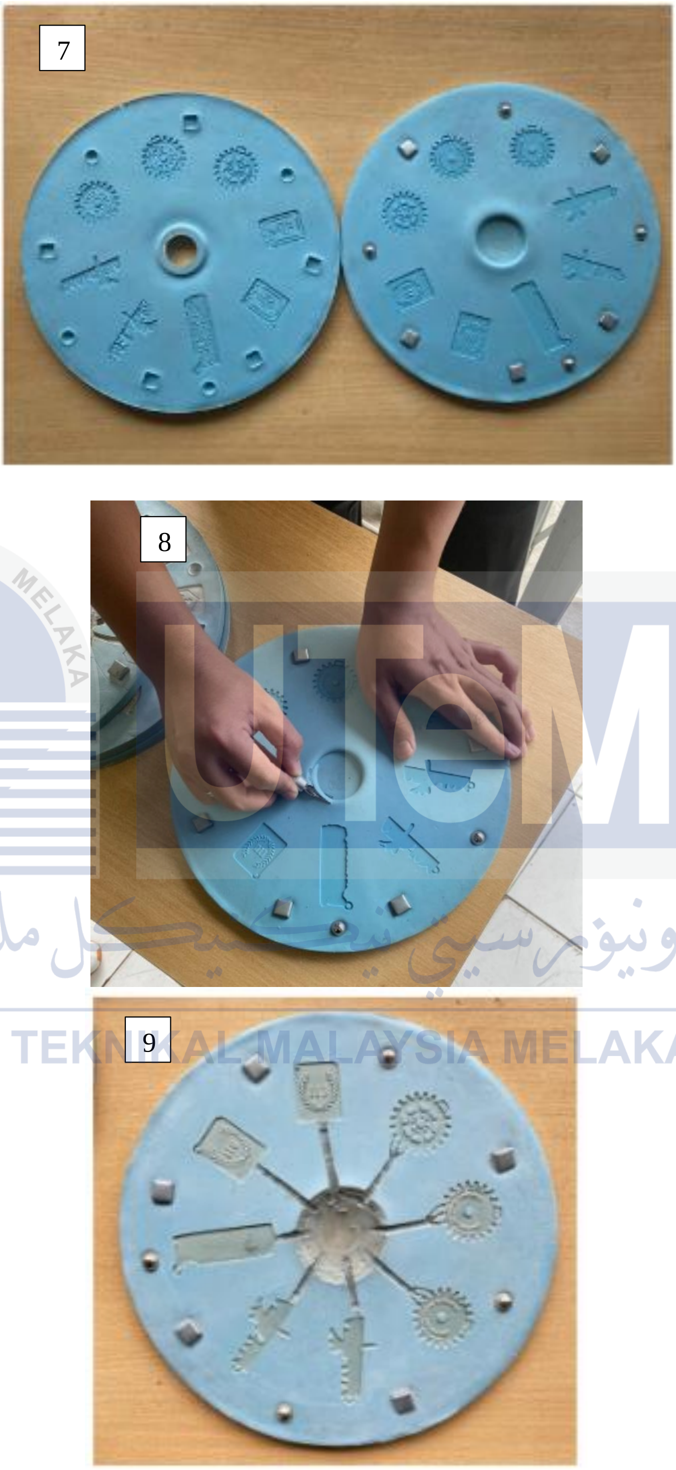


Figure 3.40: SRM Post-Process

3.13 CRMC Manufacturing

Following the completion of the vulcanization SRM process, the next step involves the casting of the product using a C-400 spin casting machine with zinc alloy as the material.

The zinc material was melted in a furnace at a temperature of 500°C (1). Before proceeding with the casting process the talc was applied to both surfaces of the rubber mold and the casting rotation speed was then set to 750 rpm. Molten zinc was poured into the mold using a ladle after the casting button was pressed (2). After 20 seconds, the rubber mold was removed from the spin casting machine (3) and the cast keychain souvenir was separated from the rubber mold to decrease the cast keychain souvenir temperature (4). This casting process was then repeated three times at the same speed. Finally, the casting rotation speed was adjusted to 700, 650, 600, 550, 500, and 450 rpm respectively.

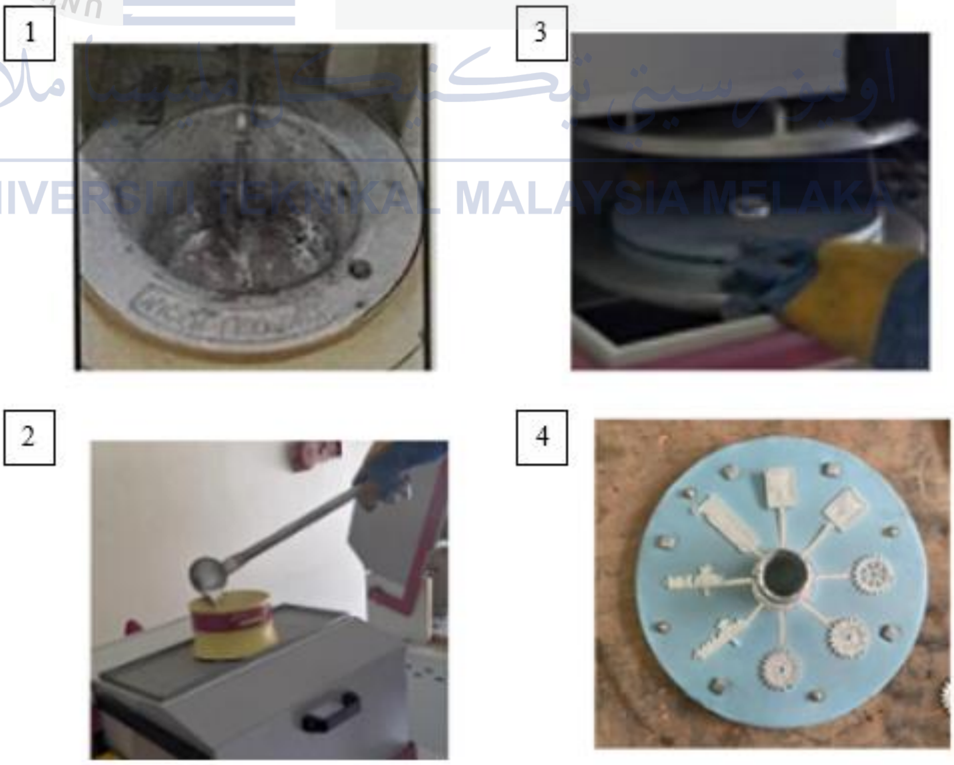


Figure 3.41: CRMC Process

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Master Model Case Study

4.1.1 SLA 3D Printing Master Model Case Study

In this case study, the placement and support settings established within Anycubic Photon software for 3D printing will be discussed. Each case will utilize different support printing settings to determine the most suitable option for analysis and comparison with the acrylic laser cutting master model. Each case will influence the separation of the printed product from the previously established support structure.

Case Study 1

The Case Study 1 will have the support parameter is shown in Figure 3.42. The medium thickness and a 50° angle were utilized for the support. The anchor distance which is the distance between support tips was set to 0.5 mm. The z-lift height that representing the support height was set to 3 mm above the base. This support setting presented challenges in separating the support from the model without causing damage due to the short support height and the close distance of the support tips.

