Dissertation Report of Slip-On Sprocket

by

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15056

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Abstract

This continuous research basically is to enhance and improve the idea of the 'Ring Chain Sprocket'. This product was proven to increase the torque of the motorcycle without changing the original sprocket and modifying the engine. As for the previous research, the product is called Ring Chain Sprocket and two prototypes was produced which is Alpha and Beta I. Alpha prototype was produced by Thermojet 3D Printer and Beta I was produced by using CNC process and the material is steel. During this research, the name was changed to 'Slip-On Sprocket' and Alpha prototype was reprinted and Beta II was fabricated by Laminated 3D Printing. Beta I, which is steel are not suitable for initial mass fabrication because it is very expensive and the CNC process will take a long time. Other than that, silicon rubber moulding will not cost as much as using injection moulding and it is feasible for final year project. This project used the method of Silicon Rubber Moulding as the fabrication process and the product of silicon rubber moulding will be polyutherane resin but the desired product cannot produce because the material was expired. However, it is proven that silicone rubber moulding is easier, faster and cheaper than CNC and injection moulding. This project was carried out in the Rapid Prototyping lab in Block 16, Universiti Teknologi Petronas.

Then, this project will test new teeth combination to make a various size of Slip-On Sprocket. It is important to produce various sizes during research for further commercialization. Different motorcycle will have different size of sprocket and various size of Slip-On Sprocket need to be produced. So, this research has found the suitable combination of sprocket size to produce a Slip-On Sprocket.

This project expected to be continued by using new material and graphene will be added to the materials compound to increase the hardness and durability to the Slip-On Sprocket.

Acknowledgement

An endeavour over a period can be successful only with the advice and support of well-wishers. The author would like to take this opportunity to express his profound gratitude to Universiti Teknologi PETRONAS for providing the platform for the research project to be conducted. The author also like to take this opportunity to express a deep sense of gratitude and regards to his supervisor, Associate Professor Dr Ahmad Majdi bin Abdul Rani, Senior Lecturer, Mechanical Engineering, Universiti Teknologi PETRONAS, for his cordial support, valuable information and exemplary guidance, which help the author in completing the final year project. The blessing, help and guidance given by hime time to time shall carry the author a long way in the journey of life on which the author about to embark. The gratitude also goes to Rapid Prototyping Lab Technician, Mr. Zamil Khairuddin who always makes himself available to supervise the author in doing 3D printing processes and post processing job. The author obliged to the Research and Innovation Office for funds and support to make this project success in the competition. With their patience and openness they created an enjoyable environment. A big contribution and hard worked from them during project progress is very great indeed. The author would like to thank Almighty, his parents, brother, sisters, and friends for their constant encouragement without which this report would not be possible.

Thank you.

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1.0 Introduction

1.1 Background of Study

The proposal described the background study of the project by the previous student regarding the ring chain sprocket which increased the torque of motorcycle to ride on the step road. Previous student have analyzed all the data and carry out the experiment to determine the design of the ring chain sprocket. As for the product, they have produced the Alpha and the Beta prototype and it has successfully achieved their objective to increase the torque of the motorcycle without changing the original sprocket (Rajindran, 2013). Previous study also only focused on one sprocket combination which is 36T and 40T. Further research in this project will determined other combination of sprocket size so that it will be useful for commercialization plan. Next, the cost of the prototype is too high and it is not reasonable for marketing. It is because the sprocket cannot be too expensive as the targeted buyer is the farmer and villagers. So, new materials for the Slip-On sprocket need to be determined which need to be cheap, easy to fabricate, and light in weight. This report also explained briefly regarding the general of plastic and injection moulding for plastic. Nevertheless, this report will cover the step used to complete this project. It was explained in the methodology on how this project was planned and the time frame from the Gantt Charts to complete this project.

1.2 Problem Statement

Based on the previous studies, this project has successfully shown that it has a lot of advantages and benefits. However, the Beta prototype has a few problems and it needs certain modifications on the fabrication or the manufacturing part. Firstly, the Slip-On Sprocket should be varies in size so that it can be used for most of the motorcycles in Malaysia. Different motorcycle will have different size of sprocket and various size of Slip-On Sprocket need to be produced. So, a study needs to be done to determine the suitable combination of sprocket size to produce a Slip-On Sprocket.

The next problem is the Beta prototype is very costly because it is made of steel. After reconsidering the market ability, the material of Beta I prototype should be change as it will be cheaper and would be affordable to the peoples of rural areas. So, manufacturing process which is silicon rubber moulding will be tested to produce Slip-On Sprocket instead of using CNC process. The Beta prototype produced through the process of CNC milling which is very expensive and takes a lot of time.

1.3 Objectives

The objectives of this project are:

1. To determine suitable sprocket size combination to make various size of Slip-On Sprocket.
2. To develop new prototype by using silicon rubber mould process prior to initial mass fabrication.
3. To develop a plastic Beta II prototype by using Rapid Prototyping-Laminated 3D Printing and Thermojet 3D Printing

1.4 Scope of Study

The scope of study based on the objectives can be simplified as follows:

i. Fabrication of the prototype by using Thermojet 3D printer and Plastic 3D Printer.
ii. Computer Aided Three-dimensional Interactive Application (CATIA) drawing.
iii. Silicon rubber mould process.

1.5 Feasibility of Project

The project is feasible to mechanical engineering courses because the project applied all aspects of mechanical engineering. As a mechanical student, subject like Manufacturing and Engineering Materials is really helpful to carry out this project. Besides that, it is also feasible because all the facilities to carry out this project are available in the campus. For example, silicon rubber is available at Manufacturing Laboratory Block 16. Other than that, the materials for this project also are not very difficult to get. The drawing can be done by using CATIA which is available at Block 17-01-06.

Next, the product of this project is marketable and affordable to user. It can be said that the uses of plastic as a materials is very helpful in order to reduce the product cost.

Based on the planning in the methodology, this project is feasible to be completed within the time frame.

2.0 Literature Review

2.1 Motorcycle Sprocket System

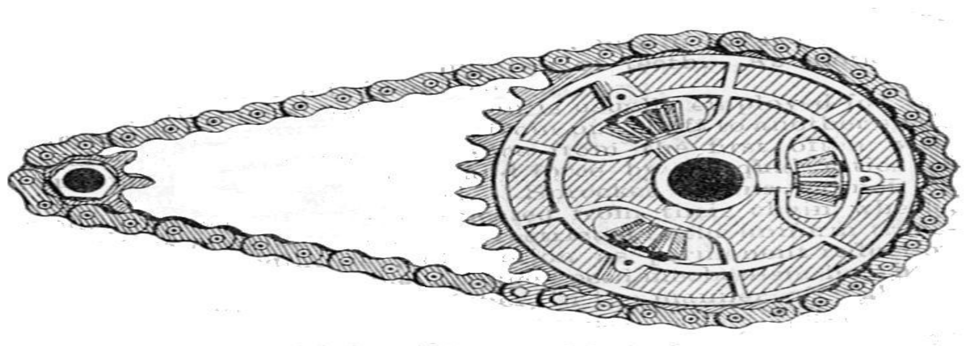

Figure 2.1: Basic motorcycle sprocket system

Sprocket systems are used in bicycles, motorcycles, car, tracked vehicles and other machine either to transfer the rotary motion between two shafts where gears are unsuitable or to impact linear motion to a track. In motorcycle, the front sprocket which have smaller number of teeth acted as a driver sprocket, while rear sprocket which have larger number of teeth is driven sprocket. Study need to be carried out in order to understand the system of sprocket and also to analyse the shape, tolerance, design and function. For application of sprocket system, sprockets should be accurately aligned in a common vertical plane, with their axes parallel. Chain should be kept clean and well lubricated with thin, light-bodied oil that will penetrate the small clearances between pins and bushings. Centre distance should not be less than 1.5 times the diameter of the larger sprocket, nor less than 30 times the chain pitch, and should not exceed 60 times the chain pitch. Centre distance should be adjustable - one chain pitch is sufficient - and failing this an idler sprocket should be used to adjust tension. A little slack is desirable, preferably on the bottom side of the drive. The chain should wrap at least 120° around the drive sprocket, which requires a ratio of no more than 3.5 to 1; for greater drive ratios, an idler sprocket may be required to increase wrap angle this is according to *Notes on Sprocket and Chain* retrieved from web.

2.2 Rapid Prototyping

Rapid Prototyping Technology is a group of manufacturing processes that enable the direct physical realization of 3D computer models. This fast developing technology is able to convert the 3D computer data provided into a physical model with high degree of accuracy, allowing the user to save more on the cost and time-consuming machinery work. RP Technology is unlikely the conventional manufacturing processes (subtractive manner: removing material from raw block until the final shape of part is achieved), which the principles of work is builds up parts layer by layer or additive manner. There are various technologies in RP that can be divided by 3 categories; liquid, discrete particles, and solid sheets.

2.2.1 Three Dimensional Printing or 3DP

3DP is an industrial manufacturing process with the potential to significantly reduce resource and energy demands as well as process-related CO_2 emissions per unit. Contrary to conventional manufacturing subtractive processes, 3DP encompasses additive means of production. Three-dimensional physical objects are produced through layer-by-layer formation of matter based on a digital blueprint (usually a CAD file). The technology evolved during the mid-1980s when computing and control systems progressed (Hopkinson et al., 2006). 3DP has recently gained much attention as the process has proven to be compatible with industrial manufacturing beyond prototyping (Berman, 2012, Gershenfeld, 2012 and Reeves, 2008).

