Design Improvement of Existing Slip-on Sprocket

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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(Mechanical)

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CERTIFICATION OF APPROVAL

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Approved by,

……………………………………...
(AP Dr Ahmad Majdi Abdul Rani)

UNIVERSITI TEKNOLOGI PETRONAS

SERI ISKANDAR, PERAK

January 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

……………………………………..
(ARIFF HAKIMY MOHD KARIM)

ABSTRACT

The sprocket is a very vital component in the transmission of power and motion in most motorcycle; there is always a pair (rear and front) in a motorcycle. The front sprocket drives the rear sprocket via chain connection. They exist in various dimensions, teeth number and are made of different materials. This project studies involve the fundamentals of slip-on sprocket design and manufacturing of the product to be slipped onto the most types of the motorcycle rear sprocket which require a novel torque booster through reverse engineering approach. It discusses analysis, dimensioning, drafting and drawing, prototype printing, chemical composition, material selection, choice of manufacturing process, heat treatment, and surface finish as the nine steps that need to be followed sequentially in this reverse engineering approach. In this work, design fro manufacturing (DFM) analysis had proven that 1 mold designation will produce a 10 outer teeth and 9 inner teeth slot per section. The dimensions information had been extracted by using Coordinate Measuring Machine for greater accuracy. This slip-on sprocket product also proven can be assembled into most types of motorcycle sprocket make from the production of the three dimensional (3D) prototype made of ceramic powder. The mold and die preparation methods are used to produce the slip-on sprocket from the blanked medium with the major chemical composition of Fe=86.3%, Al=8.22%, P=2.79%, and Ca=1.15% which analyzed by the X-ray Fluorescence Machine.

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CHAPTER 1

INTRODUCTION

1.1 Background

Sprocket is a mechanism which has a numbers of teeth around its cylindrical shape allowing a chain interlock together with the sprocket and rotating to produce a power transmission. Sprocket can be found in any of the vehicles which include motorcycles, bicycles, and cars. Sprocket usually meant to work in pair or more where in motorcycle, a small shaft drives a chain, which in turn, drives a larger sprocket on the axle of the rear wheel to generate power as shown in Fig. 1.

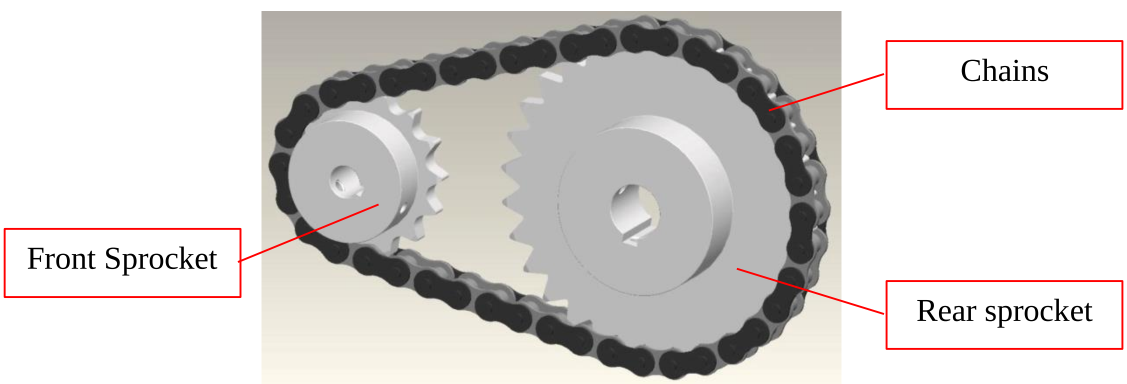


Figure 1. A simple sprocket – chain mechanism

People in rural area generally have lower levels of education and literacy and are not encouraged to pursue schooling, but they have an economic source which is agriculture. Agriculture is the main business in remote areas to support their life. However, their transportation is the limitation and becoming a main problem for them. Motorcycle is the most transportation commonly found in the urban areas. In addition, these people have another problem during harvesting season where their motorcycles are meant to have a normal ride. These motorcycles will carry a maximum load during harvesting season, thus inquiring a higher torque. As a result, they need to change the sprocket to a larger size in diameter in order to increase the gear ratio, thus increasing the torque and acceleration of the motorcycles.

There are a lot of researches and inventions going on since late 1970 until today regarding the sprocket design and it is continuously studied in order to improve the performances and the characteristics of the sprocket. Recently, a newly design slip-on sprocket has been invented and the project is currently in progress to find the correct tuning and the best mechanism. The slip-on sprocket is designed to help the people in remote area to support and ease their life during harvesting season. Sprocket size plays an important role in motorcycle drives in order to increase the torque, thus increasing the acceleration of the motorcycles. The Alpha (α) prototype has been completed and still on the verge of finding the best design to produce the Beta (β) prototype for this slip-on sprocket project. This invention project is meant to help people in rural areas to change the sprocket size quickly, easily and also inexpensive means.

1.2 Problem Statement

The slip-on sprocket project is an ongoing project which already passed the Alpha (α) phase and currently it is in the Beta (β) phase. The design and analysis of the newly mechanism slip-on sprocket has to be discovered and studied in order to produce the best product for customers. There are a few problems that happened during the previous phase and expected to be encountered which include:

- The interlocking between the chains and the slip-on sprocket is not perfect with some gaps where the curvilinear driving surfaces of the chains are not conjugate to the sprocket teeth.
- Current sprocket design is limited to a specific motorcycle make (Honda EX5).
- Previous design will requires multiple molds for production.

1.3 Objectives

This design and analysis of the slip-on sprocket is a project which mainly focuses on the β – prototype to improve the product and choosing the best combination for the mechanical design. Basically, this additional sprocket will be attached to the existing sprocket to increase the diameter and number of teeth of the sprocket. The project is still in the phase of finding the best design in terms of number of teeth for each mold. Therefore, this project which will be conducted to continue on the β – prototype should be able:

- To perform calculation and analysis for the β – prototype design improvement by using Reverse Engineering method

This project requires some calculations in order to prove the design is relevant and can be taken into consideration. There are several measurements apply in this mechanical design which include addendum circle, dedendum circle, pitch circle and also clearance circle. This action has to be measured by using a reverse engineering approach where existing sprocket sell in the market will be used as a datum to collect the data and information in order to select a proper design and suitable criteria for the slip-on sprocket, β – prototype.

- To examine β – prototype to suits all motorcycle make instead for Honda EX5 motorcycle only

The α – prototype for the slip-on sprocket was build according to the type of Honda EX5 motorcycle. This means that the survey and study should be perform deeper in order to find the best design for the sprocket that can fit most of the motorcycles being used in rural areas. This is to ensure the product will hit the market successfully once the real product has been published.

- To prepare the mold and die designation of β – prototype, testing and analyzing it after the production process is completed

The project is meant to be completed until the ramp-up phase which needed an original final product. The mold and die for the β – prototype sprocket will be designed and submit to the vendor to produce it. This process will be done during the pre-commissioning phase where the real design with correct dimensions needs to be produced for the final product during the ramp-up phase. The final product will be tested again manually on the motorcycle in order to prove the behavior of the β – prototype where it has to be perfect and safe for real life applications.

1.4 Scope of Study

The scope of study for the project is the slip-on sprocket design is only meant for motorcycle's sprocket which means it is not suitable to be used for other types of sprocket including bicycle sprocket and other types of machine sprocket. Furthermore, it is only involving the rear part of the motorcycle's sprocket where in this case, the slip-on sprocket is not suitable to be installed in the front sprocket of motorcycle. Moreover, this project is mainly focusing on 36-40 teeth of sprocket. This means that the slip on sprocket will be installed onto the existing 36 teeth rear sprocket and the chains will be interlocked with the 40 teeth slip-on sprocket above the existing sprocket.

The mold and die of the slip-on sprocket will be designed following our requirement which then will be submitted to vendor to produce the real slip-on sprocket. The detail manufacturing processes also will be explained further in this project which also include the heat treatment, surface finishing and also testing required for the final product of slip-on sprocket.

CHAPTER 2

LITERATURE REVIEW

2.1 Invention of Belt Sprocket

Miller (1973) stated that there are two circular intersecting arcs and round cross sections for the belt teeth and the sprocket which determined the driving surfaces of the teeth. The entire belt teeth receive a driving load from the sprocket to affect a stress distribution where the sprocket is matched to a one-half order isochromatic fringe of elastomeric belt teeth. The belt tensile member has to be perpendicular to the resultant driving load vector applied to the belt teeth which is at substantially large angle. Therefore, the curvilinear surfaces of positive drive belt teeth must be conjugate to this pattern.

However, Redmond et al. (1979) mentioned that there is a problem where in between the sprocket and belt teeth, there is a possibility that the foreign material may lodge. Poor fit may cause due to the effect of changing the sprocket pitch which resulting an erosion of the elastomeric belt teeth. Both belt teeth and sprocket teeth may be eroded and cause drive system failure if the foreign materials are abrasive in nature. Furthermore, over tensioning the belt could effect in increasing sprocket diameter or it could cause sufficient tension in the belt to overload sprocket shaft bearings to the point of their failure. The above discussed problems may induce to the motorcycle drive which is one of the examples of positive drive system where either abrasive or non-abrasive foreign material may stuck in between the sprocket and belt teeth.

Nevertheless, the design is still useful and has many advantages. The belt teeth is recommended to have a round shape and preferably large to gain high sprocket loading in high torque drives as shown in Fig. 2. The round shape also has enough depth showing anti-ratcheting qualities at higher tension ratios such as may be encountered in a fixed two-point drive which may become loosened through belt tension decay. In conclusion, this system and design is to provide a sprocket and a drive system adaptable for use in foreign material environments (Redmond et. al., 1979).

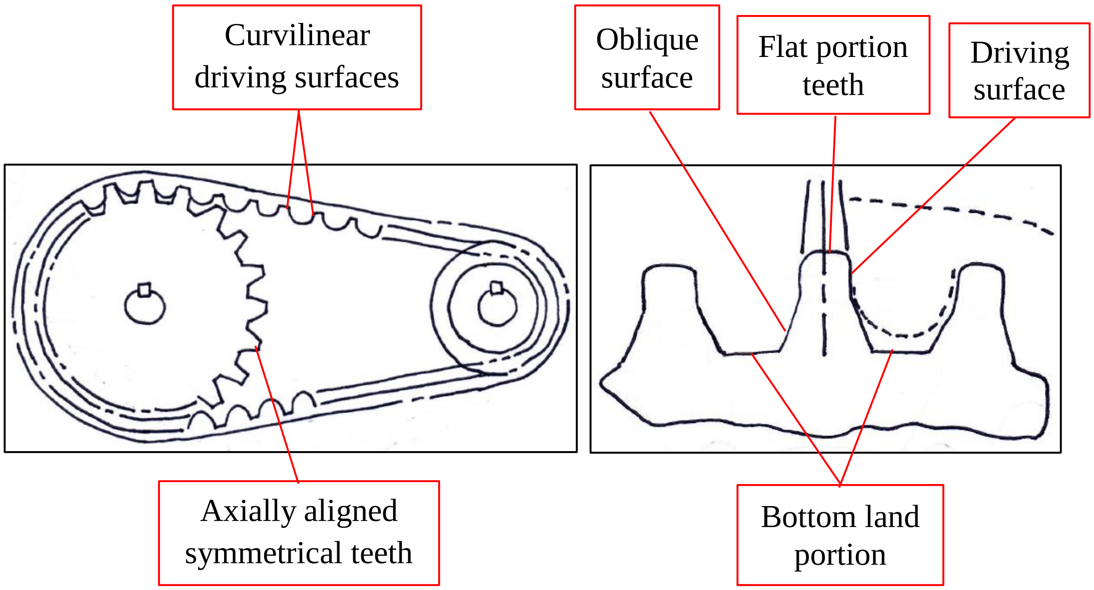


Figure 2. Belt Sprocket mechanism

Besides that, Redmond et al. (1979) discussed that there are other several advantages of the invention where the clearances provided around the belt teeth during the meshing with the sprocket will reduce an audible noise. The removal of the foreign material which includes oil, dirt, water and sand will also happen during the clearance of the sprocket and belt teeth. Furthermore, the bending moments imparted by torque drives is handled by the sprocket teeth which has a larger base and this allow the sprocket to be economically produced from low cost materials using low cost manufacturing techniques such as die casting. Finally, the main advantage of the sprocket design is the drive system has suitable life making it highly attractive for hard drive application including the replacement of chains in motorcycle drives. Another advantage of the invention is that the sprocket is suitable for use with other than round toothed belts (Worley et al., 1976).