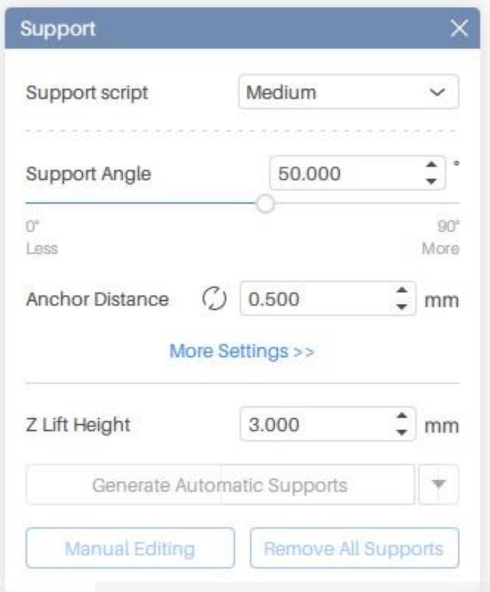


Figure 3.42: Case Study 1 Printing Support Parameter

Figure 3.43 shows the slicing process parameter that indicating a printing time of 22 minutes and 5 seconds and a resin volume of 6.791 ml. Figure 3.44 shows the model with support as displayed in Anycubic Phonton, while Figure 3.45 shows the final 3D-printed model.

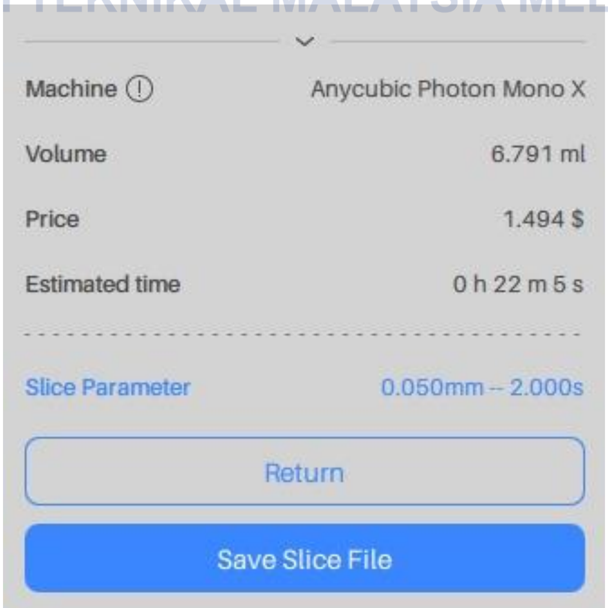


Figure 3.43: Case Study 1 Slicing Process Parameter

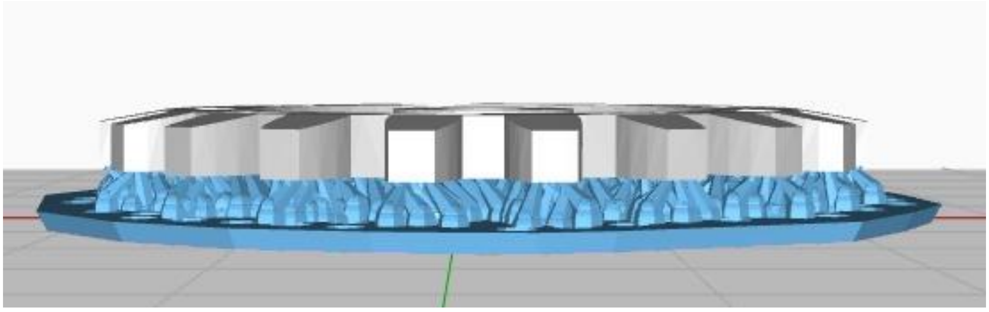


Figure 3.44: Case Study 1 Model and Support Display in Anycubic Phonton

Figure 3.45: Case Study 1 Final SLA 3D Print Model

Case Study 2

Figure 3.46 shows the support parameters for the Case Study 2 model. The support height of 10 mm and a support angle of 30° were implemented by considering the difficulty encountered in separating the support from the model in Case Study 1 due to the short support height. The support thickness and anchor distance were maintained at medium and 0.5 mm respectively as in Case Study 1. However, even with the increased support height the challenges in separating the support from the model were still observed in Case Study 2. This difficulty can be attributed to the higher support height with the same support thickness that makes the separation process even more difficult

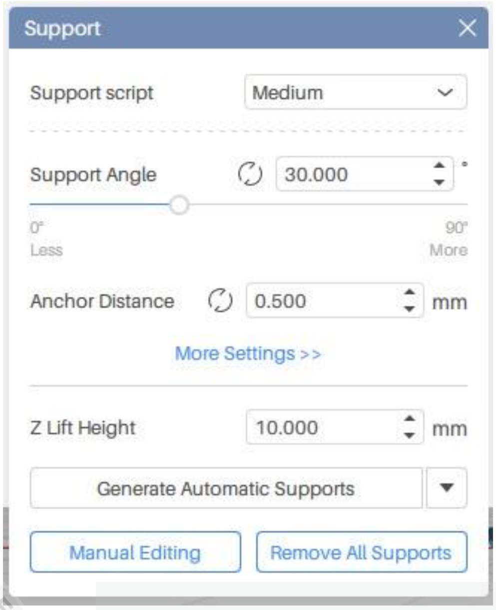


Figure 3.46: Case Study 2 Printing Support Parameter

The slicing process parameters as shows in Figure 3.47 indicate an increase in printing time to 45 minutes and 51 seconds and a resin volume to 15.378 ml. Figure 3.48 shows the Case Study 2 Model and Support Display in Anycubic Phonton, while Figure 3.49 shows the final SLA 3D-printed model for Case Study 2.

Figure 3.47: Case Study 2 Slicing Process Parameter

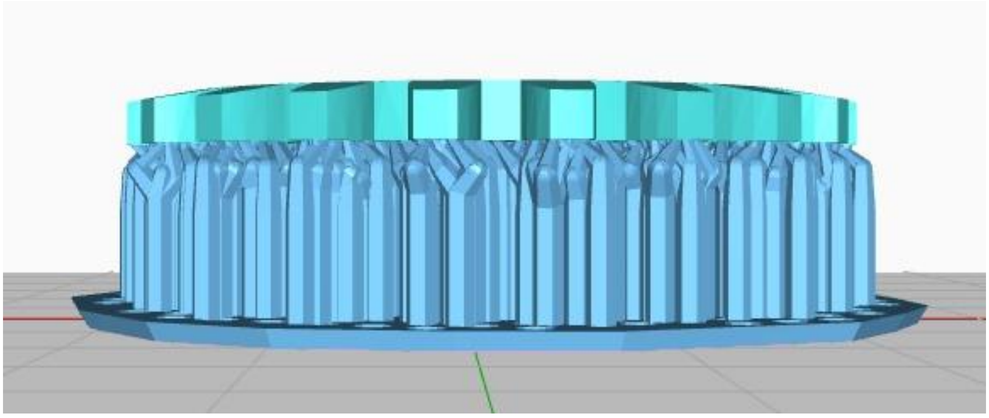


Figure3.48: Case Study 2 Model and Support Display in Anycubic Phonton

Figure 3.49: Case Study 2 Final SLA 3D Print Model

Case Study 3

Following the challenges encountered in previous case studies, the optimal support parameters were determined as shown in Figure 3.50. The light support thickness and a 60° angle were selected. The anchor distance was increased to 7 mm to ensure optimal support for the model and support height of 5 mm. These support parameters facilitate easier separation of the support from the model due to the reduced in number and thickness of support .