Hopkinson (2006) described 18 different 3DP processes. These can be divided by the physical state of the printed matter (liquid-, solid- and powder-based processes) and by the applied method to fuse matter on a molecular level (thermal, ultra violet (UV)-light, laser or electron beam. The most commonly applied processes are stereolithography (SLA), selective laser sintering (SLS), digitals light processing (DLP), fused deposition modelling (FDM), selective laser melting (SLM) and electron beam melting. Polymers, alloys of aluminium, steel and titanium, as well as ceramic composites are currently printable at a minimum layer thickness of 20–100 μm, depending on the process and the physical state of the material (Hopkinson et al., 2006). Therefore, 3DP can be applied to various manufacturing markets. It enables a potential substitution of conventional processes. 3DP has the great advantage of enabling the realization of complex freeform geometries, as the process is not constrained by the technological limitations of conventional manufacturing processes (Reeves, 2008).

2.2.2 Material Jetting (Thermojet 3D Printer)

Thermojet 3D Printer can be classified as one of the many type of material jetting technology. The difference between material jetting machine and others printing machine is the number of nozzle operates when processing. It allows a simultaneous deposition of a range of materials. In other words, the desired model can be printed out from multiple of material with a range of properties and characteristics. Materials used in the printing process are in their molten state or liquid form. It will form the product accordingly with simultaneously jetting support materials. In the research conducted by, it also stated out how the process of material jetting form a model. The materials involved are melted into molten state and ejected out from a different nozzle. It have multiple of nozzle with different molten materials. Within the analysing of reading format data, the nozzles will start to operate simultaneously. The ejection of the nozzles will form the model and the support material for the overhanging geometries, empty space inside and size of porosity. After the first layer of droplets have deposited on the surface, the cooling process will be proceed with a blower or cooler. Those nozzles will only resume when the first layer is partially solidified. Thus, the process of the material jetting is also known as solidification of molten material.

According to D.T Pham in International Journal of Machine Tools & Manufacture (1998), the cooling rate of the molten materials used are different. Issue may happen like improper weld in parts. This is because when the droplets are solidified in shape, they are unable to merge with other droplets around. To overcome the problem, the material involved are ejected from the nozzle at a certain frequency which around 60 Hz. It is depend on the size of head nozzle. For the larger droplet which require the wider separations between, lower frequency will be carry out in the process. Parameters that have to be consider in the process are frequency of ejection from nozzle, size of head nozzle, cooling rate of materials involved. This process is similar to Stereolithography (SLA), support materials are attached on the product surfaces. Normally, those support materials are easily to be removed since the joint between are point by point only. However, in some cases, it filled inside a hollow part or the subsurface areas. For those cases, support material solution are needed in order to clear out from the product.

2.2.3 Thermojet 3D Printer Specifications

	X (Left/Right)	Y (In/Out)	Z (Up/Down)
Max Print Size	250	190	200
Resolution (DPI)	400	300	600
Resolution (mm)	0.064	0.085	0.042
Resolution (um)	64	85	42

Table 2.1: Thermojet Operational Specifications

The material used in the Thermojet printer is 3D Systems TJ88. Known as a wax co-polymer, it is essentially a modified wax with a melting point around 85^{o}C. High cleanliness is required to ensure the fine jets are not blocked. This material is ideal to produce the wax patterns for model and prototype. However, the product cannot be used as working model as it is very fragile.

Properties	Value
Melt Temperature	Approx 85-95 °C
Softening Temperature	Approx 70°C
Density (g/cm3) @140°C	0.846
Density (g/cm3) @130°C	0.848
Density (g/cm3) @23°C	0.975
Volume shrinkage from 140°C to room temperature	12.9%
Linear shrinkage from 140°C to room temperature	N.A.
Ash content TJ88 Gray	0.00-0.01%

Table 2.2: Material Properties of Thermojet Printer

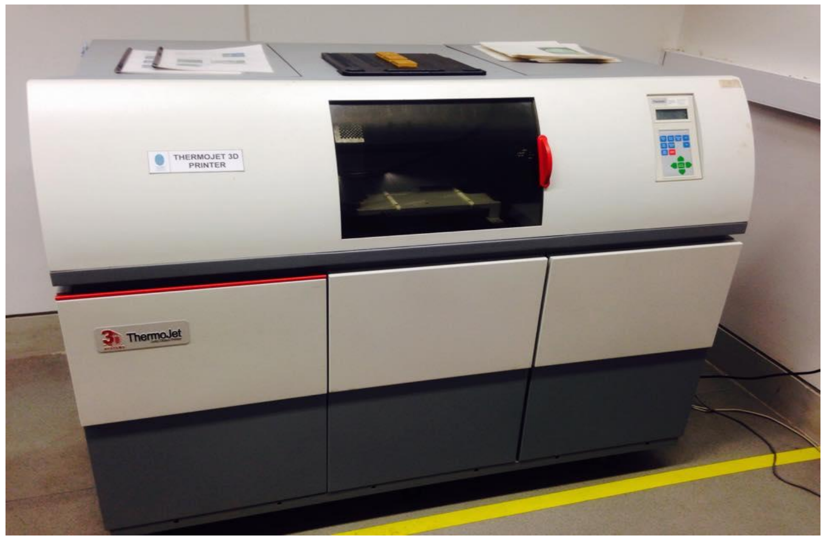

Figure 2.2: Thermojet printer in Block 16

2.2.4 Laminated Object Manufacturing (Laminated 3D Plastic Sheet Printing)

Laminated object manufacturing (LOM) is a method of 3D printing. Basically, the process started with layers of plastic or paper were fused or laminated together using heat and pressure, and then cut into the desired shape with a computer-controlled laser or blade.

Like all 3D-printed objects, models made with an LOM system start out as CAD files. Before a model is printed, its CAD file must be converted to a format that a 3D printer can understand, usually STL or 3DS.

An LOM apparatus uses a continuous sheet of material such as plastic, paper or (less commonly) metal which is drawn across a build platform by a system of feed rollers. Plastic and paper build materials are often coated with an adhesive. To form an object, a heated roller is passed over the sheet of material on the build platform, melting its adhesive and pressing it onto the platform. A computer-controlled laser or blade then cuts the material into the desired pattern. The laser also slices up any excess material in a crosshatch pattern, making it easier to remove once the object is fully printed.

After one layer of the object is formed, the build platform is lowered by about 1/16 of an inch the typical thickness of one layer. New material is then pulled across the platform and the heated roller again passes over the material, binding the new layer to the one beneath it. This process is repeated until the entire object has been formed.

Once an object is done printing, it is removed from the build platform, and any excess material is cut away. Objects printed in paper take on wood-like properties, and can be sanded or finished accordingly. Paper objects are usually sealed with a paint or lacquer to keep out moisture.

Technology	**3D printing - plastic sheet lamination**
Build material	PVC
Material color	Amber (transparent)
Accuracy	+/- 0.2 mm (XY)
Layer thickness	0.165 mm (Z)
Maximum model size	170 x 220 x 145 mm (XYZ)
Dimensions	W450 x D725 x H415 mm
Weight without cartridge and roll	30 Kg
Weight with cartridge and roll	40 Kg
Power consumption	300 VAC, 47/63 Hz, 100-120/200-240 VAC

Table 2.3: General Specification for SD300 Pro Printer

The lamination 3D product is rigid polyvinyl chloride compound or PVC. It was constructed by a plurality of rigid PVC sheets depending on the model projected. The layers then will be bonded with liquid adhesive to stick all the lamination sheets together.

Properties	Condition	Value
Appearance	Sheet	Transparent, amber
Density, g/cm3	25°C	1.38
Tension strength, MPa	ASTM D 638 25 °C	40 - 50
Elongation at break, %	ASTM D 63825 °C	30 – 100
Tensile modulus, MPa	ASTM D 638, 25 °C	1200 – 2000
Heat deflection temperature, °C	ASTM D 648@ 264 psi	45 - 55

Table 2.4: Material Properties of Laminated 3D Product

2.3 Silicon Rubber Mould

Silicone rubber is a high purity cured silicone with low compression set, great stability and ability to resist extreme temperatures of heat and cold ideally suitable for production of parts, where high quality is a must. Due to the thermosetting nature of the material, liquid silicone injection moulding requires special treatment, such as intensive distributive mixing, while maintaining the material at a low temperature before it is pushed into the heated cavity and vulcanized.

Chemically, silicone rubber is a family of thermoset elastomers that have a backbone of alternating silicon and oxygen atoms and methyl or vinyl side groups. Silicone rubbers constitute about 30% of the silicone family, making them the largest group of that family. Silicone rubbers maintain their mechanical properties over a wide range of temperatures and the presence of methyl-groups in silicone rubbers makes these materials extremely hydrophobic.

Materials for making silicon rubber mould and polyutherane product:

i. PX 226 Part A (Isocyanate)
ii. PX 226-245 Part B (Polyol)
iii. ESSIL 296 Catalyst
iv. ESSIL 296 Resin
v. Colorkit for Model

Figure 2.3: Materials for making silicon rubber mould and polytherane product.