On the other hand, a sprocket having circumferentially spaced teeth that are axially aligned and the sprocket for use with positive drive belts of the type having teeth with oppositely facing curvilinear driving surfaces that convergingly extend from the roots of each belt tooth at opposite same angles of at most 15 degrees from a plane transversely normal to the longitudinal axis of the belt (Miller, 1973).

The previous design by Miller has been improved by having a symmetrical sprocket tooth with each tooth having an axis, a tooth top land and an axial cross-section profile formed by oppositely facing driving surface portions for contacting portions of the belt teeth near the belt teeth roots. Furthermore, the improvement added are the driving surfaces of a sprocket tooth extending from the top land at an angle of at most 15 degrees to the sprocket tooth axis and each driving surface of the sprocket tooth blending into an oppositely facing oblique surface at an angle of about 150 to about 170 degrees that provides a positive clearance between the sprocket tooth and side portions of a meshing belt tooth to direct egress of material away from the sprocket. In addition, there is another improvement which is the oblique surfaces define a sprocket tooth base that is wider than the sprocket tooth top land and bottom land portions between sprocket teeth providing positive clearance between the bottom land portions and belt tooth tips (Redmond et al., 1979).

Moreover, the driving surfaces of the sprocket teeth are planar, substantially concave, extend at an angle of at most 10 degrees to the sprocket teeth axis, and having an area of both sprocket teeth and the oblique surfaces of a sprocket tooth about 30 to 60 percent of the sum of the driving surface and oblique surface area. The oblique surfaces of the sprocket teeth are substantially planar and the bottom lands between sprocket teeth are also planar while the sprocket teeth have a top land with a generally flat portion. A positive drive system comprising at least two sprockets, each having the characteristics as claimed before, and a toothed positive drive belt entrained by the sprockets and having oppositely facing curvilinear tooth driving surfaces that extend at opposite equal angles of at most 15 degrees to a plane oriented transversely and normal to a longitudinal axis of the belt (Redmond et al., 1979).

2.2 Improvement of the Sprocket and Chains Design

The studies and researches from past engineers and writers have been conducted to improve the design of the power transmission system which includes the sprocket and the chains. The improvement of any design is highly recommended to produce the best design and mechanism as technology developed from time to time while gaining the knowledge and experience about particular aspect as for this case is the chains and the sprocket design. The problems for chains and sprocket design include noise, vibration from the system and also the power transmission under slower speed due to its polygonal action and meshing impact

The study of the power transmitting chains has been conducted and this would bring the periodic fluctuation by several factors which include polygonal action and eccentricity of sprockets by treating the chain as a travelling uniform heavy string (Ariartnam & Asokanthan, 1987). Furthermore, Choi and Johnson (1993) studied axially moving material model with consideration of the effects of the periodic span length changes, impact and polygonal action have brought them to a dynamic model for the analysis of the performance of roller chain drive with a tensioner. The considerations between longitudinal and transversal vibrations encounter a discrete model of chain by lumped masses connected by linear springs (Veikos and Freudenstein, 1992).

On the other hand, the mechanics equations of the drives used in mechanical power transmission system have helped Low (1995) to use computer-aided analysis to select the roller chain drives in the system. In addition to that, the analyzation process for the acceleration response of the sleeve roller chain together with the finite element method resulting in an establishment of dynamic equation of sleeve roller chain (Yang et. al., 2005). The mechanical efficiency of roller drives and the vector loop approach for analyzing the kinetostatics plays an important role for the designation of kinematic model (Sheu et. al., 2004)

In power transmission system, vibration and noise are among the biggest challenges which engineers should involve in order to reduce it, thus making the system smooth and efficient. The study of meshing dynamics of the system, shape of chain link, the tooth profile and the elasticity of the material is highly recommended in order to reduce the noise and vibrations in the power transmission system (Rong, 2004). The involute tooth profile of the sprocket has been studied in order to find the relationship with the impact velocity between chains and the sprockets (Xue & Wang, 2006). Moreover, Zhang et. al. (1999) discussed that the conjugate meshing between the sprockets and chains can be related approximately by using roller pin. Moreover, the sprocket tooth profile for roller chain drives has been modified in order to reduce polygonal action and meshing impact under high speed (Wang, Y., et al., 2013).

A new tooth profile for the sprocket has been discovered where polygonal action made the sprocket pitch circle tangent or secant line to the center line of the roller chain and the chain velocity and instantaneous angular velocity of the driven sprocket affected by the periodical variation of the chain center line. The pitch of the chain is the same with the arc length of the pitch circle in one pitch angle. In other words, the arc length of the pitch circle to be turned is similar to the moving distance of the chain at any moment. In this case, an offset *k* has been moved transversally away from the pitch circle of the sprocket and then attains a roller pitch line in order for the line to contact with pitch circle tangentially which is the contacting pitch line as shown in Fig. 3. A new sprocket tooth profile is one equidistant curve of the trajectory curve of a roller center by assuming the contacting pitch line rolls around the pitch circle of the sprocket without sliding or by other means, the sprocket is fixed (Wang, Y., et al., 2013).

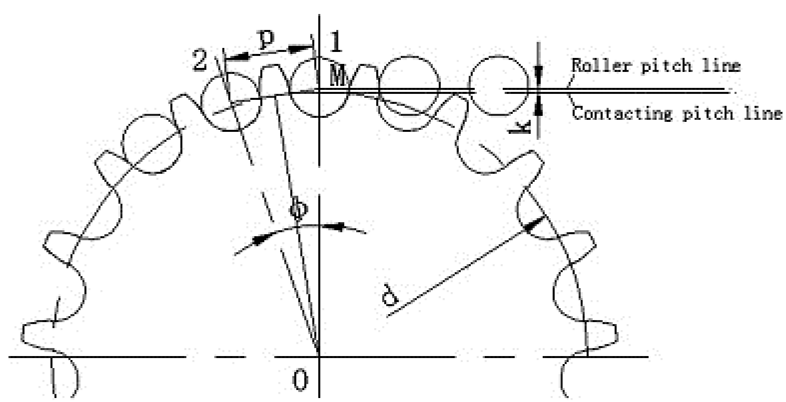


Figure 3. Inventions of belt sprocket mechanism

This modification from in the traditional involute tooth profile has reduced the dynamic effect and meshing impact of chain drive where the arc length of the pitch circle to be turned is equal to the moving distance of the chain at any moment and the roller center line of the tight side is always tangent to the pitch circle of the sprocket. This new tooth profile ensures the reduction of impact force between rollers and sprocket which allow the rollers to mesh with the sprocket gradually (Wang, Y., et al., 2013).

2.3 Cracks Identification

Cracks in the sprocket may happen due to the occurrence of large forces between the loop wheel machine and the sprocket wheels and also due to the repetitive loop of the wheel machine involving accelerated motion. The occurrence of the crack on the sprocket tip while this motion is extended with the elapse of time would finally bring to the failures of the sprocket and the breakdown of power transmission system.

The methods to detect the cracks on the sprocket have been studied over the past few years by many engineers and scientists. The location of the cracks and size in a simply supported beam has been identified using algorithm method in which the non-destructive and size estimation of open cracks in beam detected by robust damage assessment (Faverjon & Sinou, 2009). Furthermore, Moore et al. (2011) mentioned a system called Bayesian used to identify the crack location, size and orientation in a structure using strain measurements where the detection of a presence crack in a simple plate undergoing free vibration will be conducted. The location and depth of the crack in rotor system could be identified by using new method based on wavelet finite element model and high-precision modal parameter where the quality of this method has been proved by experiment results (Dong et al., 2009).

Zhao, B. (2012) mentioned the wavelet finite element can compute the frequency of the cracked sprocket where the crack tip of the sprocket wheel is meshed with the isoparametric element of crack tip and the detection of it depending on the number of the isoparametric plate element around the crack tip and the length of the crack which has been determined as both of them are directly proportional in relations. The elements involve for determining the crack identification are shown in Fig. 4.

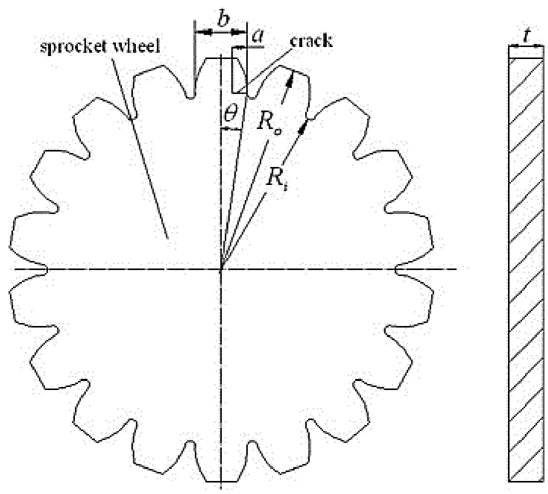


Figure 4. Cracks identification elements

where,

- *b* = dedendum width
- *a* = length of the crack
- *θ* = crack tip azimuth
- R_o = addendum circle radius
- R_i = dedendum circle radius
- *t* = thickness of the sprocket

2.4 Idea of Changing Sprocket

Nichols (2003) stated that a hybrid sprocket is useful in order to replace the high performance motorcycle which can wear out quickly if they are the light weight types of aluminium sprocket. Replacing the entire sprocket can be expensive. Nevertheless, steel sprockets wear out less rapidly but are too heavy for high performance motorcycle.

Furthermore, the gearing ratio will be affected by changing the size and number of teeth on the sprockets as shown in the table 1 below. This would lead to the advantages for varying the performance of the motorcycles for different types of uses. For cross country use, a smaller sprocket produces higher speeds. For closed-course competition use, a larger sprocket produces a higher torque, thus giving a quick acceleration. Easy and inexpensive changeability of the size and number of teeth on a sprocket would be desirable (Nichols, 2003).

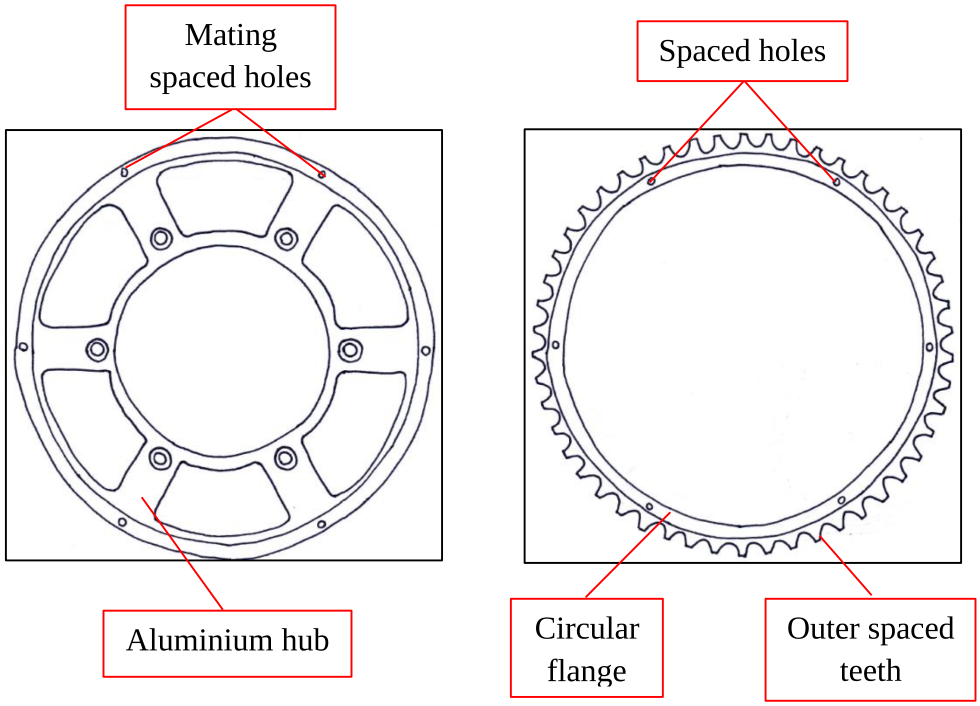


Figure 5. A sprocket with an aluminium hub and steel toothed ring

In rural areas, especially during harvesting season, many farmers will change their motorcycle's sprocket in order to carry high load as shown in Fig. 6 and will refer to the gear ratio needed as shown in Table 1. Large diameter of sprocket and high number of teeth required for the motorcycle to produce higher torque. Higher torque resulting in a quick acceleration, thus making the motorcycles to move faster even carrying a large amount of load.