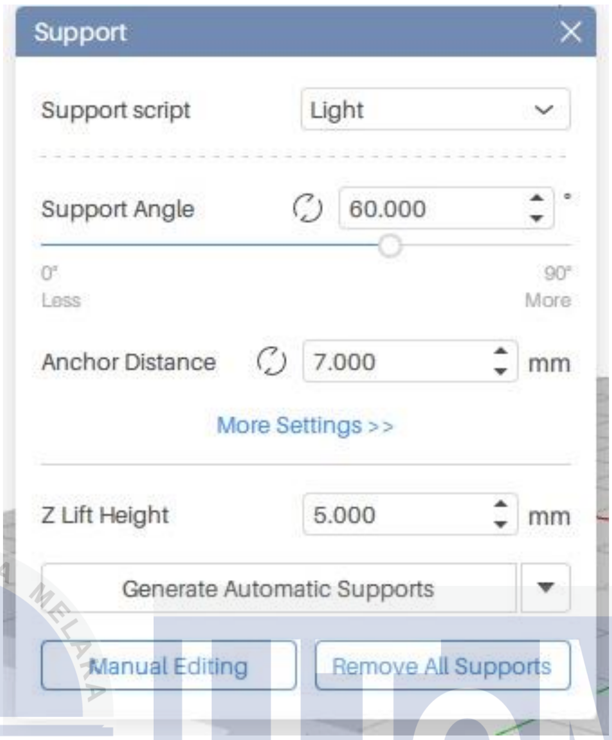


Figure 3.50: Case Study 3 Printing Support Parameter

Consider both the front and back designs the model was rotated to a vertical position as shown in Figure 3.52. In horizontal position set up the back design will be affected from the support placement at back model side like both previous cases. This orientation resulted in a printing time of 2 hours and 40 minutes and utilizing 3.740 ml of resin as shown in Figure 3.51. The final SLA 3D-printed model for Case Study 3 as shown in Figure 3.53, will be used for comparison and analysis with the acrylic laser cutting master model.

Figure 3.51: Case Study 3 Printing Support Parameter

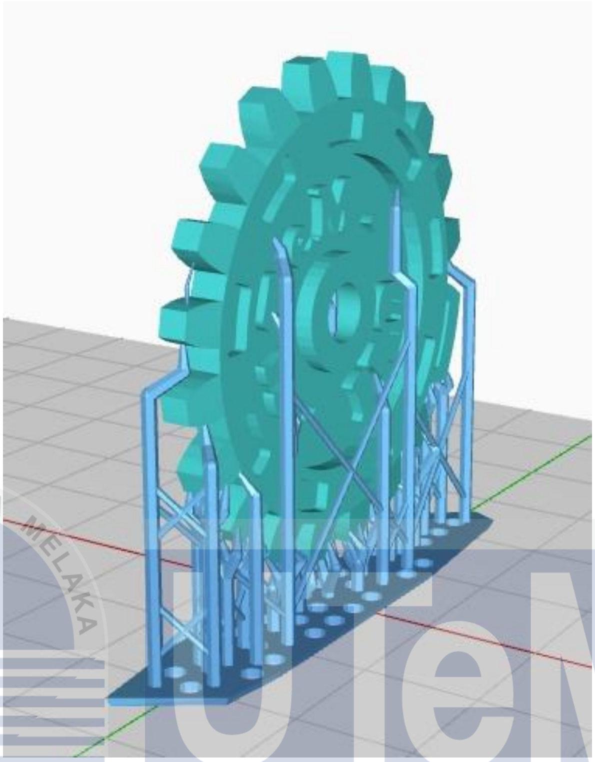


Figure 3.52: Case Study 3 Model and Support Display in Anycubic Phonton

Figure 3.53: Case Study 3 Final SLA 3D Print Model

4.1.2 Acrylic Laser Cutting Case Study

On the other hand, in this case study the challenges encountered during the acrylic laser cutting master model manufacturing process will be discussed. Unlike SLA 3D printing where primarily placement and support issues are encountered the wider range of problems arose during the acrylic laser cutting process.

Case Study 1

In this Case Study 1, the problem encountered involved errors resulting from the corruption of the DXF file within SolidWorks. The file corruption caused some polylines within the 2D sketch to remain unclosed as shown in the Figure 3.54 and Figure 3.55 below.

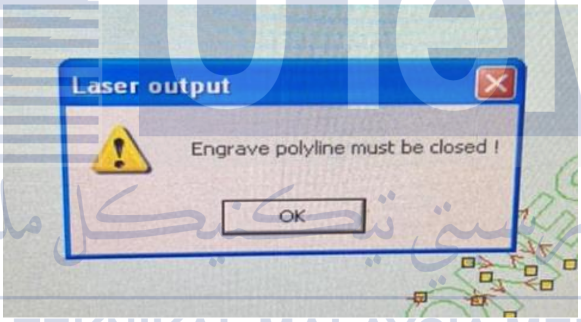


Figure 3.54: Error Display in Laser Cut 5.1 Software

Figure 3.55: Unclosed Polyline Display in CorelDRAW

This issue prevented the laser cutting machine from accurately detecting the lines intended for engraving and cutting. The solution to this problem involved importing the DXF file from SolidWorks into CorelDraw and closing the polylines using the "join curves" feature. The Figure 3.56 below shows the closed polylines that been ready for engraving and cutting process.

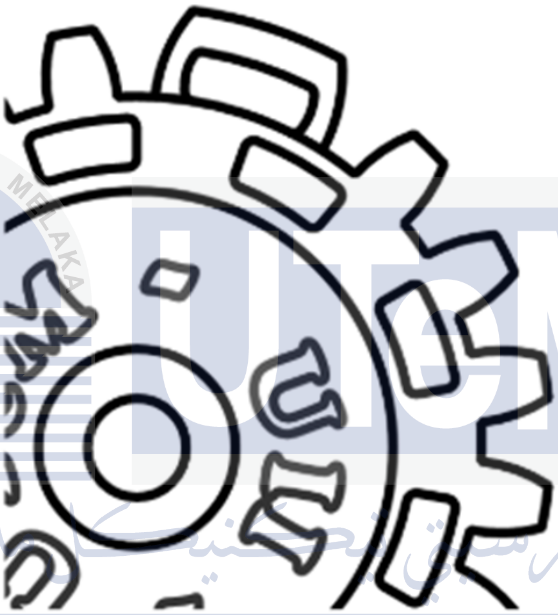


Figure 3.56: Closed Polyline Display in CorelDRAW

Case Study 2

In Case Study 2, the problem encountered involved misalignment of the front and back designs of the keychain during the flipping process for subsequent engraving. This misalignment occurred due to the movement of the master model from its original position during the flipping operation. The Figure 3.57 below shows the misaligned design after engraving the back side.

a) Aligned front design

b) Misaligned front design

Figure 3.57: Aligned and Misaligned Front Design for White Acrylic Master Model.