Figure 2.4: Samples of silicon rubber mould and polyutherane products

Physical Properties			
Composition	ISOCYANATE PX 226	POLYOL PX 226, PX 245	Mixed
Mix ratio by weight	100	50	
Aspect	Liquid	Liquid	Liquid
Colour	Straw yellow	Colourless	White
Viscosity at 25°C	175	700	2,000 (2)
Specific gravity at 25°C (g/cm3)	1.22	1.10	1.20
Pot life at 25°C on 100 g (min)		PX 226-245 PX 226L-245/ L	4 7,5

Table 2.5: Physical properties of isocyanate and polyol mixture (polyutherane)

Mechanical Properties at 23 °C			
Flexural modulus	ISO 178 : 2001	MPa	2500
Flexural strength	ISO 178 : 2001	MPa	105
Elongation at break	ISO 527 : 1993	%	15
Tensile strength	ISO 527 : 1993	MPa	70
Impact strength (Charpy test) Unnotched specimens	ISO 179/1eU : 1994	kJ/m2	70
Hardness	ISO 868 : 2003	Shore D1	82

Table 2.5: Mechanical properties of isocyanate and polyol mixture (polyutherane)

3.0 Methodology

3.1 Project Planning

This project was planned as the figure below

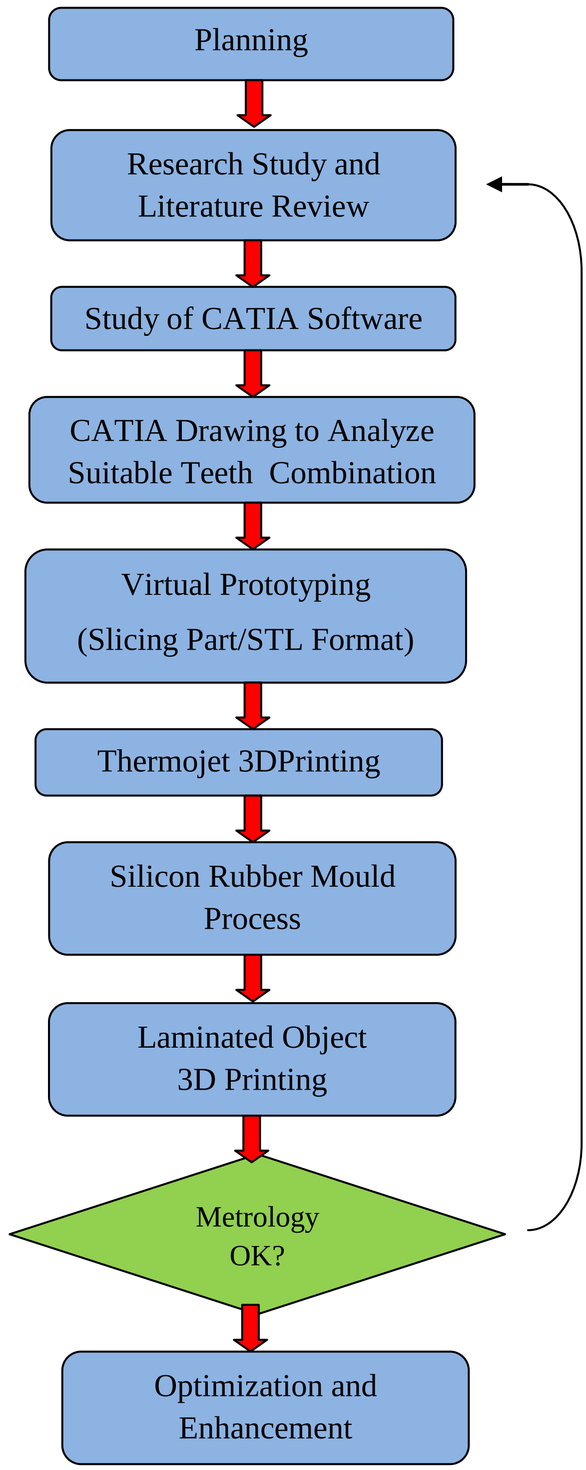

Figure 3.1: Flow of Project Planning

3.2 Gantt Charts

No	Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of project topic														
2	Preliminary Research/ Revision of previous study														
3	Literature Review														
4	CATIA Training														
5	Teeth Combination Analysis														
6	Analysis of STL file for 3D Printing														
7	Produce 3D Printing Model using Thermojet														

Table 3.1: Gantt's Chart report II

No	Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Literature Review														
2	RP using Silicon Rubber Mould														
3	Prepare CATIA drawing for Laminated 3D Printing														
4	Produce 3D Model using Laminated 3D Printing														
6	Purchasing Silicon Rubber Mould														
7	Report Completion														

Table 3.2: Gantt's Chart report FYP II

	Key Milestone 1	To complete the teeth combination analysis by Catia Software
	Key Milestone 2	To produce Alpha prototype using Thermojet 3D printer
	Key Milestone 3	To test silicon rubber mould process to produce polyutherane product
	Key Milestone 4	To produce 3D Beta II byl using Laminated 3D Printer

Table 3.3: Table of Key Milestone's

3.3_3D Modelling by Using CATIA V5 Software

The early stages basically focused on the research of the slip-on sprocket and also understand the parameters required to produce the slip-on sprocket. The most important step would be understand and able to produce Catia drawing because it will be a core to this project design. The idea to get 3D model drawings for this project is by using the concept of Boolean operation (extrusion). The author has to get the dimension of the actual sprocket either by measuring the sprocket scale or by using 3D Scanner.

Figure 3.2: Process during 3D Scanning of Sprocket

Once the dimension is ready, it will be converted to '.cat' format for further operation by using CATIA V5 software. In order the drawing to be completed, it must have both size of the sprocket which is 36T and 40T and other combination. The process of producing the slip on sprocket will be shown below.

3.3.1 Slip On Sprocket 36T and 40T combination

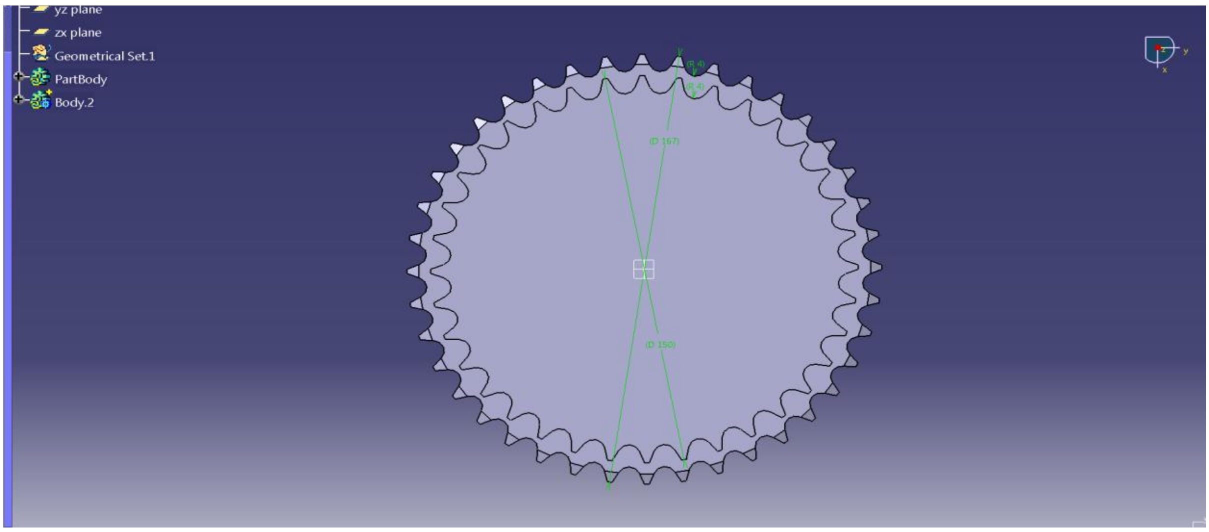

Figure 3.3: Overlap both sprocket 36T and 40T

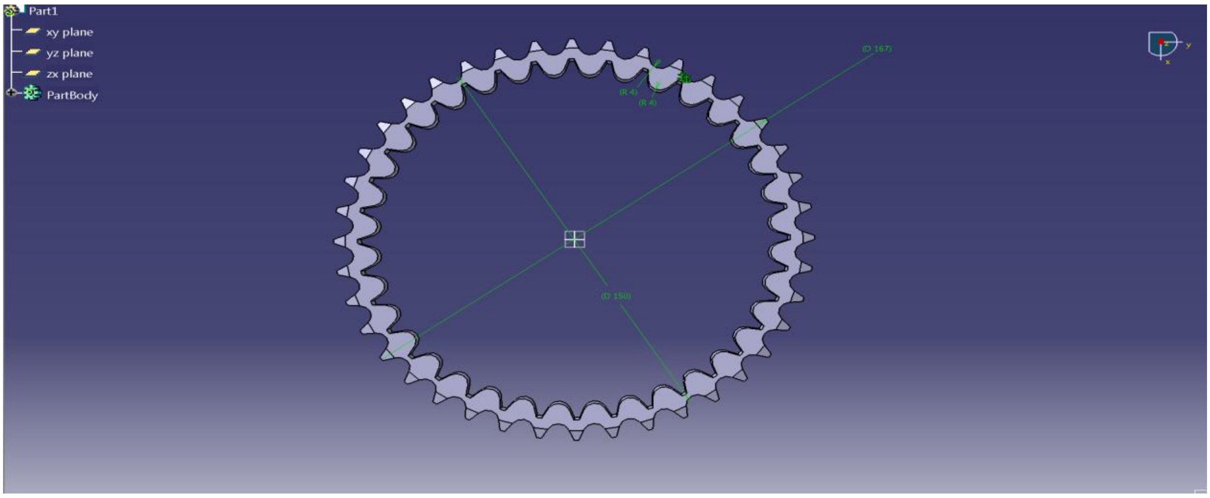

Figure 3.3: Do Boolean (Extrusion) for the inner sprocket to get the sprocket ring