Figure 6. Amount of load carried by farmer using motorcycle

Table 1. Gear ratios for sprocket

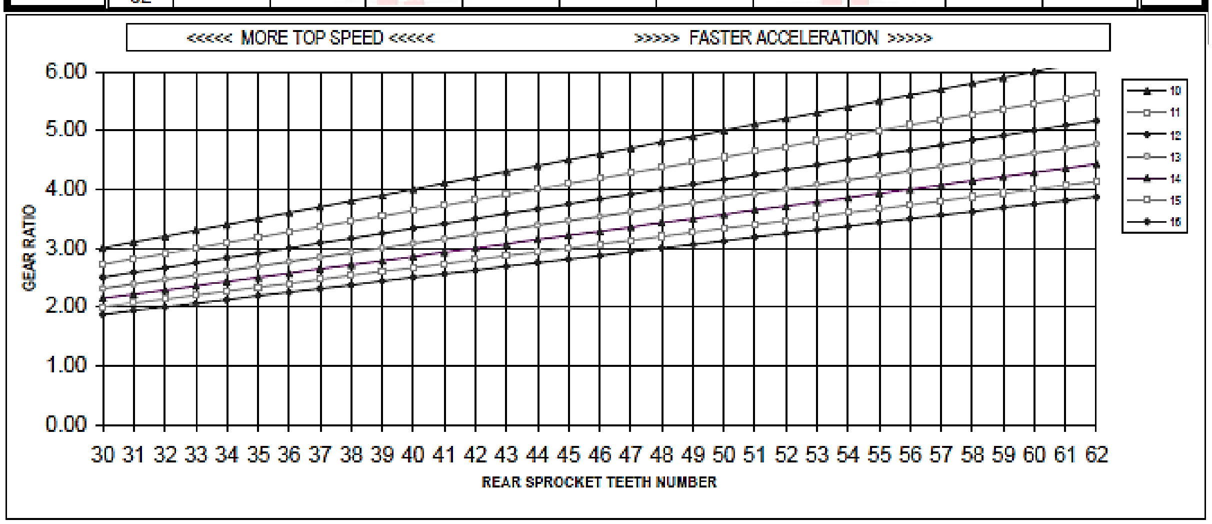
GEAR RATIOS FOR SPROCKETS

FRONT SPROCKET TEETH

<<< FASTER ACCELERATION <<<<<< >>>>>>MORE TOP END SPEED >>>

REAR SPROCKET TEETH — <<< FASTER ACCELERATION <<<<<< >>>>>>MORE TOP END SPEED >>>

	10	11	12	13	14	15	16	17	18	19
30	3.00	2.73	2.50	2.31	2.14	2.00	1.88	1.76	1.67	1.58
31	3.10	2.82	2.58	2.38	2.21	2.07	1.94	1.82	1.72	1.63
32	3.20	2.91	2.67	2.46	2.29	2.13	2.00	1.88	1.78	1.68
33	3.30	3.00	2.75	2.54	2.36	2.20	2.06	1.94	1.83	1.74
34	3.40	3.09	2.83	2.62	2.43	2.27	2.13	2.00	1.89	1.79
35	3.50	3.18	2.92	2.69	2.50	2.33	2.19	2.06	1.94	1.84
36	3.60	3.27	3.00	2.77	2.57	2.40	2.25	2.12	2.00	1.89
37	3.70	3.36	3.08	2.85	2.64	2.47	2.31	2.18	2.06	1.95
38	3.80	3.45	3.17	2.92	2.71	2.53	2.38	2.24	2.11	2.00
39	3.90	3.55	3.25	3.00	2.79	2.60	2.44	2.29	2.17	2.05
40	4.00	3.64	3.33	3.08	2.86	2.67	2.50	2.35	2.22	2.11
41	4.10	3.73	3.42	3.15	2.93	2.73	2.56	2.41	2.28	2.16
42	4.20	3.82	3.50	3.23	3.00	2.80	2.63	2.47	2.33	2.21
43	4.30	3.91	3.58	3.31	3.07	2.87	2.69	2.53	2.39	2.26
44	4.40	4.00	3.67	3.38	3.14	2.93	2.75	2.59	2.44	2.32
45	4.50	4.09	3.75	3.46	3.21	3.00	2.81	2.65	2.50	2.37
46	4.60	4.18	3.83	3.54	3.29	3.07	2.88	2.71	2.56	2.42
47	4.70	4.27	3.92	3.62	3.36	3.13	2.94	2.76	2.61	2.47
48	4.80	4.36	4.00	3.69	3.43	3.20	3.00	2.82	2.67	2.53
49	4.90	4.45	4.08	3.77	3.50	3.27	3.06	2.88	2.72	2.58
50	5.00	4.55	4.17	3.85	3.57	3.33	3.13	2.94	2.78	2.63
51	5.10	4.64	4.25	3.92	3.64	3.40	3.19	3.00	2.83	2.68
52	5.20	4.73	4.33	4.00	3.71	3.47	3.25	3.06	2.89	2.74
53	5.30	4.82	4.42	4.08	3.79	3.53	3.31	3.12	2.94	2.79
54	5.40	4.91	4.50	4.15	3.86	3.60	3.38	3.18	3.00	2.84
55	5.50	5.00	4.58	4.23	3.93	3.67	3.44	3.24	3.06	2.89
56	5.60	5.09	4.67	4.31	4.00	3.73	3.50	3.29	3.11	2.95
57	5.70	5.18	4.75	4.38	4.07	3.80	3.56	3.35	3.17	3.00
58	5.80	5.27	4.83	4.46	4.14	3.87	3.63	3.41	3.22	3.05
59	5.90	5.36	4.92	4.54	4.21	3.93	3.69	3.47	3.28	3.11
60	6.00	5.45	5.00	4.62	4.29	4.00	3.75	3.53	3.33	3.16
61	6.10	5.55	5.08	4.69	4.36	4.07	3.81	3.59	3.39	3.21
62	6.20	5.64	5.17	4.77	4.43	4.13	3.88	3.65	3.44	3.26



Gear ratio (GR) means the ratio of the number of teeth on the output gear ($N_{o)}$ or sometimes called driven gear to the number of teeth on the input gear ($N_{i)}$ or drive gear as shown in equation (1). This ratio can be in any means which include the radius of the driven gear (ro) to the radius of the drive gear (ri) and also the circumference of the driven gear (Co) to the circumference of the drive gear (Ci). On the other hand, Morris and Langari (2012) stated that torque is a measure of force acting on an object which caused the object to rotate. Torque (τ) is derived as a product of force (F) and a distance from the acting force to the center of rotation, radius (d) as shown in equation (2). For a driven sprocket, the amount of torque will increase as the radius of the sprocket increase. Increase the radius of the sprocket subsequently increasing the number of teeth will result in a higher amount of torque

$$GR = \frac{No}{Ni} = \frac{ro}{ri} = \frac{Co}{Ci} \tag{1}$$

$$\tau = F x d \tag{2}$$

Furthermore, Halliday et al. (2010) discussed that acceleration is a rate of change of a velocity of an object and as described in the Newton's Second Law of Motion, the object's acceleration (a) is directly proportional to the net force acting on it (F), and inversely proportional to its mass (m). This can be expressed by equation (3).

$$a = \frac{F}{m} \tag{3}$$

Besides that, the amount of torque produced by driven sprocket (τ_o) can be computed by multiple the amount of the drive torque given from the motor specifications (τ_i) with the gear ratio (GR) as shown in equation (4).

$$\tau_o = \tau_i \ x \ GR \tag{4}$$

By changing the driven sprocket to the higher number of teeth, the gear ratio for the sprockets will automatically increase. From equation (4), the amount of torque of the driven sprocket will be higher if the gear ratio increase. The force acting on the wheel at the driven sprocket will also increase by substituting the value of torque of driven sprocket into equation (2). Therefore, the amount of acceleration will also increase when the force acting on the wheel is increase by using equation (3) in order to prove the result.

Buell (2001) suggested that the motorcycle sprockets should be fabricated in parts by a less manufacturing process. In addition to that, the material designed for the sprocket may be aluminium or steel, but not that an aluminium hub be combined with a steel ring. On the other hand, the manufacturing of a combined pinion and ratchet with a toothed ring attached to a ratchet hub must be formed separately (Hart, 1886).

Moreover, in order to reduce noise, a chain wheel having a shrink ring made of polymer material should be attached to the outside of the metal sprocket for receiving the brunt of the contact of the chain with the sprocket (Langhof, 1993). Besides that, the method and design of an embedded metal of a ring plate in the web section to join the hub and gear sections together with the making of a cast material gear body has been shown (Brandenstein, 1986).

Therefore, in order to change the gear ratio, a removable and separable tooth ring from the hub was invented by changing the size or number of teeth of the outside ring and this is an effective way as the cost is cheap. The aluminium hub will be designed necessarily for lighter weight while the toothed ring will be made up of steel for greater strength and longer use period as a result for the hybrid motorcycle to achieve high performance (Nichols, 2003).

The durable steel toothed ring will be joined together with the lightweight aluminium hub by using bolt of the two overlapping flanges or by a tongue and groove type interlocking connection between them as shown in Fig. 5. The process to change the sprocket is very quick, easy and especially inexpensive, thus making this invention very efficient and user friendly (Nichols, 2003).

2.5 Summary of conceptual perspective

Generally, in the motorcycle, the chains and sprockets actually transfer the engine power to the rear wheel. The sprocket size determine the number of times that the countershaft must turn in order to spin the rear wheel. The gear ratio is the final drive, which is a numerical indication of how many turns the front sprocket makes in relation to the rear. Equal size of front and rear sprockets would be a 1:1 ratio of power transferred from countershaft to the rear wheel. To make better use of available power, a lower final-drive ratio is used to multiply torque from the engine and transmission to the wheel.

Changing the size of either sprocket (front or rear) is what modifies the final-drive ratio, and determining what ratio is best depends on the type of riding (e.g. riding on a steep road). A lower gear ratio will bolster the bottom end for better light-to-light performance, while higher gear ratio will help out on the top end. In gear-ratio terminology, lower or shorter gears are numerically higher and higher or taller gears are numerically lower. For example, a 3:1 ratio is lower than a 2:1 ratio.

In a simple word, changing sprocket sizes or gearing does not increase or decrease the bikes power. It just changing on how the power is delivered. If the standard gearing is 17 front and 43 rear (17/43) for example, and remove a tooth from the front to make it 16/43, it will make the bike accelerate quicker but loose top speed slightly. The same effect happens if the size of the rear sprocket increase. Moreover, if the purpose is to make the bike more 'cruisey' or give it more speed, then people will only go for a bigger size on the front or smaller on the rear or both.

In this project, the focus is to assist and help farmers during harvesting season and also flood victims during raining season. Therefore the most suitable ways to solve their problems is to alter the size of the rear sprocket which in other means to increase the number of teeth of the rear sprocket. This would definitely help the bike accelerate quicker although it will lose top speed slightly, thus helps them to have an easy ride and saving petrol consumption.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In Mechanical engineering design, engineers usually deal with a lot of software and design methods in order to build the prototype. The slip-on sprocket β – prototype is required a new model or design where the previous α – prototype as shown in Fig. 7 has to be improved in terms of several conditions which include the number of teeth of the sprocket, the number of mold and also the design which can fit most of the motorcycles sprocket in the market. Therefore, for this project, a several methodologies as shown in Fig. 8 have been planned to complete the β – prototype of the slip-on sprocket, thus completing the entire product which want to be sold in the market.