The solution for this problem was implemented a slot mechanism for keychains with front and back designs. This implementation minimized the movement of the keychain from its original position during the flipping process. CorelDRAW was utilized to design a square slot around the keychain within the software. The slot was designed with a minimum 2mm distance from the keychain to facilitate easy flipping. The Figure 3.58 an Figure 3.59 shows the implementation of the slot in real-case acrylic laser cutting master model process.

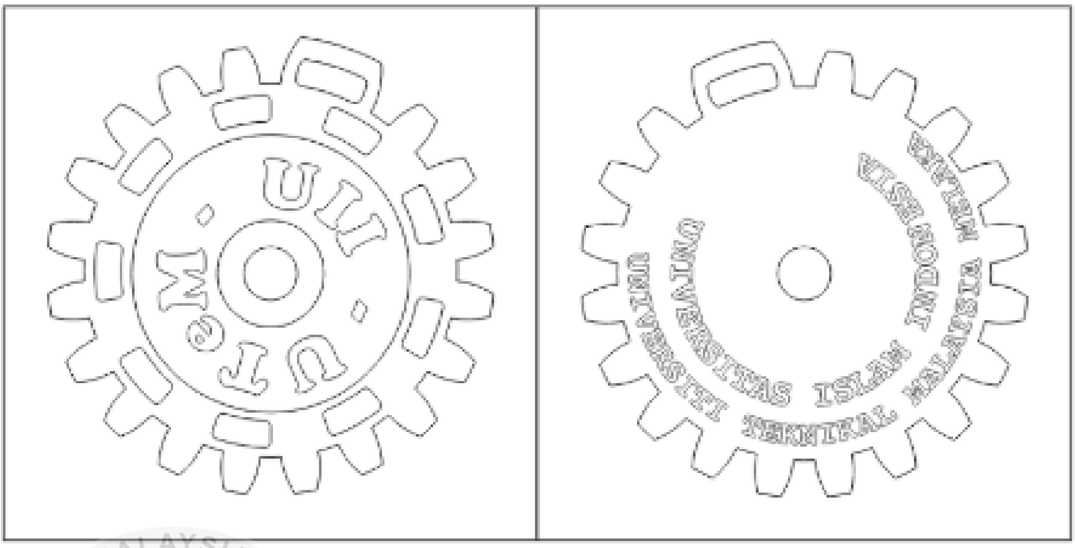
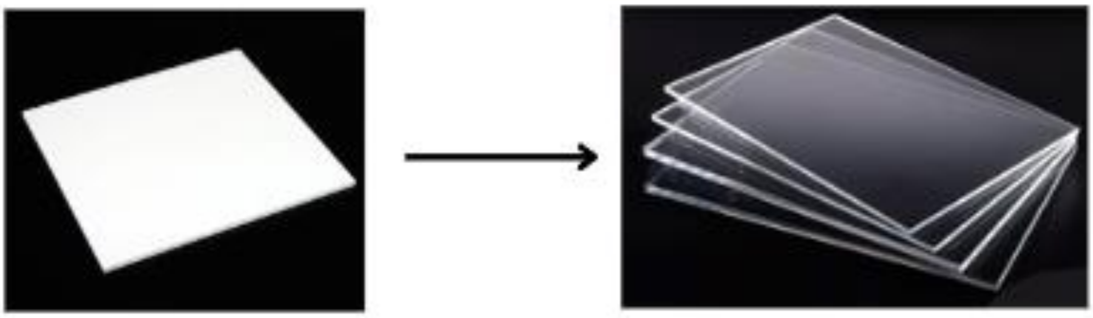


Figure 3.58: Slot Mechanism Display in CorelDRAW

Figure 3.59: Slot Mechanism in Real-Case Process

Case Study 3

Lastly in Case Study 3, the acrylic master model was improved by replacing the white acrylic material with transparent acrylic as shown in the Figure 3.60. This material change resulted in a reduction in surface roughness that particularly at the edge of the circle as demonstrated in the Figure 3.61. The difference in master model surface roughness can be observed due to the higher strength of transparent acrylic compared to white acrylic.



a) White Acrylic
b) Transparent Acrylic

Figure 3.60: Type of Acrylic

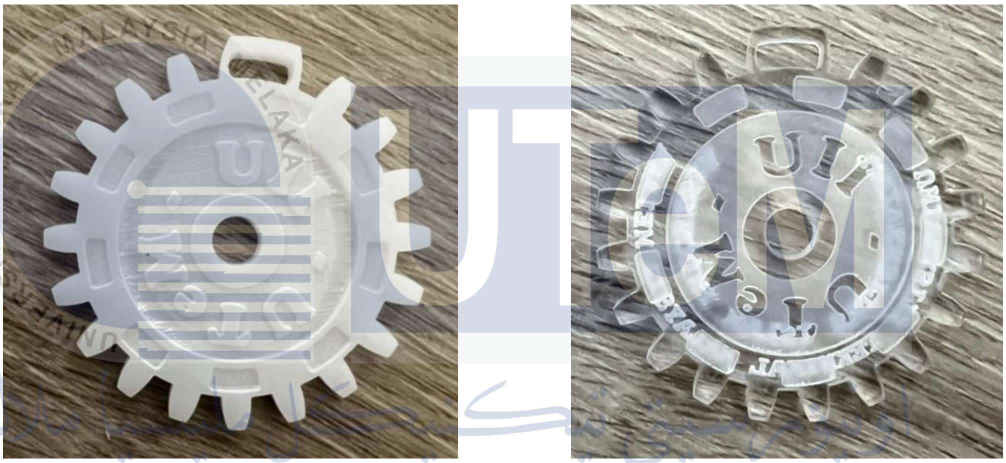


Figure 3.61: White and Transparent Acrylic Master Model

4.1.3 Finalize Type of Master Model

In this part, the analysis and comparison will be justified following the case studies for both SLA 3D printing and acrylic laser cutting. Acrylic laser cutting has been identified as the suitable master model method as previously mentioned in "New Keychain Design." Acrylic laser cutting was chosen as the final method for master model production due to its significant advantages over SLA 3D printing. The Table 4.1 below summarizes the advantages and disadvantages of both master model processes.

The time and cost savings in master model manufacturing are achieved with the acrylic laser cutting method. This is due to the higher cost of resin as printing material used in SLA 3D printing compared to acrylic sheets. Furthermore, the laser cutting process for engraving and cutting requires significantly less time that commonly around 10-15 minutes while the SLA 3D printing process can take up to 10 hours depending on the design complexity. Additionally, acrylic sheet shows higher material strength compared to the resin that led in resulting the better surface quality for the master model.

However, acrylic laser cutting also presents certain disadvantages when compared to SLA 3D printing. The laser cutting machine might be more challenging to operate for novice users compared to an SLA 3D printer. Initial difficulties may be encountered due to detail engraving and cutting parameter settings. Moreover, SLA 3D printing offers greater design complexity due to its layer-by-layer process while laser cutting is limited to flat designs.

` Despite these disadvantages, acrylic laser cutting remains the preferred method for master model production due to its better surface quality which is a critical factor in master model manufacturing. Better surface quality master models are crucial for achieving optimal surface roughness in the cast product. Although the laser cutting machine may initially present a learning curve however the operator proficiency will increase with continued use.