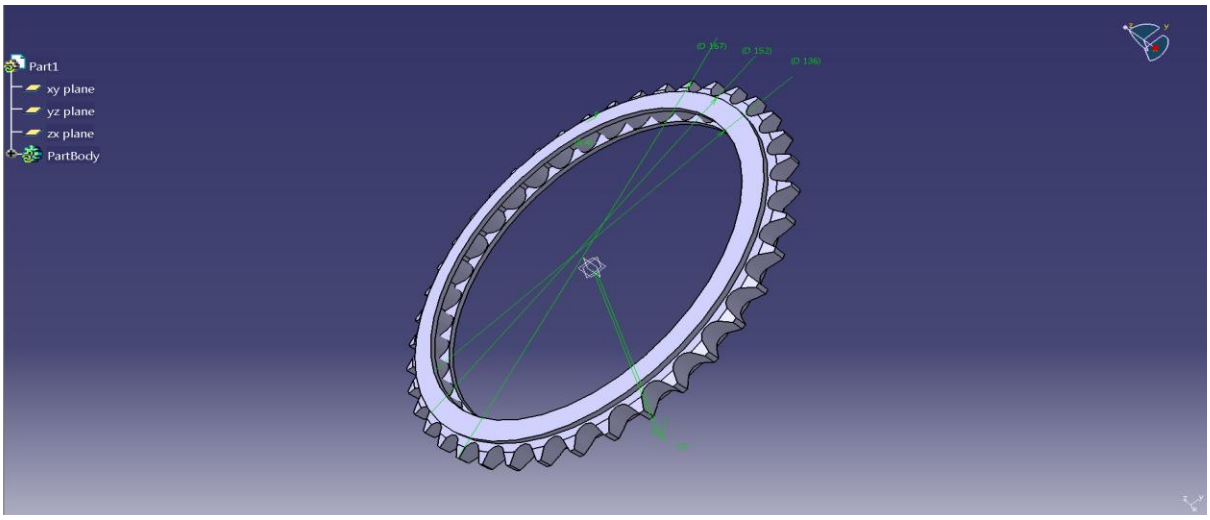

Figure 3.4: Insert outer skirting for both sides (to prevent it slips during use)

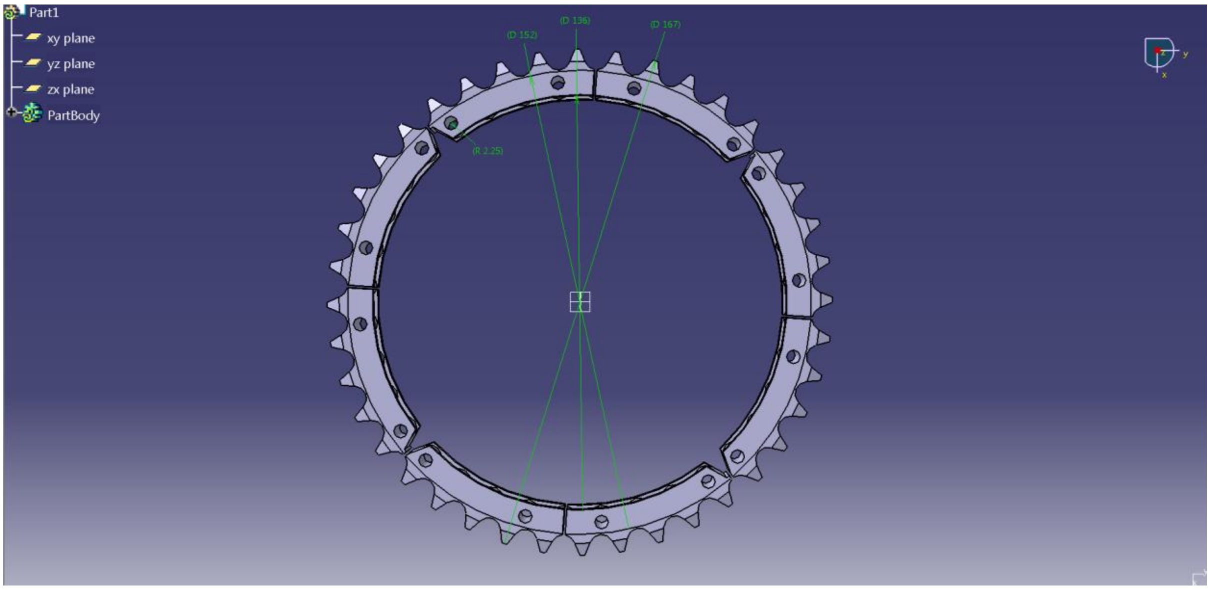

Figure 3.4: Break the sprocket into eight pieces and make a hole for the clips.

3.3.2 Slip On Sprocket 38T and 40T Combination

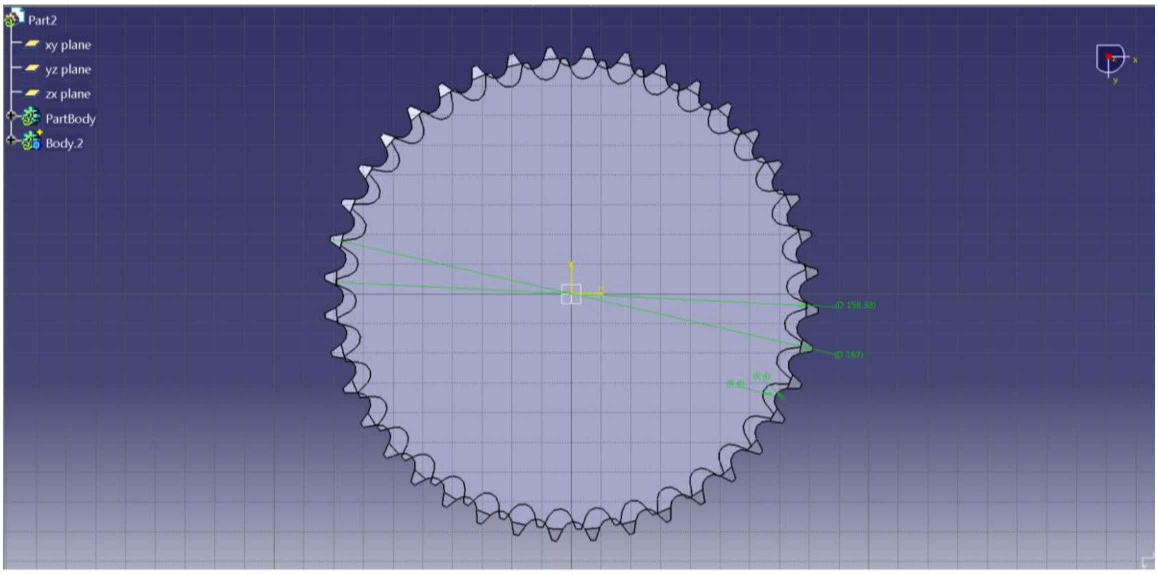

Figure 3.5: Overlap both sprocket 38T and 40T

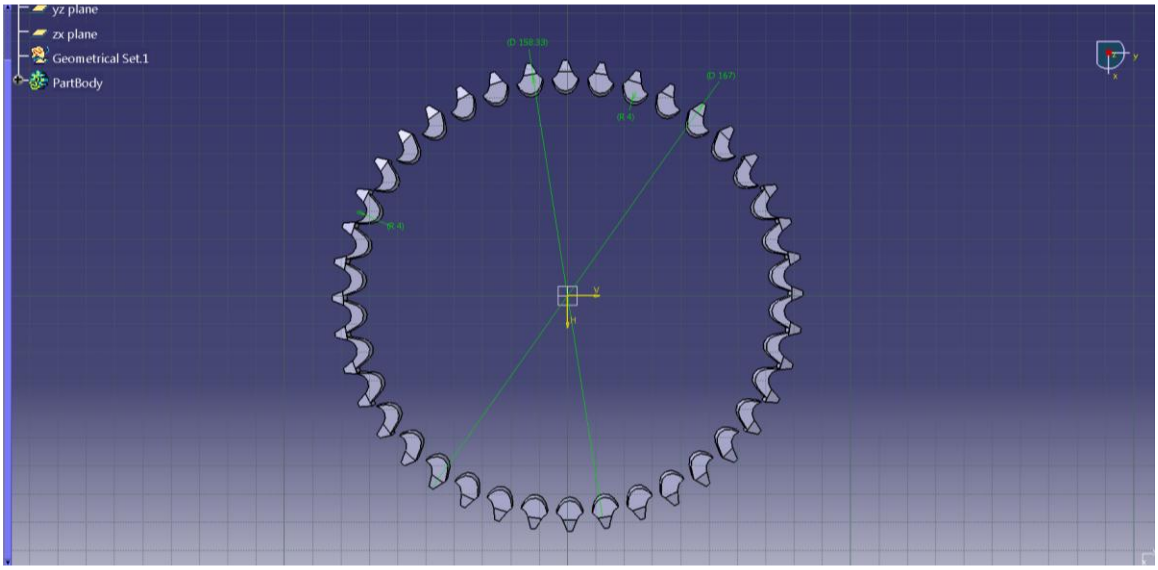

Figure 3.6: Do Boolean (Extrusion) for the inner sprocket to get the sprocket ring.