Figure 7. Mechanism of α – Prototype

3.2 Procedure

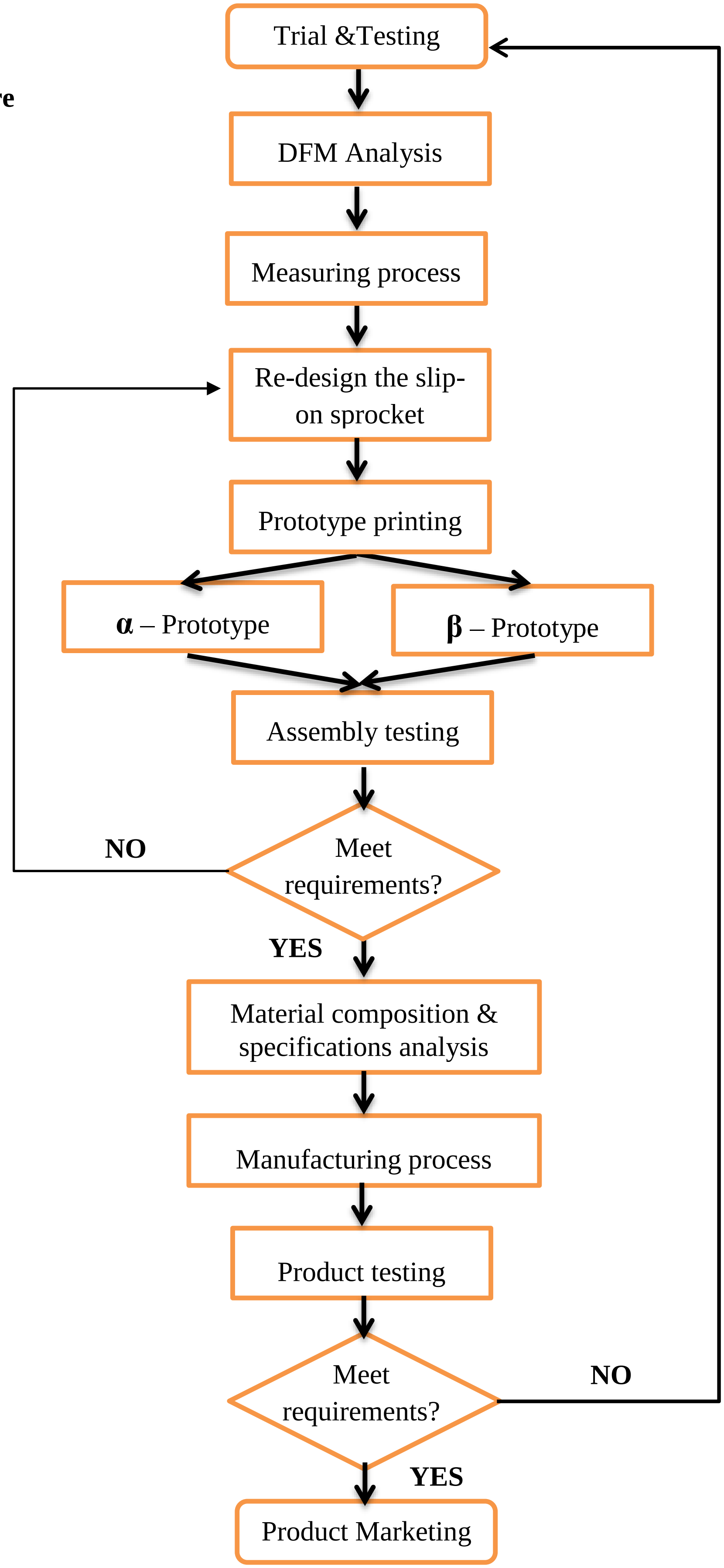


Figure 8. Flow chart of the procedures

3.3 Defining Procedures

Nowadays, reverse engineering has become more popular and the application has widened, together with the development of computer-aided design (CAD) in order to create a 3D model of an existing physical part. Reverse engineering is the process of extracting knowledge or design information from anything man-made and re-producing it or re-producing anything based on the extracted information. The process always required disassembling any engineering parts, components and devices, thus analyzing and extracting all information from those things including dimensions and working principles. The reverse-engineering process involves in this project is measured an object (sprocket) and then reconstructing it as a three dimensional (3D) model. The physical sprocket made can be measured in various ways by using 3D scanning technologies which include laser scanners, structured light digitizers and coordinate measuring machine. Usable format such as CAD model, set of NURBS surfaces and triangular-faced mesh have been processed and modeled from the measured data alone which usually represented as a point cloud and lacks of topological information.

Hybrid Modelling is commonly used term when NURBS and parametric modelling are implemented together. A powerful method of 3D modelling can be provided from a combination of geometric and freeform surfaces. On the other hand, a hybrid model can be created from a combination of areas of freeform with exact geometric surfaces. The procedures in detail below explain every steps and process involves in this slip-on sprocket project.

1. Prototype trial and testing

The existing slip-on sprocket is tested and analyzed as shown in Fig. 9 below before any reverse engineering process is done. This procedure is a very important process where the design improvement need to be tackled from the problems existed before. In this case, the problem for the existing slip-on sprocket design is that the interlocking between the chains and the slip-on sprocket itself is not perfect with some gaps after several complete rotations. This problem occurred due to the wrong dimensioning of the tooth profile for the existing slip-on sprocket and also the gaps tolerance between the connections of the slip-on sprocket.

Figure 9. Trial and testing process of existing slip-on sprocket

2. Design for manufacturing (DFM) analysis

Designing a product in an easy way to manufacture is called design for manufacturing (DFM). This DFM concept is widely being used and exist in almost all engineering disciplines but the difference for this concept is its implementation depending on the manufacturing technology. DFM plays a big role in designing an engineering product by facilitating the manufacturing process in order to reduce the manufacturing cost. DFM creates a path to allow potential problems to be fixed in the design phase which is the least expensive place to address them. The existing slip-on sprocket requires multiple molds for production and this will lead to high cost of manufacturing process. Therefore, DFM analysis is done to produce only 1 mold design for the production of slip-on sprocket in order to reduce the cost.

3. Measuring process

Measuring process is done onto the existing sprocket sell in the market. The 36 teeth sprocket and 40 teeth sprocket has been measured by using coordinate measuring machine (CMM) for accurate precision as shown in Fig. 10 below. There are a lot of dimensions taken from both original sprocket which include pitch circle diameter, addendum circle diameter, dedendum circle diameter, clearance circle diameter, width of the tooth profile and also the thickness of the sprockets.

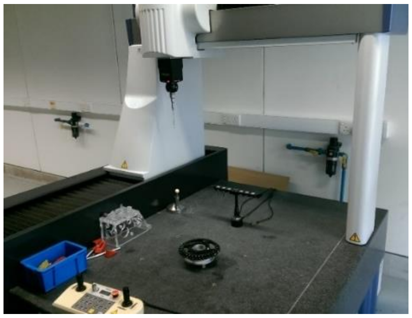


Figure 10. Coordinate Measuring Machine (CMM)

4. Slip-on sprocket design process

The drawing of the improvement for the slip-on sprocket is done successfully by using CATIA software. The information and data collected from the measuring process are used in the designation process of this slip-on sprocket. There are a lot of functions used in this software while designing the slip-on sprocket which include pocket function, pad function, circular pattern and also drafting function for the preparation of the engineering detail drawings.

5. 3D prototype printing process

After the drawings and designs of the slip-on sprocket finished, 3D prototype printing process is done by using 3D printing machine as shown in Fig. 11 below. This printing machine also called additive manufacturing, function as a machine to process a three dimensional product by using a program set up. It is computerized printers which can be synchronized with the computer aided design (CAD) like CATIA software in the form of stl file and creating successive layers of material until the entire object is created.

Figure 11. 3D printing machine

6. Prototype testing and measurements analysis

After the prototype is printed, it is analyzed and tested. An assembly test for the powder form prototype is done on the original 36 teeth sprocket. The interlocking between the chains and the teeth of slip-on sprocket and also the meshing between the slip-on sprocket and the 36 teeth original sprocket are observed. The processes are done repetitively with the different sprocket product of motorcycle make, in order to examine the suitability of the slip-on sprocket design for most types of motorcycles.

7. Material composition and specifications analysis

In this phase, one of the used sprocket collected from the motorcycle shop is used and sacrificed to perform material composition analysis by using X-ray fluorescence machine. The sprocket are cut into small square pieces with a maximum of 40mm dimension by using a linear hack saw machine and abrasive cutter. Once the sample is prepared, the specimen is analyzed in the X-ray fluorescence machine and the chemical compositions are tabulated automatically by the software in the computer. The detail processes explained in Fig. 12 below.