Table 4.1: Summarize Advantages and Disadvantages for Both Type Master Model

SLA 3D Printing	Acrylic Laser Cutting
Advantanges	
• Ease of handling is observed • More complex designs can be achieved	• Saving time and cost • Better surface quality is achieved • Harder materials can be utilized
Disadvantages	
• Rough surface quality is typically exhibited • Higher costs are associated with this method • Softer materials are often used.	• Difficulty in handling is encountered • Designs are limited to flat

4.2 Keychain Cast Product Result for Rotation Speed

In this part, the results of the keychain cast products for each speed group that ranging from 750 rpm to 450 rpm will be presented. This section will solely present the results with discussion and analysis reserved for the next part. Each speed group will be accompanied by a presentation of the cast keychain products and a data table summarizing the successful and defective cast products.

4.2.1 Keychain Cast for 750 rpm Rotation Speed

Figure 3.62: Result Keychain Cast Product for 750 rpm Rotation Speed

Table 4.2: Succes and Defect Keychain Cast Product Data for 750 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	21
Defect Cast	0

4.2.2 Keychain Cast for 700 rpm Rotation Speed

Figure 3.63: Result Keychain Cast Product for 700 rpm Rotation Speed

Table 4.3: Succes and Defect Keychain Cast Product Data for 700 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	21
Defect Cast	0

4.2.3 Keychain Cast for 650 rpm Rotation Speed

Figure 3.64: Result Keychain Cast Product for 650 rpm Rotation Speed

Table 4.4: Succes and Defect Keychain Cast Product Data for 650 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	17
Defect Cast	4

4.2.4 Keychain Cast for 600 rpm Rotation Speed

Figure 3.65: Result Keychain Cast Product for 600 rpm Rotation Speed

Table 4.5: Succes and Defect Keychain Cast Product Data for 600 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	14
Defect Cast	7

4.2.5 Keychain Cast for 550 rpm Rotation Speed

Figure 3.66: Result Keychain Cast Product for 550 rpm Rotation Speed

Table 4.6: Succes and Defect Keychain Cast Product Data for 550 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	12
Defect Cast	9

4.2.6 Keychain Cast for 500 rpm Rotation Speed

Figure 3.67: Result Keychain Cast Product for 500 rpm Rotation Speed

Table 4.7: Succes and Defect Keychain Cast Product Data for 500 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	6
Defect Cast	15

4.2.7 Keychain Cast for 450 rpm Rotation Speed

Figure 3.68: Result Keychain Cast Product for 450 rpm Rotation Speed

Table 4.8: Succes and Defect Keychain Cast Product Data for 450 rpm Rotation Speed

Keychain Cast Product	Quantity
Success Cast	5
Defect Cast	16

4.3 Keychain Cast Product

4.3.1 KD 1 Cast Product

As shown in the Figure 3.69, the KD 1 cast product demonstrates successful casting that represents a detailed and complex design. All design features as depicted in the master model are accurately reproduced in the cast product. On the front design, the fillet around the gear and the abbreviations are clearly visible. The gear teeth are also cast with high fidelity. Furthermore, the writing on the back is clearly legible due to the effective font size settings.

The surface quality of this design may be high than other KD due to the absence of a surface finishing process for the master model following laser cutting process. Surface roughness is particularly clearly around the inner circle areas.

Figure 3.69: KD 1 Cast Product

4.3.2 KD 2 Cast Product

As shown in the Figure 3.70, the KD 2 cast products demonstrate the ability of CRMC to produce products with the internal holes features. The difference in depth between the inner and outer parts is also clearly visible. However, the designed text may not be clearly recognizable due to the small font size which limits the level of detail achievable through the SRM vulcanization process. Furthermore, some gear teeth may not exhibit satisfactory detail when compare it to KD 1.

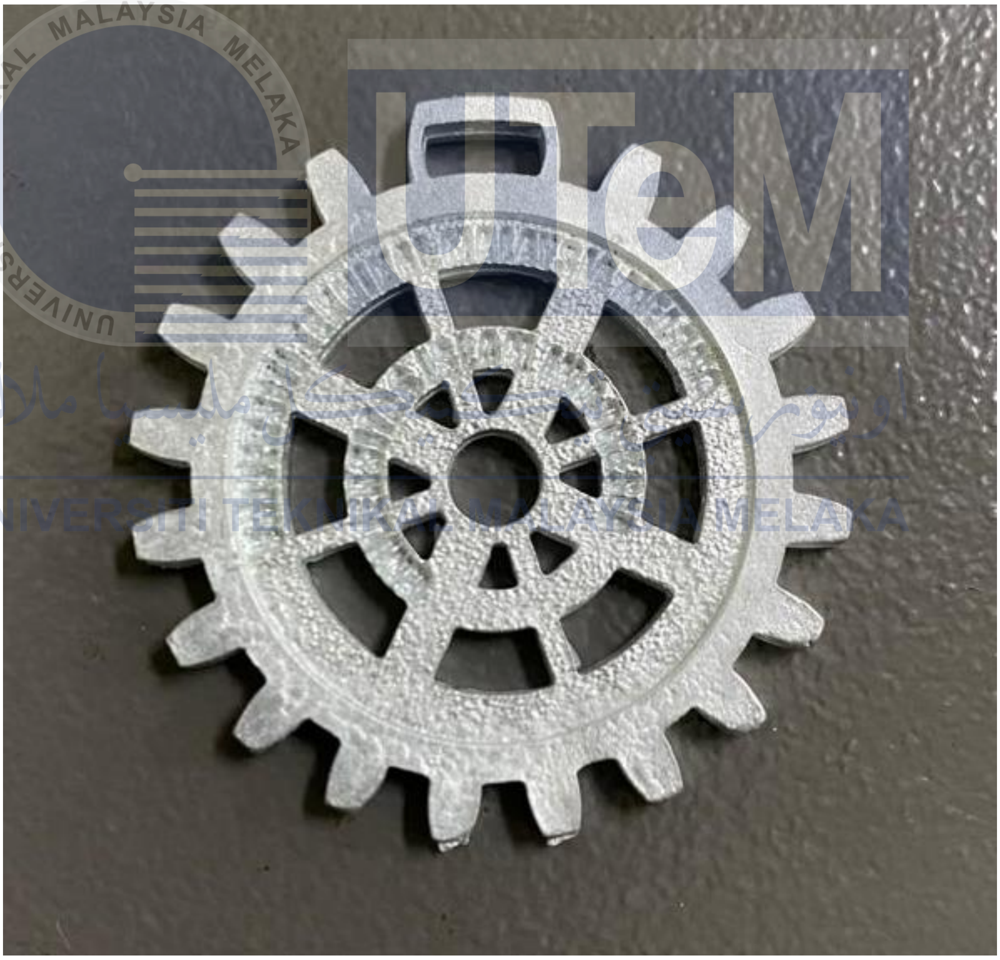


Figure 3.70: KD 2 Cast Product

4.3.3 KD 3 Cast Product

As shown in the Figure 3.71, the KD 3 keychain cast product exhibits fine design details. The engraved UII logo is clearly visible and the text is also easily legible. The back design also demonstrates satisfactory detail for the abbreviations and leaf motifs. However, casting this design consistently presents challenges with defects often observed at the edges. Like KD 1, this design also exhibits the higher surface roughness around the ends of the inner keychain.