3.3.3 Slip-On Sprocket 37T and 40T Combination

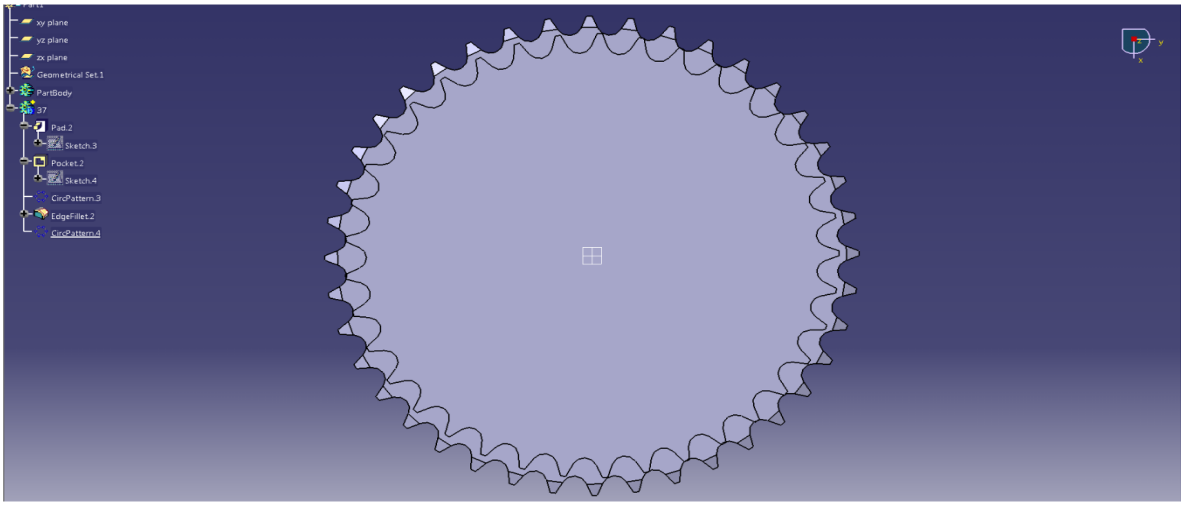

Figure 3.7: Overlap both sprocket 37T and 40T

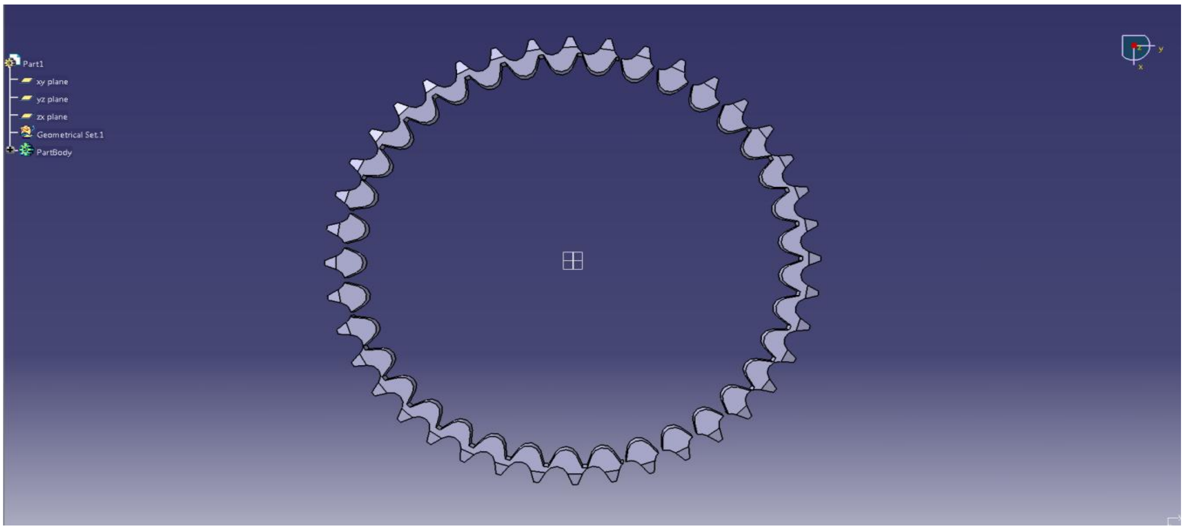

Figure 3.8: Do Boolean (Extrusion) for the inner sprocket to get the sprocket ring. (Tops view)

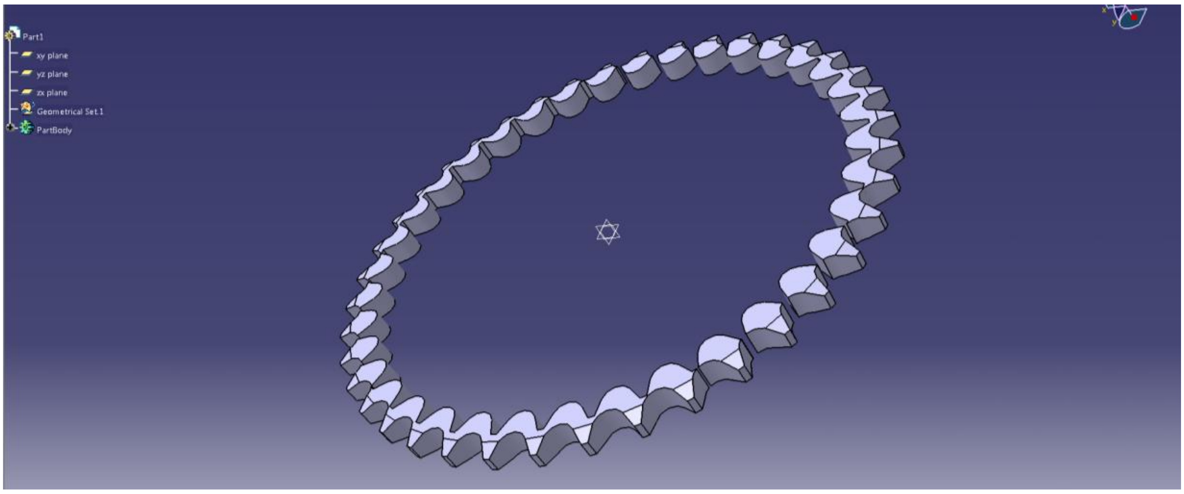

Figure 3.9: After extrusion process (Isometrics view)

3.3.4 Slip On Sprocket 38T and 42T Combination

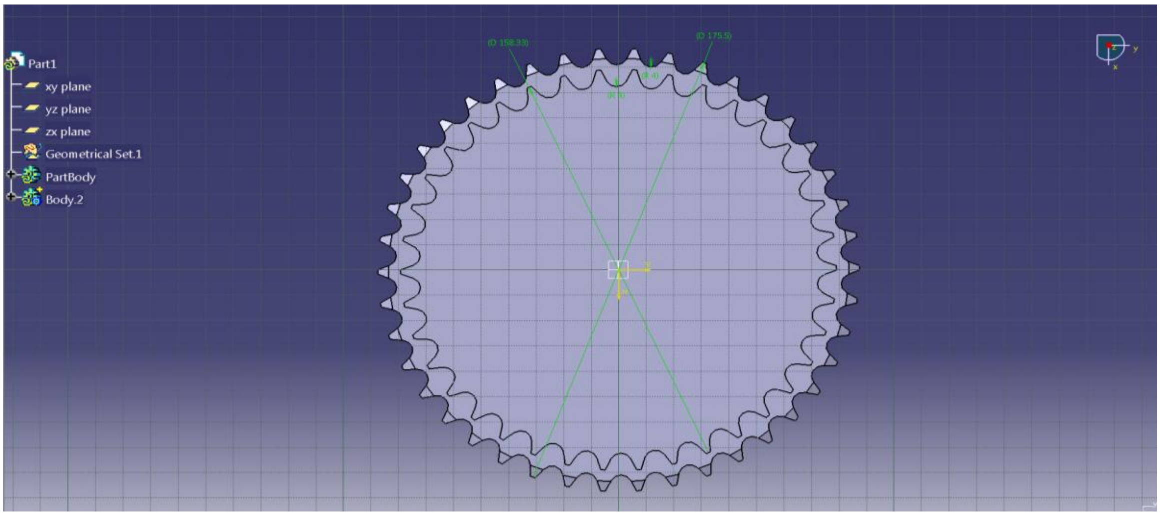

Figure 3.10: Overlap both sprocket 38T and 42T

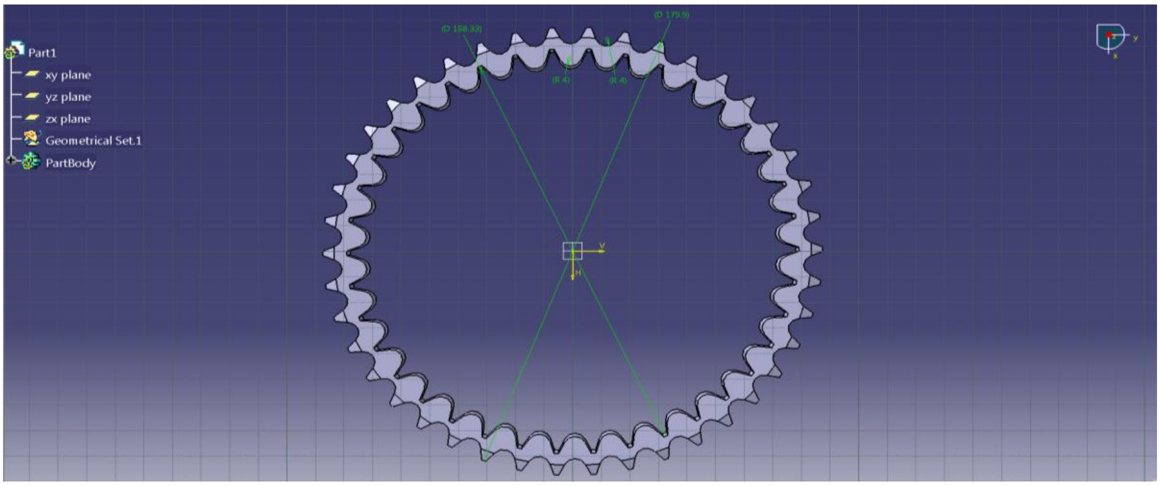

Figure 3.11: Do extrusion for the inner sprocket to get the sprocket ring. (Tops view)