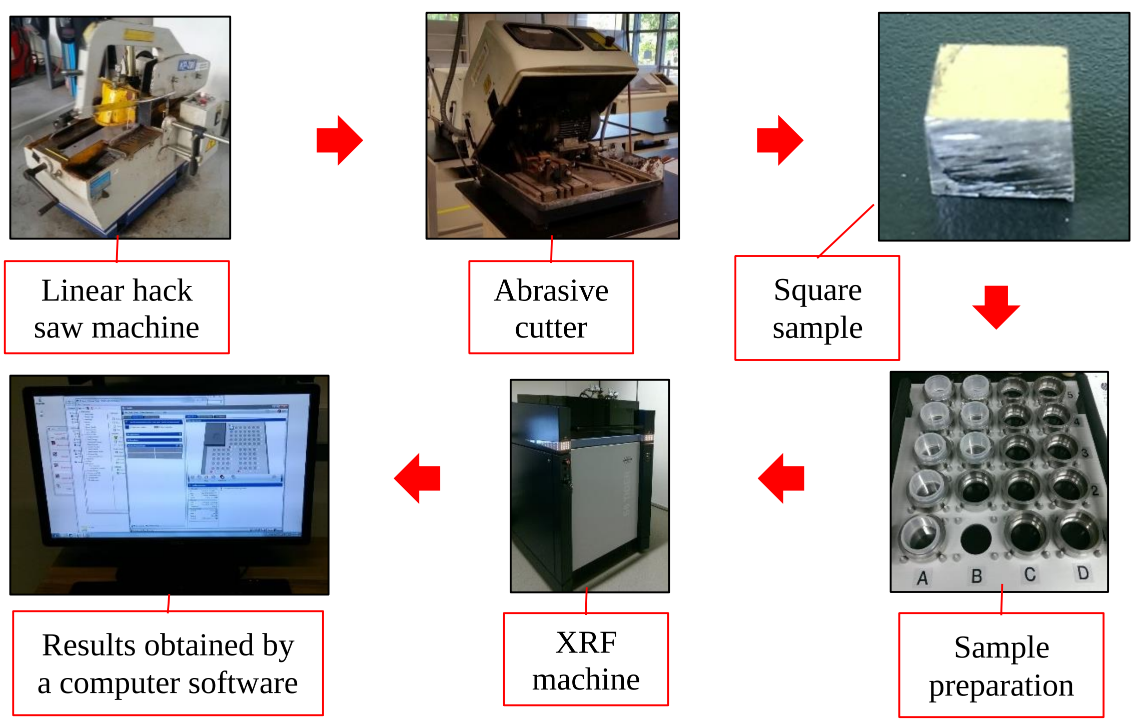


Figure 12. Material composition analysis procedures

8. Manufacturing process

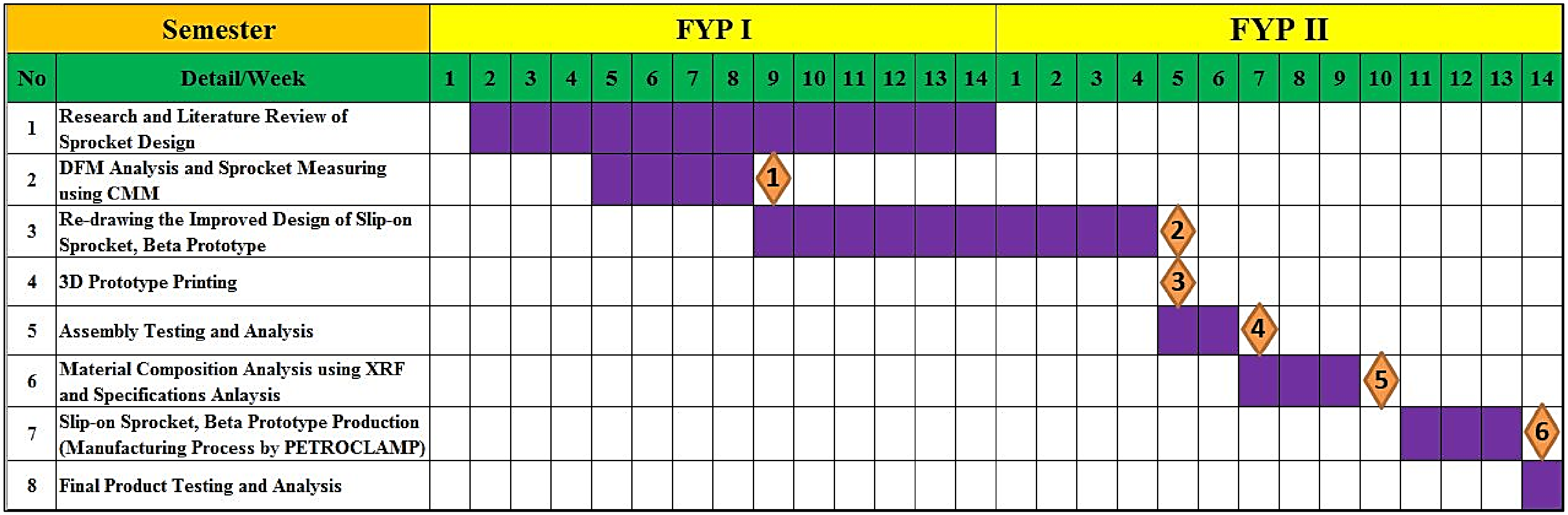
This phase is a very critical phase where the slip-on sprocket will be produced by one of the outside vendor named PETROCLAMP Company. They will start from the beginning of the manufacturing process which is mold and die preparation until the packaging process of the slip-on sprocket product to be sold in the market.

9. Prototype testing (final product)

Once the final product is receive, the profile diameter will be measured first to check the measurements are within the tolerance in the drawing. A few mechanical tests will be conducted on the original slip-on sprocket, β – prototype. All the mechanical testing which include tensile test, yield stress, impact testing, pressure testing, metallographic testing and also magnetic particle flaw inspection will be handled by the vendor itself with the collaboration with Standards and Industrial Research Institute of Malaysia (SIRIM). The slip-on sprocket will be sold in the market once all the manufacturing process and testing are done successfully. After everything is done, the product will be run on the motorcycle as shown in the Fig. 13 to test it and observe the behavior of the slip-on sprocket on the road. The data will be recorded as a proof that the slip-on sprocket, β – prototype is safe and can be sold in the market.

Figure 13. Motorcycle for testing purpose

3.4 Gantt Chart and Key Milestones



	Project Progress
1	Completed DFM analysis and sprocket measuring
2	Completed re-drawing improved design of slip-on sprocket
3	Completed printing of slip-on sprocket prototype (powder form)
4	Completed assembly testing and analysis of the slip-on sprocket prototype
	Completed material composition and specifications analysis
6	Completed several manufacturing process of Slip-on sprocket product

Figure 14. Gantt chart and Key Milestones

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Trial and testing of existing slip-on sprocket

The previous slip-on sprocket, α – prototype has been found theoretically that the interlocking between the chains and the slip-on sprocket teeth was not perfectly joined with some gaps where the curvilinear driving surfaces of the chains were not conjugate to the sprocket teeth as shown in Fig 15 below. In order to get the experimental data, the α – prototype has been tested manually in the lab on the simple mechanism and the result shown in Table 2 below.

Table 2. Experimental data for the previous α - prototype

Number of run	Time taken for the chain slipped from the sprocket (s)	Number of complete turns of the slip-on sprocket (turns)
1	7.8	3
2	10.2	4
3	5.6	2
Average	7.9 s/run 2.6 s/turn	3 turns/run

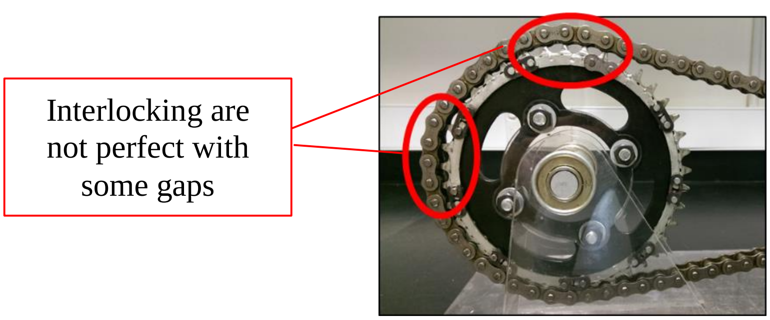


Figure 15. The interlocking problem for existing slip-on sprocket

The data above clearly shown that α – prototype has a problem to interlock perfectly and constant with the existing 36 teeth sprocket on the simple mechanism. This is one of the factor that need to be tackled and solved for the β – prototype in order to improve and develop the invention. This problem occurred mainly due to the different number of teeth per mold. This difference allowing the gap between each mold inconsistent, thus making the chains slipped from the previous slip-on sprocket.

4.2 Design for manufacturing (DFM) analysis

The original 36 teeth sprocket and 40 teeth sprocket which are having the same hub design were connected together in order to analyze the product to find the possibility to produce only 1 mold design for the slip-on sprocket in order to reduce the cost and make the manufacturing process become easier and quicker. Fig. 16 below shown the result that there is a possibility to produce only 1 mold designation of the slip-on sprocket which consist of 10 teeth on the outer part and 9 teeth for the inner slot. This is because the teeth for 40 teeth sprocket were aligned with the 36 teeth sprocket for four times in total. This conclude that, the slip-on sprocket can be designed with four identical parts in order to complete the circulation of the slip-on sprocket.

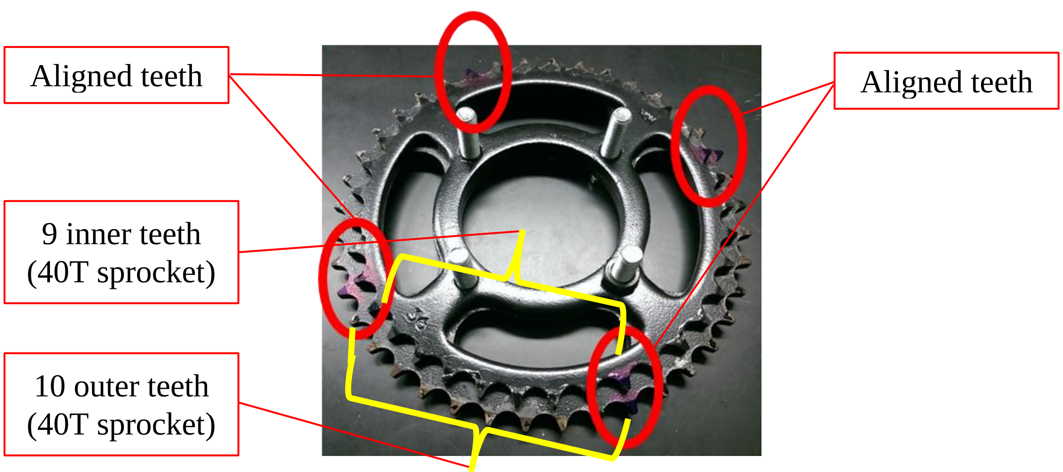


Figure 16. DFM analysis for a new 1 mold designation of slip-on sprocket

After an analysis was made that 1 mold design can produce a complete of four identical parts of slip-on sprocket, the process was continued to measure the dimensions of the original sprocket by using coordinate measuring machine (CMM) as shown in Fig. 17. The critical dimensions that were measured including the thickness of the sprocket, the width, b and thickness, t of the tooth profile, the addendum, Da and dedendum, Dd circle, the gap distance, d between the tooth profile and also the fillet radius, r between the oblique surface of the tooth profile and the bottom land portion. A tabulated data from the results of CMM are shown in Table 3 below.

Table 3. Sprocket dimensions data from the CMM machine

Description	Dimension data (mm)					
36 teeth sprocket	**Reading 1**	**Reading 2**	**Reading 3**	**Mean**	**Variance**	**Standard Deviation**
Addendum diameter, Da	150.232	150.115	149.995	**150.114**	**0.009362**	**0.096757**
Dedendum diameter, Dd	136.981	137.004	136.995	**136.993**	**0.000090**	**0.009463**
Pitch radius, Rp	71.803	71.780	71.748	**71.777**	**0.000522**	**0.022853**
Clearance radius, Rb	67.495	67.473	67.443	**67.470**	**0.000461**	**0.021482**
Fillet diameter, r	8.134	8.309	7.984	**8.142**	**0.017639**	**0.132811**
Tooth width, b	1.981	1.995	2.002	**1.993**	**0.000076**	**0.008731**
Thickness, t	7.002	7.013	6.998	**7.004**	**0.000040**	**0.006342**
Distance between tooth, d	11.762	11.588	11.678	**11.676**	**0.005048**	**0.071049**
40 teeth sprocket	**Reading 1**	**Reading 2**	**Reading 3**	**Mean**	**Variance**	**Standard Deviation**
Addendum diameter, Da	166.887	166.962	167.338	**167.062**	**0.038934**	**0.197316**
Dedendum diameter, Dd	153.442	152.869	153.201	**153.171**	**0.055182**	**0.234908**
Pitch radius, Rp	80.082	79.958	80.135	**80.058**	**0.005509**	**0.074226**
Clearance radius, Rb	75.277	75.160	75.327	**75.255**	**0.004868**	**0.069772**
Fillet diameter, r	7.991	8.012	7.996	**8.000**	**0.000080**	**0.008957**
Tooth width, b	2.332	2.012	1.88	**2.075**	**0.036014**	**0.189774**
Thickness, t	7.001	6.996	7.005	**7.001**	**0.000014**	**0.003682**
Distance between tooth, d	12.163	12.005	11.889	**12.019**	**0.012611**	**0.112297**

The pitch radius, Rp and clearance radius, Rb were determined from the formula given as shown in equation (5) and (6) below:

$$Rp = ((Da - Dd) / 2) + Dd) / 2 \quad (5)$$

$$Rb = 0.94 * Rp \quad (6)$$

Figure 17. Sprocket preparation and working process of CMM machine

4.3 Re-drawing the slip-on sprocket by using computer aided design (CAD)

A complete 40 teeth slip-on sprocket was drew by using CATIA software with the dimensions following the previous data obtained from the CMM. The primary objectives for this β – prototype of slip-on sprocket is to get an equal units of the slip-on sprocket parts with the section lies between the curvilinear driving surfaces of the slip-on sprocket as shown in Fig. 2, not at the teeth itself as produced in the previous α – prototype. Therefore, a certain number of trials were done in order to find the best design to divide the units into a perfect sectioning and equal parts of the slip-on sprocket. In order to draw a complete 40-36 teeth of slip-on sprocket in CATIA, some formulas were used and considered as described in equation (5) and (6) above to produce the best drawing with the correct dimensions.

First of all, the sprocket drawing's formulas and calculations for this β – prototype were followed a 20º pressure angle criteria. The number of teeth, N was identified first where in this case, N for the outer teeth of slip-on sprocket is 40.

The formulas and dimensions required for the drawings of the slip-on sprocket were inserted in the CATIA software while drawing the design of the slip-on sprocket. After that, the drawings of the slip-on sprocket β – prototype started with a single tooth design of 40 teeth slip-on sprocket as shown in Fig 18. Then, the cover of the 36 teeth slot was drew just below the existing tooth with a 2.8 mm gap for safety precaution which is shown in Fig 20. Next, a single tooth slot of 36 teeth sprocket was drew between the cover and just below the tooth of the 40 teeth slip-on sprocket as shown in Fig 21.