Figure 3.71: KD 3 Cast Product

4.3.4 KD 4 Cast Product

For KD 4, two versions of the cast product were produced the corresponding to the two types of master models and both versions demonstrate successful casting results. Version 1 (Figure 3.72) is perceived as more visually appealing compared to Version 2 (Figure 3.73). However, KD 2 Version 2 highlights the casting capabilities of the process which accurately reproducing the engraved depths and holes from the master model.

Figure 3.72: KD 4 Version 1 Cast Product

Figure 3.73: KD 4 Version 2 Cast Product

4.4 Defect Keychain Cast Product

4.4.1 Major Defect Keychain Cast Product

The major defect observed was that the cast keychain products did not exceed 70% of the expected dimensions based on the mold cavity. This deficiency was due to slower rotation speeds which may have hindered the flow of molten metal due to reduced centrifugal force. This lower centrifugal force would have impeded the flow of molten metal through the runners and ingates of the mold that particularly due to their small gaps which require greater force for proper metal flow. Consequently, the molten metal solidified within the center of the SRM during the casting process.

As shown in the Figure 3.74 below, the keychain cast products for KD 1 and KD 3 exhibited this major defect with the base shape of the keychain being incompletely formed.

Figure 3.74: Example Major Defect Keychain Cast Product

4.4.2 Minor Defect Keychain Cast Product

On the other hand, minor defects as shown in the Figure 3.75 were observed in some cases. These defects included incomplete design details such as missing teeth in the gear design for KD 1 and KD 2 and an undefined edge for KD 3. These defects typically occurred before the optimal rotation speed for casting the keychain products was achieved.

Figure 3.75: Example Minor Defect Keychain Cast Product

4.5 Keychain Cast Product Analysis

4.5.1 CRMC Speed Parameter Analysis

Table 4.9: Data Cast Product According to Rotation Speed

	Gear (KD1)		Hole Gear (KD2)		UII Logo (KD3)		Malaysia Logo (KD4)		
Rotation Speed (rpm)	Success	Defect	Success	Defect	Success	Defect	Success	Defect	Percentage (%)
750	6	0	3	0	6	0	6	0	100
700	6	0	3	0	6	0	6	0	100
650	3	3	2	1	6	0	6	0	83.3
700	2	4	1	2	5	1	6	0	70.8
550	1	5	1	2	4	2	6	0	62.5
500	0	6	0	3	2	4	6	0	45.8
450	0	6	0	3	0	6	5	1	33.3

The table 4.9 summarizes the results of a casting experiment conducted on four different keychain base shapes which are Gear-shape (KD1), Hole Gear-shape (KD2), Square-shape (KD3), and Rectangle-shape (KD4). Data were collected by varying the casting speed (rpm) and recording the number of successful and defective castings for each design at each speed. The relationship between rotation speed and the percentage of successful cast products was observed to be a direct proportional. This is evident as the percentage of successful castings generally decreases with decreasing casting speed. At higher speeds of 750 rpm and 700 rpm, a 100% success rate was achieved for all designs.

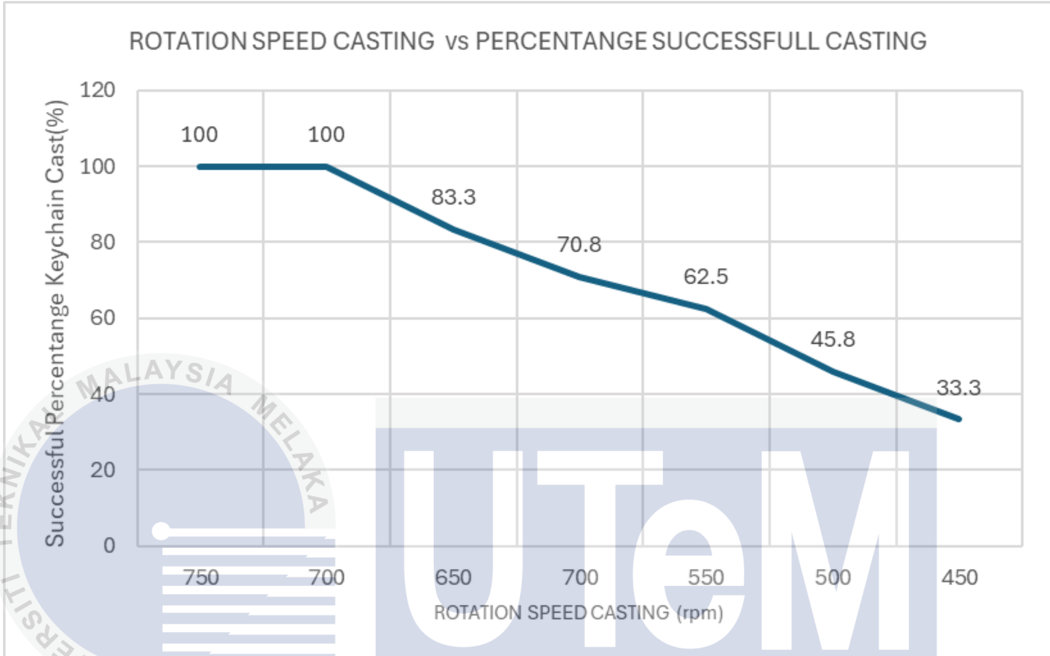


Figure 3.76: Graph Between Rotation Speed Casting and Percentage Successful Casting

Figure 3.76 clearly demonstrates the crucial role of casting speed in determining the success rate. Lower rotation speeds appear to increase the probability of defects that may potentially be due to insufficient centrifugal force to completely fill the molds.

Based on the data, an optimal rotation speed for 100% casting success was observed for each keychain base shape in one SRM. However, the Gear-shape (KD1) and Hole Gear-shape (KD2) designs required higher rotation speeds specifically 700 rpm to achieve successful castings. The Square-shape (KD3) design required a lower rotation speed of 650 rpm compared to the Gear-shape (KD1) and Hole Gear-shape (KD2) designs. While the Rectangle-shape (KD4) exhibited the lowest optimal rotation speed at 500 rpm.

4.5.2 SRM Analysis

In this section, the influence of runners and ingates on the casting process will be analyzed. As shown in the Figure 3.77, the KD 4 cast product exhibits incomplete detail at the end of the letter "Y." This incomplete filling occurred due to insufficient molten metal flow caused by inadequate runner and ingate. The limited space within the mold cavity hindered the flow of molten zinc during the casting process.

Figure 3.77: KD 4 Version 1 Mold Cavity Before Modifications

Therefore, the modifications were made by increase the runner and ingate as shown in the Figure 3.78. These SRM modifications improved molten zinc flow into the previously inaccessible areas of the mold cavity. This resulted in the production of KD 4 cast products with greater detail and more accurately reflecting the master model design. These findings demonstrate that the addition of appropriately designed runners and ingates to the mold cavity enhances the production of cast products with greater detail.