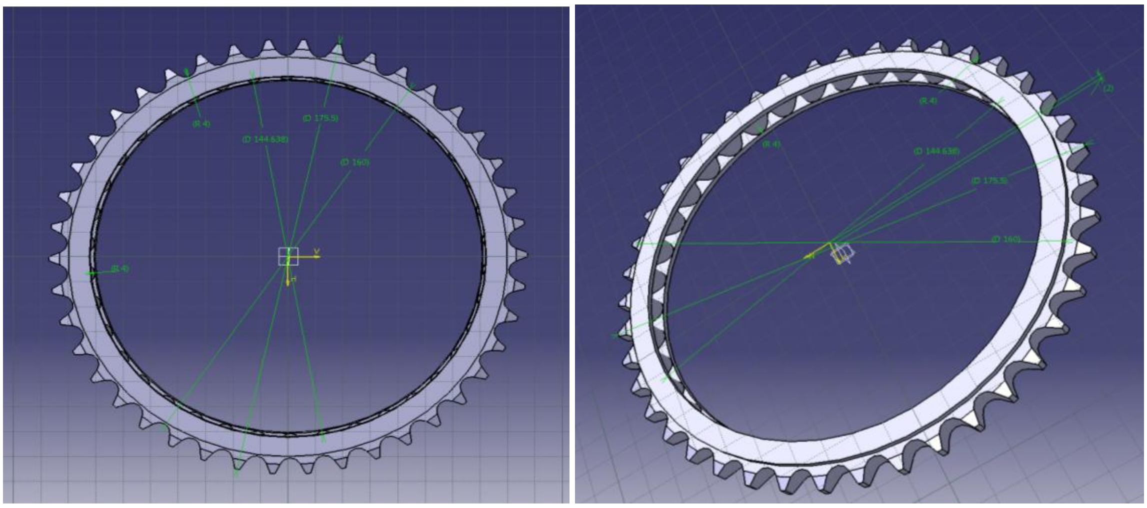

Figure 3.12: Insert outer skirting for both sides (Top view: left, Isometric view: right)

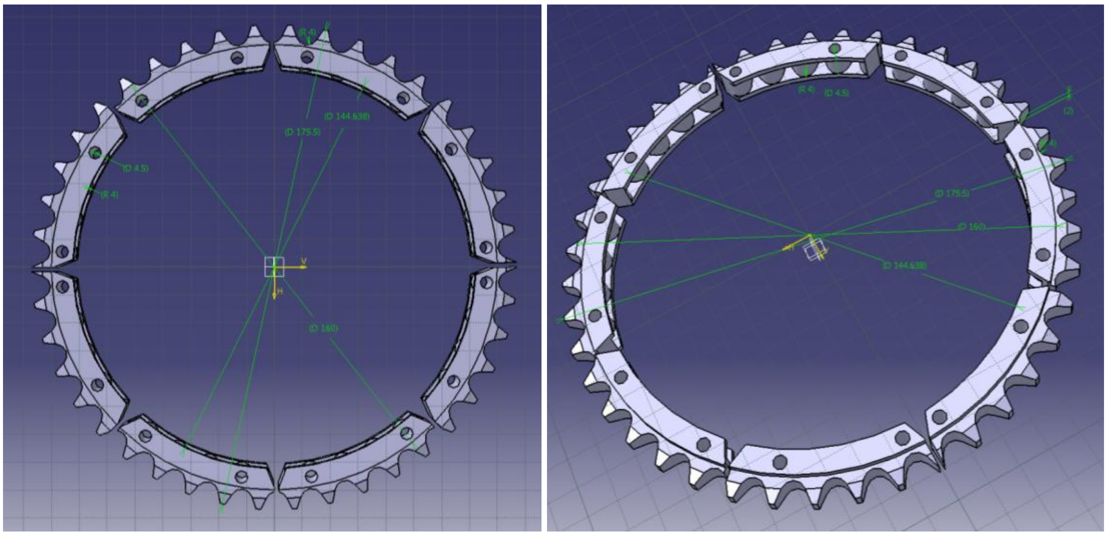

Figure 3.13: Break the sprocket into eight pieces and make a hole for the clips
(Top view: left, Isometric view: right).

3.4 Printing Thermojet 3D Model

Making the 3D prototypes with the RP machine involves the conversion of STL files of the parts in the machine's software. To produce the physical model of the part, the corresponding STL file is transformed by using CATIA software before set for ThermoJet printer client software, that enables to verify the STL file, auto-fix errors and determine the better position of the model on the working apparatus area, optimising both build space and time.

After the conversion of format is done, the drawing will be transferred to the connected computer to adjust the position of the sprocket pieces. This is very important in order to minimize the loss of printing material. For printing process, it will take about 6 to 8 hours before completion. The figures below show the process after 3D printing is completed.

Figure 3.14: Printing process by using Thermojet 3D printer

Figure 3.15: Bonding process

Figure 3.16: Drying process.

Figure 3.17: Slip-On Sprocket engaged to 36T sprocket for testing the fitness

3.5 Printing Laminated 3D Model

This method is easier and faster than the Thermojet 3D printing. It is basically using the layering techniques and glued it to make it as 3D object. This section will show the step taken to produce the laminated 3D printing model. This printer can read CATIA format so the drawing no need to be converted to any other format. Only the sprocket breaks need to be configured to avoid over clearance.

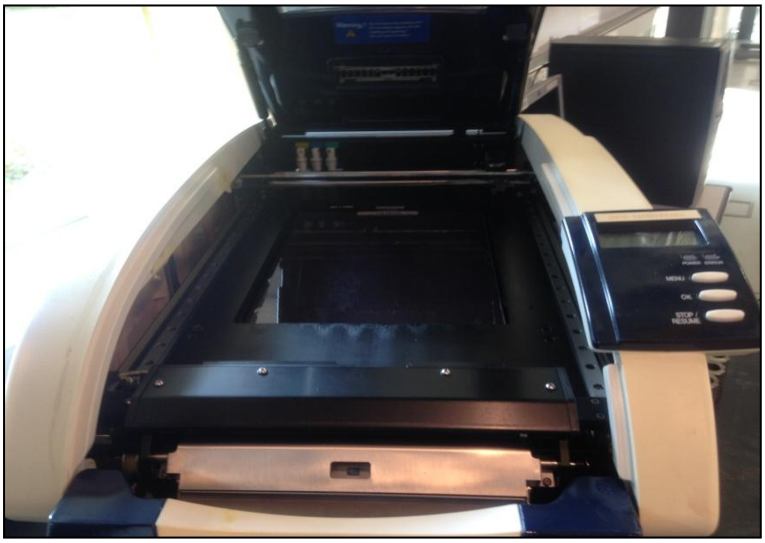

Figure 3.18: Printing process by SD300 Pro Printer

Figure 3.19: Slip-On Sprocket pieces after peeled.

The printed product will be in one block of laminated sheets. So, it has to be taken out by peeling one by one of the sheet until the excess sheet is finished. The process took a long time and it has to be done carefully to avoid defect at the product.

3.6 Silicon Rubber Moulding

Silicon rubber moulding is a quick and easy manufacturing process to produce a mass product. In this project, the author needs to produce another prototype by using this method of manufacturing. Below are the step and process of making silicon rubber mould.

Process of making silicon rubber mould:

1) Calculate the volume of the plastic container in which the model pattern is fixed.
2) Mixing of silicone and hardener after pouring process by applying the ratio of silicone hardener 10:1.
3) Degass the resin in the vacuum chamber
4) Prepare following items for mould preparation,
   - Plastic model, plastic container, Hot glue gun, Metal wire
5) Mould preparation
   - The plastic model is held such way to the plastic container for pouring process.
6) Degass the resin in the vacuum chamber again.
7) Finally do the curing process. Curing process is to let the resin at ambient temperature until hardened.

Figure 3.20: Degassing process

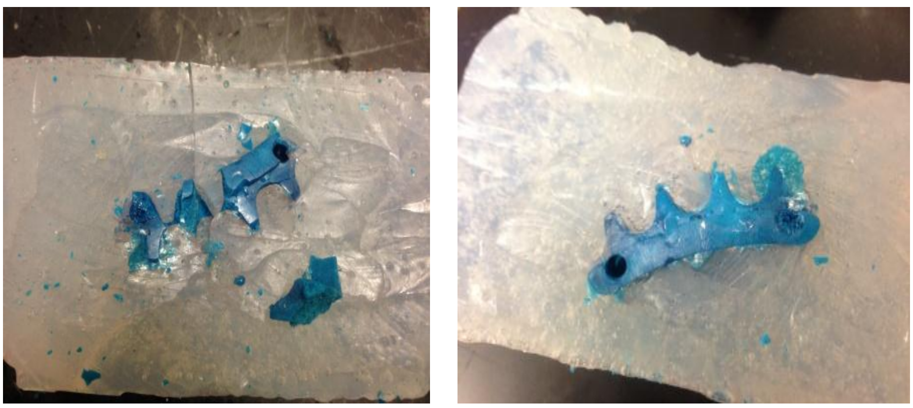

Figure 3.21: Product of Silicon rubber moulding

4.0 Result and Discussion

This section will be discussing the result of the project output which contains three parts. The first part is discussion on the combination of sprocket size based on the drawing produced. Secondly, the author will discussed about the comparison between Thermojet 3D Printing and Laminated 3D Printing. Lastly, discussion will be on the process of fabricating Slip-On Sprocket by using silicon rubber mould.