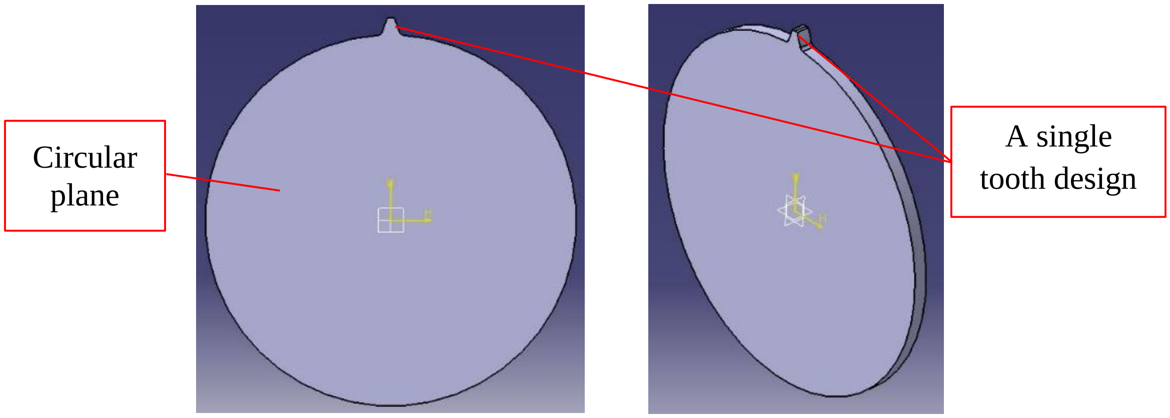


Figure 18. First stage of single tooth 2D and 3D drawings of the slip-on sprocket

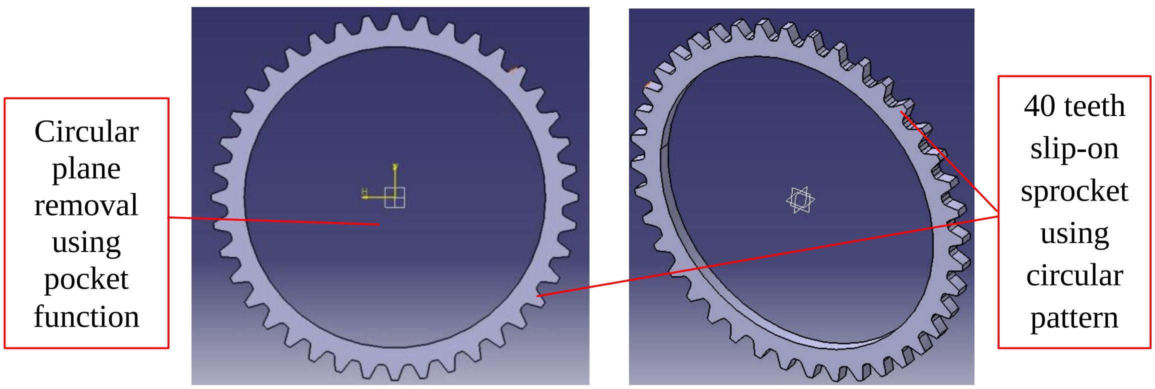


Figure 19. A complete 40 teeth slip-on sprocket 2D and 3D drawings by using circular pattern function

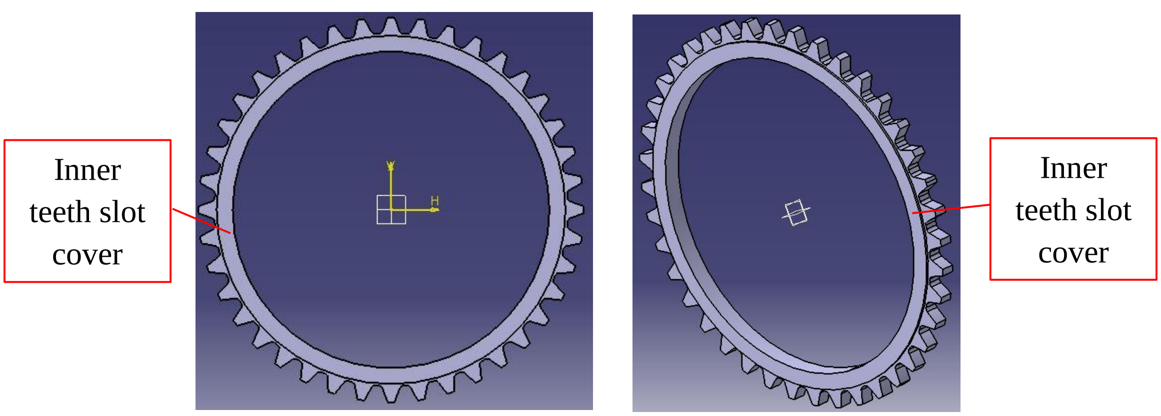


Figure 20. The 2D and 3D drawings of the 36 inner teeth slot cover

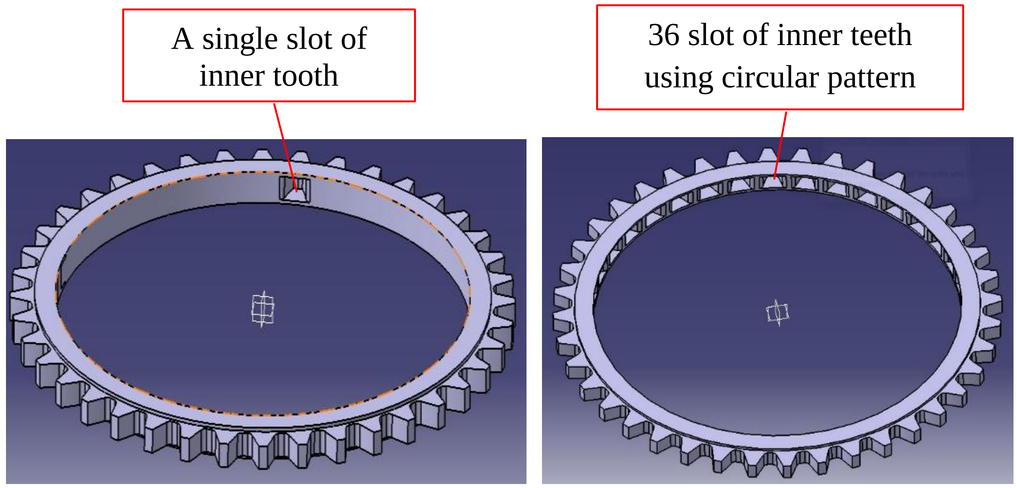


Figure 21. The 3D drawings of the slot of 36 inner teeth

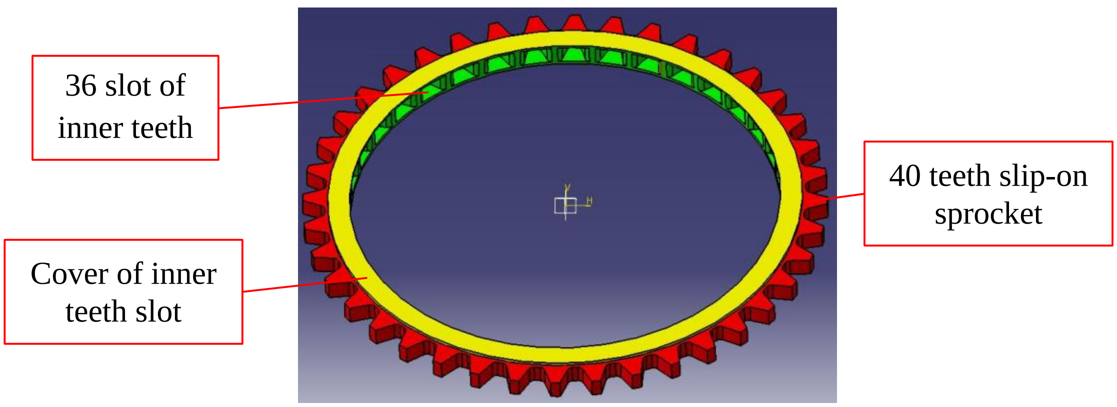


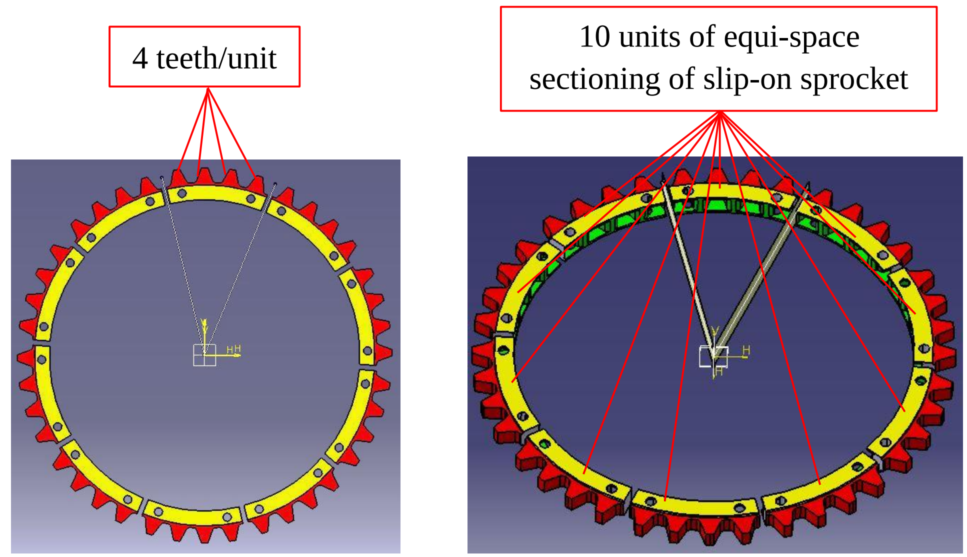
Figure 22. The complete 3D drawing of the slip-on sprocket without sectioning

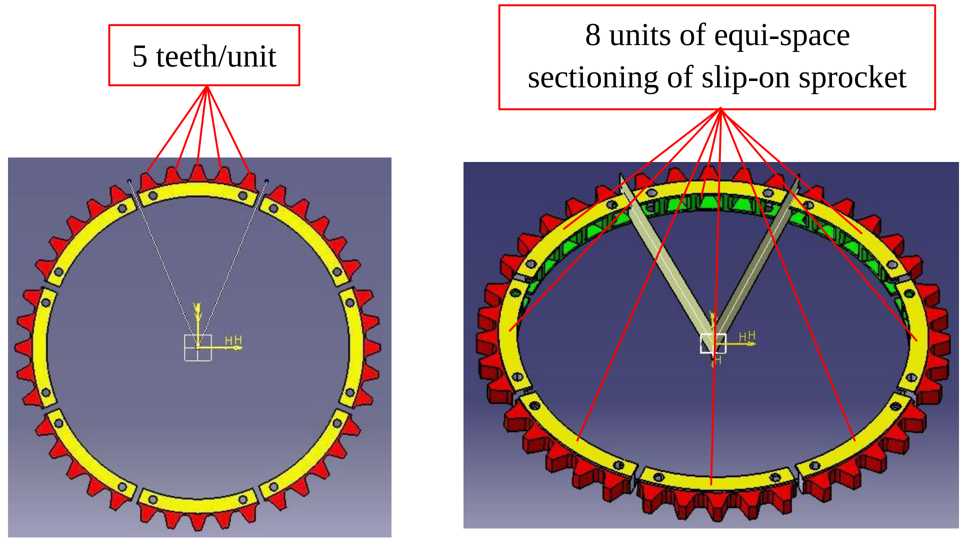
A complete crown function was used for those three different sketches in order to get a complete circle of slip-on sprocket for β – prototype. From analysis, problems and conclusion which have been identified in the previous α – prototype, the sections of each units were not uniform and not equally divided where some of the sections were cut at the teeth of the slip-on sprocket and therefore, this time, the task is to section all the units of the slip-on sprocket equally and also lies between the curvilinear driving surfaces of the sprocket teeth.