Figure 3.78: KD 4 Version 1 Mold Cavity After Modifications

4.5.3 Keychain Base-Shape Analysis

Data on both successful and defective cast products were collected and presented in bar graph format as shown in the Figure 3.79. The data presented represents the number of keychains cast products obtained from three casting repetitions. Gear shape (KD 1), Square shape (KD 3), and Rectangle shape KD 4 each yielded a total of 42 cast keychains due to two types of master models were utilized. While Hole Gear shape (KD 2) resulted in a total of 22 cast keychains because only one type of master model was employed.

Figure 3.79: Bar Graph Between Keychain Shape and Cast Keychain Pieces

The recorded data values will be utilized to calculate the percentage of successful cast products based on the keychain base shape using the Equation (2) below.

$$Successful\ Keychain\ Cast, \% = \frac{Sucess\ Casting}{Success\ Casting + Defect\ Casting} \times 100 \quad (2)$$

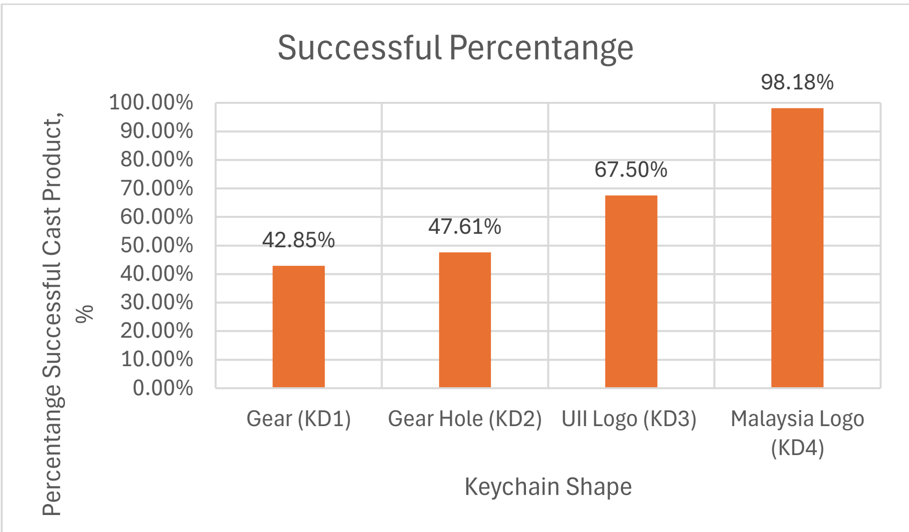


Figure 3.80: Graph Between Keychain Shape and Successful Percentage Keychain Cast

After calculating the data using the formula, the results were recorded in the form of a bar graph as shown in Figure 3.80. Based on the graph, the Rectangle-shape (KD4) was identified as the most suitable for mass production casting at 98.18% success keychain cast. The Square-shape also demonstrated the high success rate with 67.5% of castings successful. Mass production of keychain cast products using the square base shape could be achieved by increasing the casting rotation speed. Meanwhile, the Gear and Hole Gear shape with success rates of 42.85% and 47.61%, respectively are exhibited poorer casting results. This lower success rate can be attributed to the design complexity that particularly due to the presence of gear teeth. To improve casting success for these designs in mass production the addition of runners and ingates to the SRM is recommended.

4.5.4 Keychain Cast Product Mass and Perimeter Analysis

In this analysis, KD 4 version 1 cast products will be utilized due to the highest percentage of successful castings. This analysis aims to differentiate the casting results obtained at different rotation speeds. The focus will be on identifying the factors contributing to these differences by analyzing the mass of each cast product. All necessary data for this analysis are presented in the Table 4.10.

Table 4.10: KD 4 Version 1 Keychain Cast Product Dimension Data

SPEED, rpm	LENGTH, mm	HIGH, mm	MASS, g
750	61.65	33.05	12.3
700	61.60	33.00	12.0
650	61.55	32.95	11.9
600	61.50	32.90	11.7
550	61.45	32.85	11.4
500	61.40	32.85	11.3
450	61.40	32.85	11.3

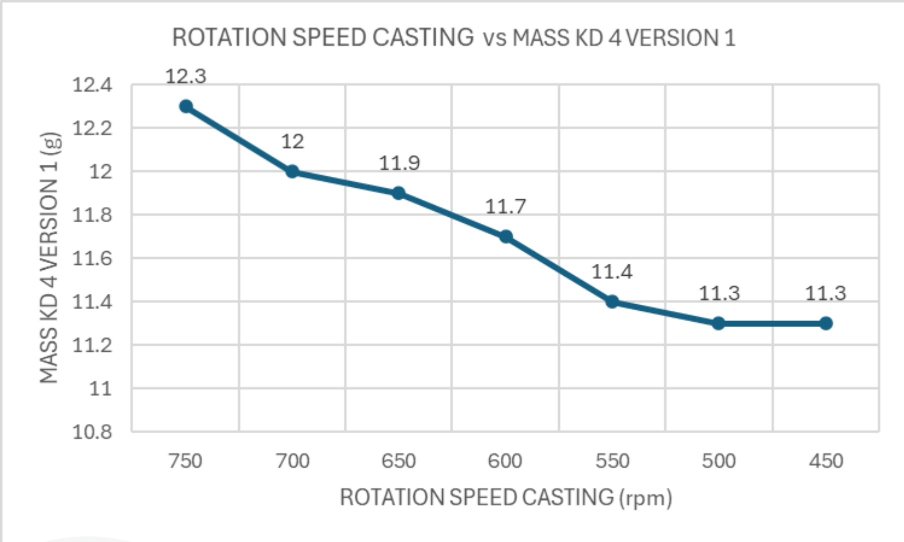


Figure 3.81: Graph Between Rotation Speed Casting and Mass KD 4 Version 1

Based on the data in the graph shows in Figure 3.81, an increase in the mass of the cast product is observed with increasing rotation speed. This increasing in mass may be due to differences in the density of molten zinc flow into the mold cavity at each rotation speed. However, upon reviewing the length and height dimensions of each cast product the increase in cast product dimensions was also observed. This suggests that the SRM experiences elongation at higher rotation speeds. This horizontal and vertical elongation results in an increase in the mold cavity area that consequently increasing the volume of molten zinc filling the mold. As the result, the volume of the cast product will also be increase that leading to a corresponding increase in weight cast product. This explanation describes the increase in the weight of the cast product observed with increasing rotation speed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORKS

5.1 Conclusions

Based on the results of the project research, CRMC is an optimal manufacturing process for producing small souvenir like keychain in mass production. However, producing larger souvenir items using this method may present challenges. This can be solved by dividing the larger product into several smaller parts and then joining them together using a suitable process such as welding. Furthermore, the use of acrylic laser cutting for master model fabrication was determined to be the most effective approach for achieving a smoother cast product surface.

SRM during the vulcanization process can be optimized by reduce the presence of air bubbles when placing uncured silicone rubber into the bottom position in molding frames. Additionally, incorporating runners and ingates can significantly improve casting results. This is because it can facilitate the flow of molten zinc into the smaller area of mold cavities during the casting process.