4.1 Result of Sprocket Size Combination

4.1.1 Result of combining 36T and 40T sprockets

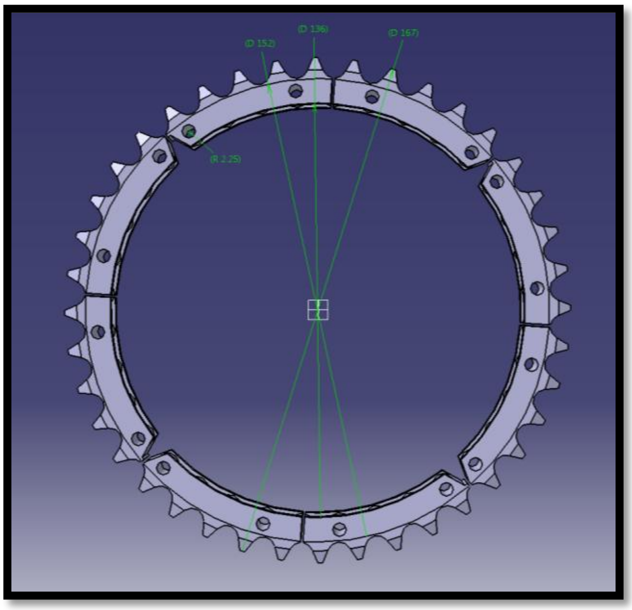

Figure 4.1: Successful combination of 36T and 40T sprockets

As the result, the combination between 36T and 40T sprockets will produce the sprocket ring as shown above. The diameter for 36T is 150mm while 40T sprocket is 167mm, so the difference of 17mm or 4T is sufficient to produce a sprocket ring without any hole or gap. As a conclusion, this combination is suitable to become a Slip-On Sprocket. In the other hand, previous research by A.R Tanesh shown that this combination will increase the torque of the motorcycle from 37.3 N.m up to 50.98 N.m while 40T sprocket will have the torque up to 53.1 N.m. The amount of torque in the ring chain sprocket is lesser is because of the amount of friction between the Slip-On sprocket and the 36T sprocket when the motorcycle tyre is rotating.

4.1.2 Result of combining 37T and 40T sprockets

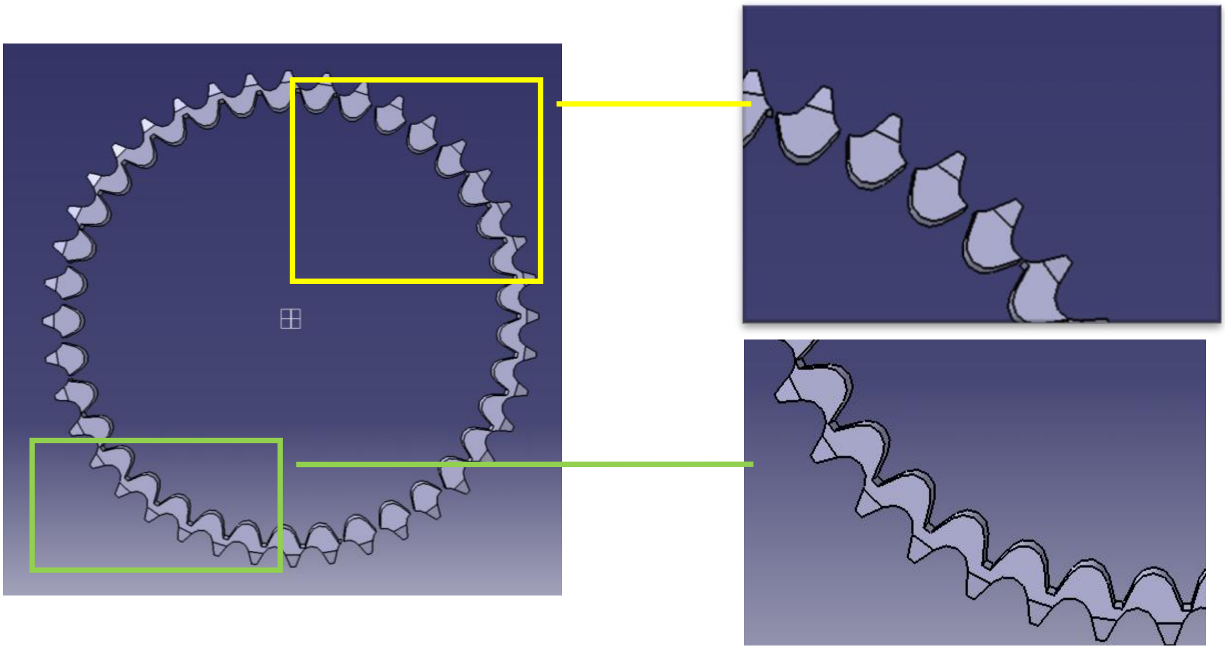

Figure 4.2: Unsuccessful combination of 37T and 40T sprockets
(Green zoom: Good area, Yellow zoom: Bad area)

As shown in the figure above, the combination between 37T and 40T sprocket will cause a hole or gap on the sprocket ring. The hole or gap will appear when the inner teeth are located between the gaps of outer teeth. If the inner teeth are located just behind the outer teeth the problem will disappear. However, the hole or gap is still unavoidable even when the inner sprocket is rotated for many times. It is because the difference of teeth number and diameter of the sprocket itself. The diameter of 37T sprocket is 154mm and the diameter of 40T sprocket is 167mm. So, the difference between both diameter sizes is not suitable to produce Slip-On Sprocket.

4.1.3 Result of combining 38T and 40T sprockets

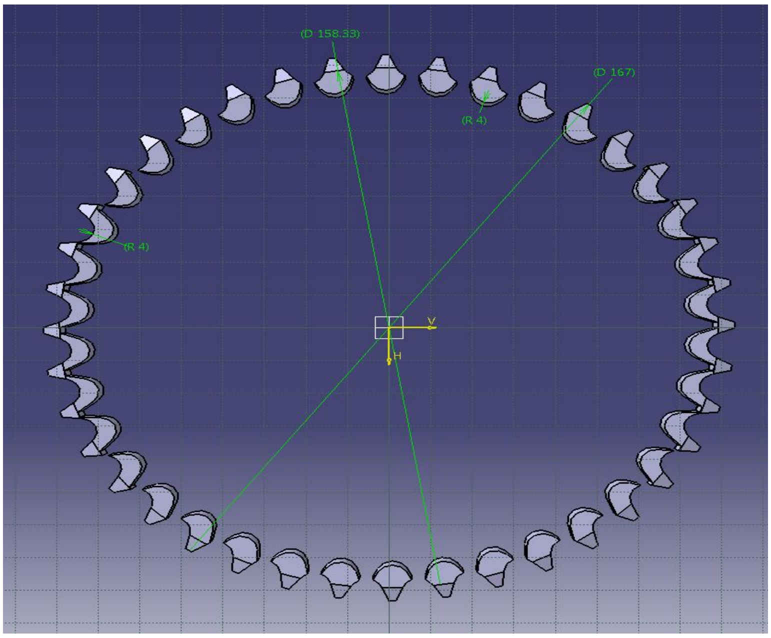

Figure 4.3: Unsuccessful combination of 38T and 40T sprockets

As shown in the figure above, it is clearly shown that the sprocket combination between 38T and 40T will produce a lot of gaps and holes on the sprocket ring. The hole or gap is unavoidable because the difference in diameters is very small which 158mm for 38T sprocket and 167mm for 40T sprocket.

4.1.4 Result of combining 38T and 42T sprockets

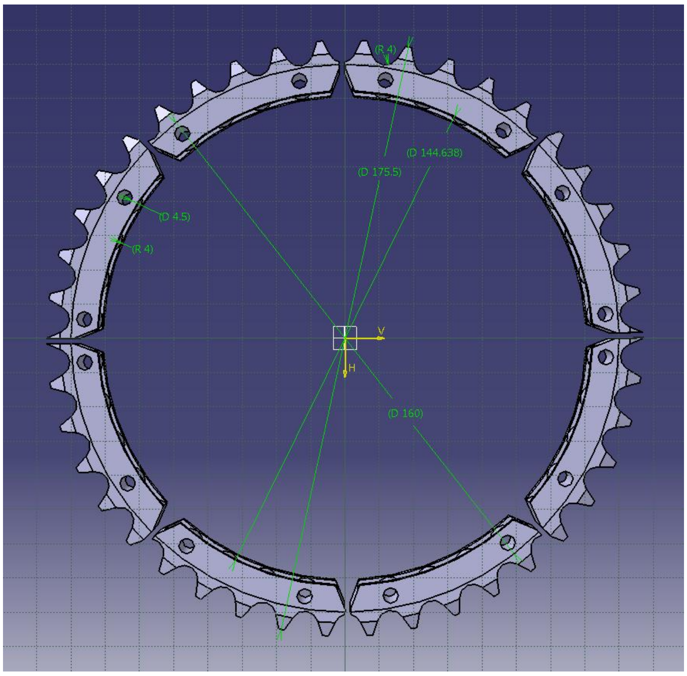

Figure 4.4: Successful combination of 38T and 42T sprockets

This combination is basically the same as combination between 36T and 40T sprocket which the teeth different is ‘4’. However, the diameter size is different which 38T has a diameter of 158 mm and 42T has a diameter of 175mm. It can be proven here that the minimum difference between the teeth combination is ‘4’ and the minimum diameter difference required is 16mm to 17mm. The difference of the teeth cannot be larger than ‘4’ because the chain itself is not long enough to cover the sprocket. The chain can be pushed to fit with the sprocket but it will be very tight and the possibility of break is high during ride. The table below show the summary of this section result.