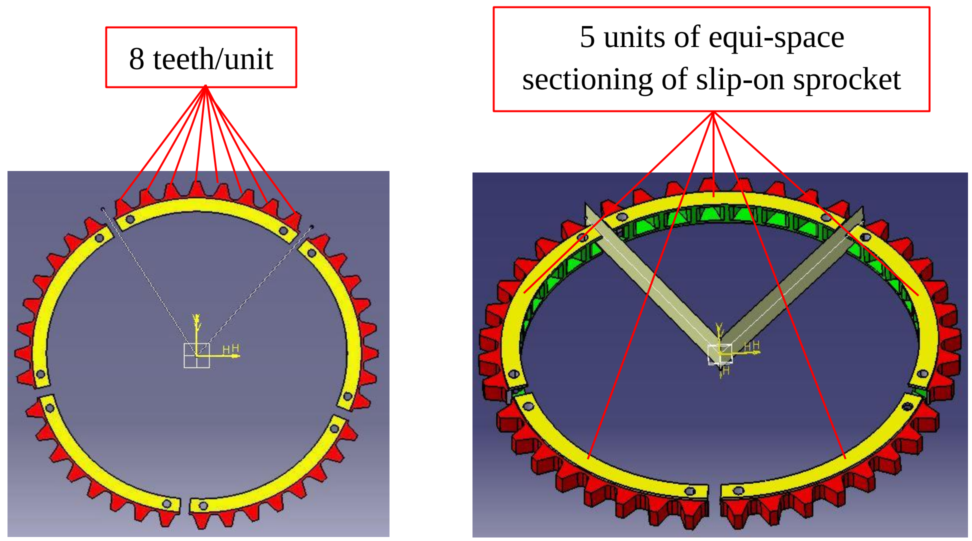
From the complete drawing of the slip-on sprocket β – prototype, the sections of units were discovered with a several trials of 4 units, 5 units, 6 units, 7 units, 8 units, 9 units and 10 units of slip-on sprocket where each unit consist of 10 teeth, 8 teeth, $6\frac{2}{3}$

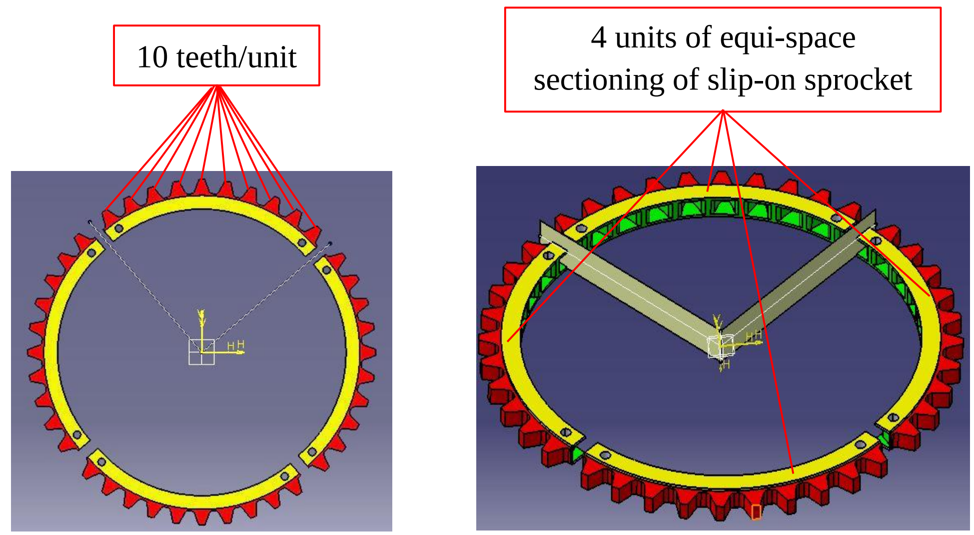
teeth, $5\frac{5}{7}$ teeth, 5 teeth, $4\frac{4}{9}$ teeth and 4 teeth respectively. From this analysis, it is clearly shown that the sectioning process for 6 units, 7 units and 9 units will not be successful because they have a fraction number of teeth for each unit, therefore Table 5 below shows a description and configuration of the trials for sectioning the slip-on sprocket drawing in CATIA for the 4 units, 5 units, 8 units and 10 units only.

Table 4. Description and configuration of the trials for sectioning the slip-on sprocket drawing

	Angle for each section (°)	No. of outer teeth for each unit	Drawing Pictures
10 units	36	4	 Figure 23. The 2D and 3D drawings of the 10 units sectioning of slip-on sprocket

	Angle for each section (º)	No. of outer teeth for each unit	Drawing Pictures
8 units	45	5	 Figure 24. The 2D and 3D drawings of the 8 units sectioning of slip-on sprocket

	Angle for each section (°)	No. of outer teeth for each unit	Drawing Pictures
5 units	72	8	 Figure 25. The 2D and 3D drawings of the 5 units sectioning of slip-on sprocket

	Angle for each section (º)	No. of outer teeth for each unit	Drawing Pictures
4 units	90	10	 Figure 26. The 2D and 3D drawings of the 4 units sectioning of slip-on sprocket

From the results above, 4 units criteria was chosen for the design of the slip-on sprocket drawing, β – prototype. The reason because the section of each unit is perfectly lies between the curvilinear driving surfaces. For the outer 40 teeth slip-on sprocket, each angular teeth from one another is 9º where a complete circle (360º) divided by 40 numbers of teeth. In order to get a perfect section for each unit, the angle for each section has to be a value with a factor of 9 so that the line for the sectioning lies between the curvilinear driving surfaces. Therefore, in this case, the suitable numbers of units for the sectioning are 10 units, 8 units, 5 units and 4 units as shown in Table 5.

Theoretically, from the four choices mentioned above, 4 units (10 teeth/unit) of 40-36 teeth slip-on sprocket was chosen for the prototype to be printed in a 3D printing machine because the results obtained from DFM analysis shown that there is only 1 possible mold designation where the tooth of 40 teeth sprocket aligned with the tooth of 36 teeth sprocket for four times in a complete circle. This means that the sectioning of the parts of the slip-on sprocket is equal for every quarter.

Besides that, the reason for the 4 units sectioning was chosen because of the least number of the gap exist between the joining of the sprocket units. Hypothetically, the least number of the gap between units, the least tolerance considered during the interlocking of the slip-on sprocket with the existing 36 teeth sprocket on the motorcycle. This can allow a perfect interlocking configuration between the slip-on sprocket and the chains, thus avoiding the slippage of the chains when it rotates. This problem was mentioned earlier for α – prototype and this is another reason that 4 units of slip-on sprocket was considered and chosen among the other three options (10 units, 8 units & 5 units).

However, this option has a problem in general where the high number of teeth in each unit would lead to the complicated installation. This is because in general concept, the longer the circumference length for each unit, the harder the process to slot in the slip-on sprocket into the existing 36 teeth sprocket on the motorcycle. After some modifications were made on the slot of slip-on sprocket for 36 teeth sprocket to be interlocked, the prototype had no problem to be installed easily as the distance of each tooth slot had been widened and the width for the slot also had been increased.

Therefore, this configuration considered successful and 1 mold designation for slip-on sprocket is possible for production.

As 4 units option was chosen for the first batch of 40-36 teeth slip-on sprocket, the complete details and drawings are as follows:

1. **40 teeth slip-on sprocket (outer teeth)**

- Pitch circle radius, Rp = 80mm
- Clearance circle radius, Rb = 75.2mm
- Addendum circle, Ra = 83.5mm
- Dedendum circle, Rd = 76.5mm
- Fillet radius, r = 4mm

2. **36 teeth slot for the slip-on sprocket (inner teeth)**

- Pitch circle radius, Rp = 71.8mm
- Clearance circle radius, Rb = 67.5mm
- Addendum circle, Ra = 75mm
- Dedendum circle, Rd = 68.5mm
- Fillet radius, r = 4mm
- Radius of rivet hole = 2.2mm

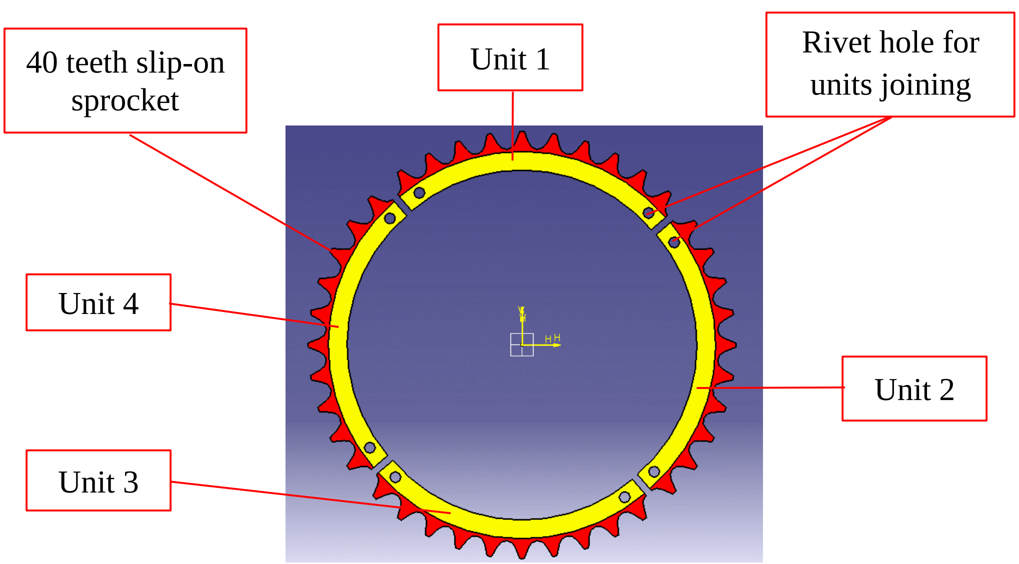


Figure 27. 2D drawing of slip-on sprocket for selected sectioning option

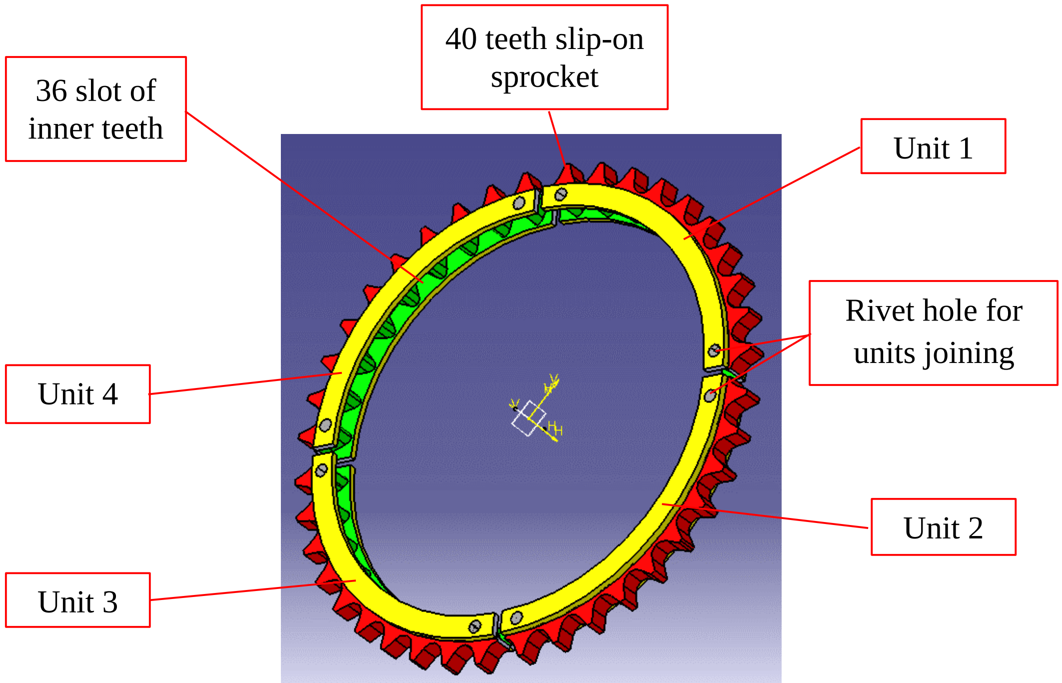


Figure 28. Isometric drawing view of slip-on sprocket for selected sectioning option