Each keychain with a different base shape required a different optimal casting rotation speed. In this project, the rectangular base shape which is KD 4 was found to be most suitable for low rotational speed casting. However, due to the advantages of CRMC even more detailed gears base shapes such as KD 1 and KD 2 can also be produced with the requirement of more runners and inserts in SRM and higher rotation speeds when do the casting process. This issue also can be addressed by creating the RSM with one only shape base design and producing the maximum quantity of mold cavity per mold. This approach will utilizing the optimal speed for each base shape design to achieve 100% successful casting outcomes for each casting process. Lastly, if the CRMC process uses higher rotation speeds than the optimal values might affect the mass of the keychain cast product. As discussed in the results, the mass of the KD4 version 1 was observed to increase when using higher speeds. This mass increase is attributed to elongations that occur within the mold cavity of SRM. This elongation arises from the elastic behaviour of the SRM used.

5.2 Recommendations for Future Study

Based on the results of this research, several improvements can be implemented for future studies such as further investigation involves comparing the use of different metals such as Aluminium (Al), Magnesium (Mg) and Copper (Cu) in the casting process and analyzing the optimal metal choices for CRMC. Additionally, the research can be expanded to explore the impact of other parameters such as molten metal casting temperature and spin time on the casting process. This would enable a more in-depth investigation of CRMC parameters and identify the most critical factors for CRMC. Furthermore, the design of the keychain models can be further enhanced by incorporating more intricate features or motifs. This would allow for an assessment of CRMC's capabilities in producing cast products with high levels of detail and in large quantities.

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APPENDIX A

C 400 Matic Spin Casting Machine Catalog Specifications

Nicem®
BEST QUALITY SINCE 1970

C 400 MATIC

CENTRIFUGE FOR LOW-MELTING METAL ALLOYS
CENTRIFUGA PER LEGHE METALLICHE BASSOFONDENTI

One-station semi-automatic centrifuge for the production of medium items made of low-melting metal alloys with a productivity of up to 100 castings/h. Equipped with timer for timed work cycle.
Nicem's centrifuges allow to cast the materials in the rotating mould with great ease and safety.

Centrifuga semiautomatica a una stazione per la produzione di pezzi di medie dimensioni in leghe metalliche bassofondenti con una produttività fino a 100 colate/h. Dotata di timer per ciclo di lavoro temporizzato.
Le centrifughe Nicem permettono di colare i materiali nello stampo in rotazione con grande facilità e sicurezza.

CHARACTERISTICS

1. Sturdy steel structure processed by CNC machining centre
2. Perfect parallelism of the centrifugation unit
3. Mould closing pressure adjustment
4. Pressure indicator manometer
5. Direction of rotation adjustment
6. Rotation speed adjustment managed by inverter
7. Cycle programming timer
8. Digital tachometer
9. Work cycle start button
10. Lid opening button
11. Emergency button
12. Main switch

CARATTERISTICHE

1. Robusta struttura in acciaio lavorata tramite centro di lavoro CNC
2. Perfetto parallelismo del gruppo di centrifugazione
3. Regolazione pressione di chiusura stampo
4. Manometro indicatore di pressione
5. Regolazione senso di rotazione
6. Regolazione velocità di rotazione gestita da inverter
7. Timer di programmazione ciclo
8. Contagiri digitale
9. Pulsante di avvio ciclo di lavoro
10. Pulsante di apertura coperchio
11. Pulsante di emergenza
12. Interruttore generale

TECHNICAL DATA DATI TECNICI

Mould diameter	Diametro stampo	400 mm | 15.7"
Maximum mould height	Altezza massima stampo	120 mm | 4.7"
Spins per minute	Giri al minuto	0 - 1500 RPM
Pressure	Pressione	2 - 6 bar
Power	Potenza	2500 W
Voltage	Tensione	400 V three-phase | trifase
Frequency	Frequenza	50/60 Hz
Dimensions	Dimensioni	700 x 865 x 1222 mm | 27.6 x 34.1 x 48.1"
Weight	Peso	330 kg | 728 lbs
Noise output	Rumorosità	< 80 dB

WWW.NICEM.IT | VIA PALMIRO TOGLIATTI, 38 - 20030 SENAGO (MI) – ITALY +39 02 990 90 1 | NICEM@NICEM.IT

APPENDIX B

P 400 Matic Vulcanizing Machine Catalog Specifications

Nicem

P 400 MATIC
VULCANIZING PRESS
PRESSA VULCANIZZATRICE

AUTOMATIC VULCANIZING PRESS

Machine for the vulcanizing of silicone and organic-rubber dies, equipped with heated plates from electric resistances.

PRESSA VULCANIZZATRICE AUTOMATICA

Macchina per la vulcanizzazione di matrici in gomma siliconica e organica, con piani riscaldati da resistenze elettriche.

CHARACTERISTICS

- Sturdy steel structure processed by CNC machining centres
- Hydraulic control unit with motor, pump, electrovalve and automatic pressure regulation
- Timer for vulcanizing cycle
- Digital thermoregulator for detection and regulation of temperature
- Pressure gauge for monitoring of pressure
- Pressure accumulator
- Cylinder processed by CNC machining centres
- Chrome-plated and rectified-steel plunging piston Ø 110 mm
- Emergency button
- General switch

CARATTERISTICHE

- Robusta struttura in acciaio lavorata tramite centro di lavoro CNC
- Centralina oleodinamica con motore, pompa, elettrovalvola e regolazione automatica della pressione
- Temporizzatore per ciclo di vulcanizzazione
- Termoregolatore digitale per rilevamento e regolazione della temperatura
- Manometro indicatore di pressione
- Accumulatore di pressione
- Cilindro lavorato tramite centro di lavoro CNC
- Pistone tuffante in acciaio cromato e rettificato Ø 110 mm
- Pulsante di emergenza
- Interruttore generale

TECHNICAL DATA
DATI TECNICI

400 x 400 mm / 15,7 x 15,7"
Heating plates dimensions
Dimensioni piastre di riscaldo

Ø 230 - 400 mm / 9 – 15,7"
Maximum frame diameter
Diametro massimo staffe

200 mm / 7,9"
Opening between plates
Apertura tra le piastre

25 T
Maximum clamping force
Forza di chiusura massima

0 - 250 bar
Pressure
Pressione

20 - 200°C / 68 - 392°F
Adjustable temperature
Temperatura regolabile

POWER POTENZA	**4750 W**
VOLTAGE TENSIONE	**400 V** THREE-PHASE | TRIFASE on request | su richiesta 230 V three-phase | trifase
FREQUENCY FREQUENZA	**50 / 60 Hz**
DIMENSIONS DIMENSIONI	**700 x 865 x 1156 mm / 27,6 x 34,1 x 45,5"**
WEIGHT PESO	**418 kg / 922 lbs**
NOISE OUTPUT RUMOROSITÀ	**< 80 dB**

MATIC LINE

P 400 MATIC
VULCANIZING PRESS
PRESSA VULCANIZZATRICE

C 400 MATIC
CENTRIFUGE
CENTRIFUGA

F MATIC
FURNACE
FORNO

3-STATION LINE

P 400 MATIC
VULCANIZING PRESS
PRESSA VULCANIZZATRICE

TRSME 350 AUTOMAT
CENTRIFUGE
CENTRIFUGA

F MATIC
FURNACE
FORNO

8-STATION LINE

P 400 MATIC
VULCANIZING PRESS
PRESSA VULCANIZZATRICE

8-STATION TRANFER
TRANSFER A 8 STAZIONI

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