Teeth combination	Inner Diameter	Outer Diameter	Diameter Difference/Teeth	Status
36T and 40T	150mm	167mm	17mm/4T	Success
37T and 40T	154mm	167mm	13mm/3T	Failed
38T and 40T	158mm	167mm	9mm/2T	Failed
36T and 42T	150mm	176mm	16mm/4T	Success

Table 4.1: Teeth Combination and Diameter Differences

It can be concluded that the difference of 4 teeth is the optimal for producing Slip-On Sprocket. The table shown below are some of the common motorcycle used in Malaysia. The table below show the original rear sprocket and the recommended Slip-On Sprocket size to be used.

Motorcycle	Engine Capacity (Cubic centimetres)	Rear Sprocket Size	Recommended Size
Honda EX-5	100	36T	36T-40T
Honda Dash	110	36T	36T-40T
Modenas Kriss 110	110	38T	38T-42T
Modenas Kriss 120	120	41T	41T-45T
Yamaha Lagenda	115	40T	40T-44T
Yamaha LC 135	135	38T	38T-42T
Yamaha FZ 150	150	42T	42T-46T
Suzuki Shogun	125	34T	34T-38T

Table 4.2: Common motorcycle at Malaysia and recommended Slip-On Sprocket Size

4.2 The result of silicon rubber moulding method

The fabrication process by using silicon rubber moulding is done in the lab with the supervision of lab technician and all the step was inspected carefully with referring to the manual provided. During the fabrication process, all steps need to be done carefully to prevent any defects. The total time required to conduct this process is shown in the timeline below.

Step	**Process**	**Time Taken (mins)**
1	Prepare the exact volume of the model and silicon rubber.	10
2	Mixing silicon and hardener	10
3	Degassing the silicon rubber *depends on the volume and efficiency of vacuum chamber	15-30
4	Preparing items for mould preparation and	20
5	Pouring process	5
6	Degassing the mould with the product inside	10-30
7	Curing process to let the mould dry	180
8	Preparation of isocyanate and polyol	10
9	Degassing the isocyanate and polyol	10
10	Pouring the product into silicon rubber mould	10
11	Curing process under 70°C	60
12	Drying process	>60
	Total time taken	**400 minutes**

Table 4.3: Time taken for silicon rubber mould process

So, the approximate total time taken to complete all the silicon rubber moulding process is 400 minutes or 6 hours and 40 minutes. It is consider reliable because the mould can be prepared for a few sets of Slip-On Sprocket and the time taken should be almost the same. For mass fabrication, the total time taken also can be reduced if more manpower is added. The silicon mould also need to be prepare for more set as it can save a lot of time but the more model for the mould need to be produced.

The product of silicon rubber moulding

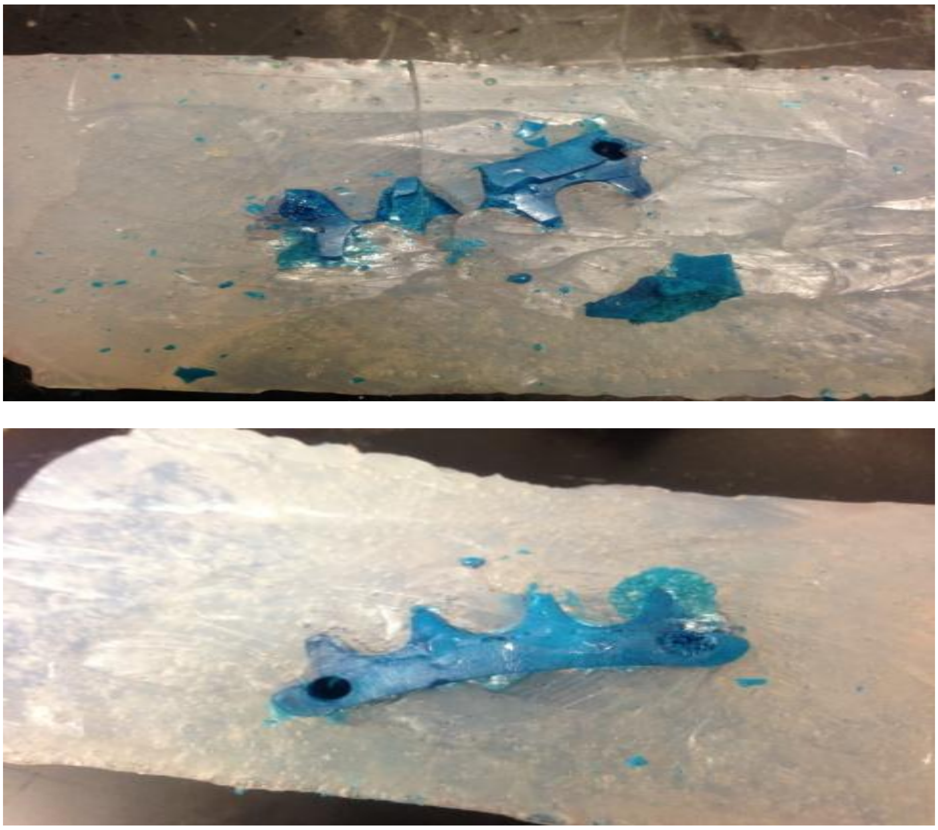

Figure 4.5: Silicon rubber moulding product (isocyanate and polyol mixture)

As shown in the figure above, it is the product of isocyanate and polyol by silicon rubber moulding. It has a total defect and it cannot be used as a prototype for a few reasons. The main reasons of this defect are the materials to carry out this processes is expired. This product is not strong and very fragile due to this problem. However, this process is still reliable and student managed to get the shape of the product. The bubbles are formed during mixing in the silicon rubber mould. The bubbles are trapped because the viscosity of the silicon became higher when it is expired. The degassing process should be able to lift up the bubbles and makes the silicon mould to become clear.

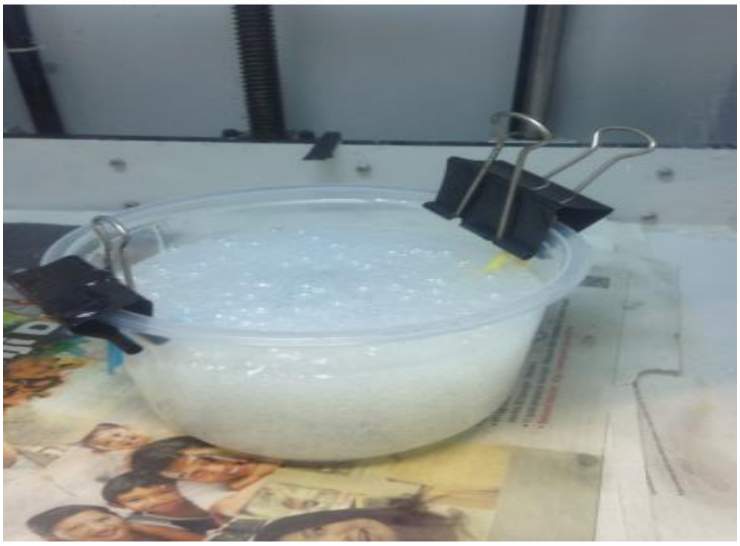

Figure 4.6: Silicon rubber mould with bubbles trapped inside

Figure 4.7: Surface defect on tested model

The problem with the bubbles in the mould is it will be hard to cut the mould into pieces and take out the model inside the mould. The silicon mould should be cut properly to easier the process of taking out the product and prevent any leak inside the silicon mould. Other than that, the bubble formation also caused the surface defect on the product. The smooth surface cannot be produced because it was affected by the formation of bubbles.

Vacuum Machine Problem

Figure 4.8: Vacuum Machine for degassing process

This pump powered machine is used in this process for degassing purpose. The bubbles will be sucked from the liquid silicone rubber mould and goes up to the surface. With a strong pump and no leakage, this machine supposedly can degas all the bubbles. This machine cannot perform perfectly because the rubber seal at the door is become harder and broken. The chamber cannot perform vacuum condition because of this leak. This causes the air from outside to be sucked in the vacuum chamber and the pressure did not drop to zero. To minimize the error, the student and technician have put a rubber tape to block the air from entering the vacuum chamber. The seal need to be replaced to perform a vacuum condition and degassing all the bubbles.

4.3 The product of Laminated 3D Printing

Figure 4.9: Beta II after printing.

Figure 4.10**:** Beta II with clips

Figure 4.11**:** Beta II attached to 36T sprocket on the hub

5.0 Conclusion

Through the learning process, the student is able to learn the basic of Catia software to make the drawing, hence implement the knowledge to check the suitable combination of sprocket size in order to produce variety of Slip-On Sprocket. Next, student is able study on the three dimension printing process, methodology, product and discussion about what and how it can be done. After that, the student also able to learned and create his own silicon rubber moulding product, prior to project objective. All the processes were done by the student and an instruction by the technician.

As for the conclusion, the materials should be replaced in order to make a good mould and polyutherane products. However, application of rapid prototyping and silicon rubber moulding in the fabrication of Slip-On Sprocket is much faster, cheaper and effective compare to the CNC method. It is shown that silicone rubber moulding is reliable to be used as a method of manufacturing Beta Prototype II for the Slip-On Sprocket but the materials has to be renewed. This project will be continued to the next semester with a new material and graphene technology will be used.

Future Work

1. The study on how to prevent the break at the tip of the sprocket teeth.
2. The application of graphene in producing Slip-On Sprocket.
3. The study on how to improve the efficiency of silicon rubber moulding process.
4. The research on the strength of the sprocket material before it is failed.

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