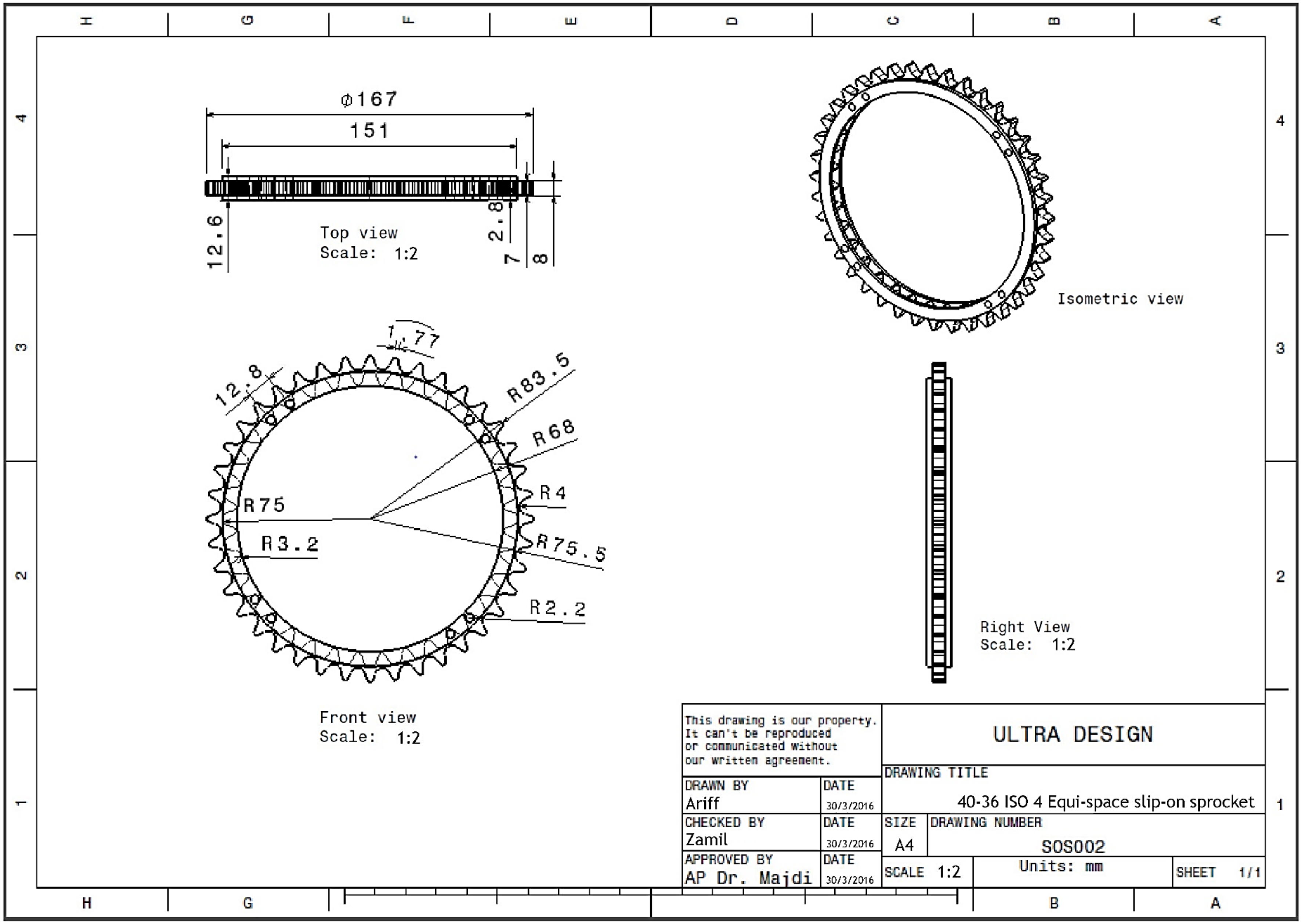


Figure 29. Engineering detail drawings of improved slip-on sprocket design

4.4 Prototype printing and assembly testing

The prototype of 4 equal units as shown in the 3D drawing in Fig. 28 was printed by using 3D printing machine. Each unit consist of 10 teeth in the outer part and 9 slot of inner teeth in the inner part. The process of prototype printing began with the file converting from CAT file into stl file and input into ZPrint software. After the 3D printer able to read the file, the printing machine started to fill the bed with the powder (ZP150). Then, the printing process was done layer by layer and Z-bond sealant was applied on printed prototype as the binder for the model. The results of the printed prototype are shown in Fig. 30 below. After the prototype has finished its printing process, it was cleaned by using a vacuum chamber inside the printer manually before proceed for the next step. After that, a super glue was applied onto the overall surfaces of the prototype to strengthen the model. Although the dimensions were slightly difference from the drawing after the super glue was applied, it still can be used for assembly testing to examine the interlocking behavior of the slip-on sprocket with the original 36 teeth sprocket and also the interlocking behavior of the chains with the slip-on sprocket. The detail drawings of the slip-on sprocket design as shown in Fig. 29 above will be used by the PETROCLAMP Company to design and prepare the mold and die for the production of slip-on sprocket. All the manufacturing process will be handled by the PETROCLAMP Company until the product can be sold in the market.

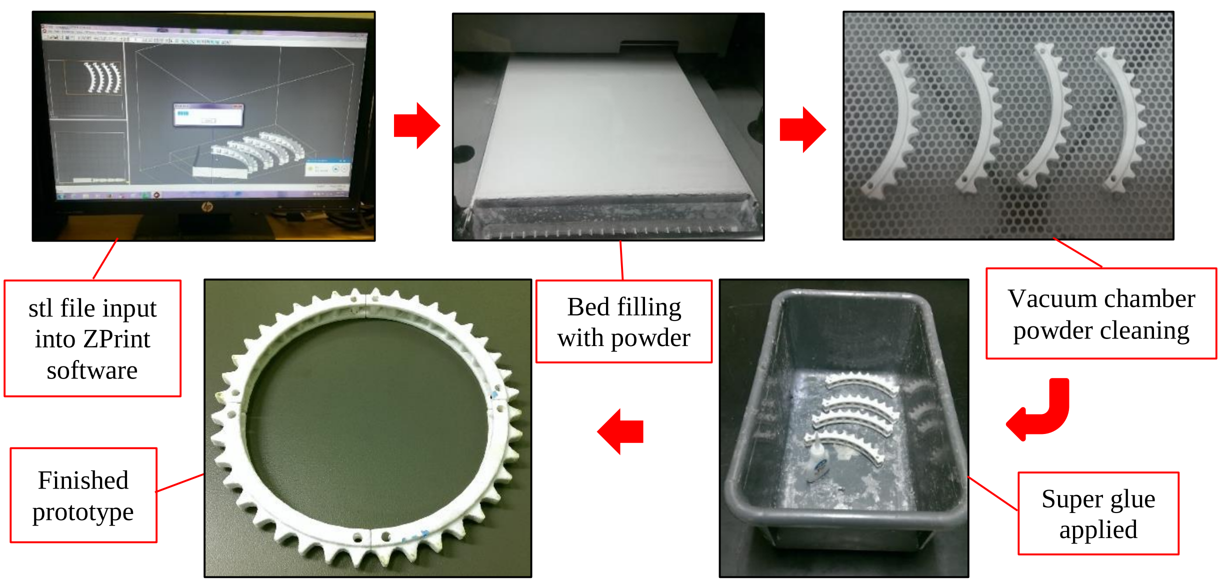


Figure 30. 3D prototype printing process

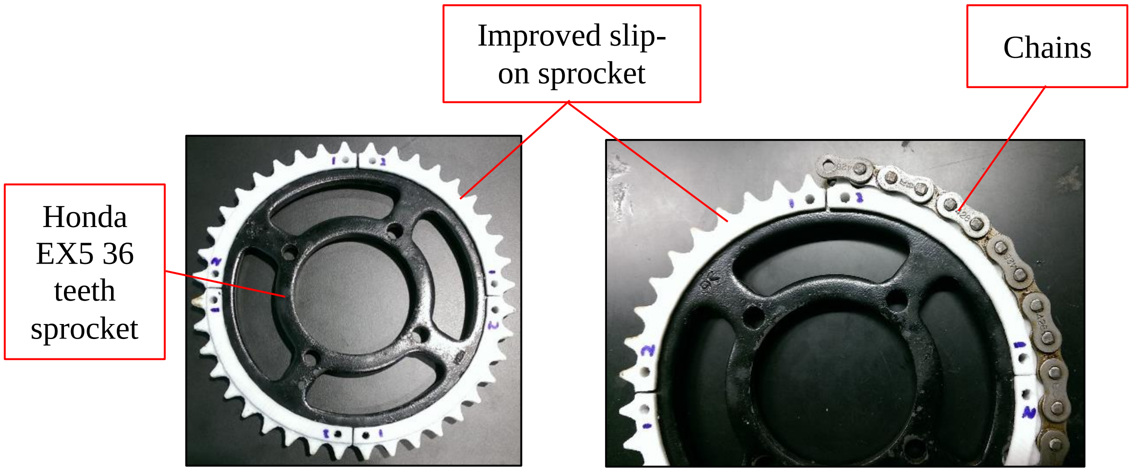


Figure 31. Assembly test of slip-on sprocket with 36 teeth original sprocket and chains

From the results shown in Fig. 31 above, it can be concluded that the slip-on sprocket powder prototype has passed its assembly test by interlocking it with the Honda EX5 36 teeth sprocket perfectly and also passed the assembly test of chains interlocking above the slip-on sprocket teeth. The prototype also was tested onto other types of motorcycle's 36 teeth sprocket in order to examine whether the slip-on sprocket product suits all motorcycle make instead of only one make which is Honda EX5 motorcycle. The results for testing the prototype onto other types of motorcycle's sprocket are shown in Table 5 below including Honda Wave, Modenas Kriss, and also Yamaha LC.

Table 5. Assembly testing for other types of motorcycle's sprocket (36T)

Motorcycle	Honda Wave	Modenas Kriss	Yamaha LC
Assembly testing			

From the results above, the printed prototype shown a positive result where this new β – prototype model can suits most of the 36 teeth sprocket of motorcycle make. This means that, as long as the size of the sprocket dimensions for each 36 teeth motorcycle sprocket are same including its tooth profile, addendum circle, dedendum circle, pitch circle, and also fillet radius between the bottom land portion and oblique surface, the slip-on sprocket product is able to be interlocked together for a novel torque booster performance.

The difference between those 36 teeth sprocket is only the hub design in the middle section of the product for the connection of nuts and bolts. For slip-on sprocket product, it does not require a hub design where it will be slotted into the existing 36 teeth sprocket, thus make it a novel and portable design in the transportation market.

4.5 Material composition and specifications analysis

A sample of original sprocket was sacrificed and used in order to determine the chemical composition of the material used to produce the original sprocket. In order to determine this findings, X-ray fluorescence (XRF) method was used. X-ray fluorescence is a method of non-destructive testing being used to examine the composition of elements in every product materials. The fluorescent or secondary x-ray emitted from a sample was measured by XRF analyzers in order to determine the chemistry of a sample. Each of the elements present in a sample produces a set of characteristic fluorescent x-rays ("a fingerprint") that is unique for that specific element. The results obtained from this XRF experiment for the original sprocket are as shown in the Table 6 below.

Table 6. Elemental composition of sprocket materials

Formula	Calc. concentration	Concentration	Stat. error	Net int.	LLD	Analyzed layer
Fe	86.26	86.30%	0.19%	925.8	150.9 PPM	29.5 um
Al	8.22	8.22%	2.70%	4.472	129.1 PPM	0.73 um
P	2.79	2.79%	2.76%	4.494	164.4 PPM	1.42 um
Ca	1.15	1.15%	2.79%	4.265	49.1 PPM	6.7 um
S	0.4	0.40%	6.12%	1.317	136.5 PPM	1.95 um
Si	0.33	0.33%	12.40%	0.2781	91.1 PPM	0.99 um
Mn	0.321	0.32%	4.00%	2.981	65.5 PPM	23.5 um
Cu	0.21	0.21%	9.26%	1.479	89.7 PPM	8.5 um
Zn	0.089	0.09%	18.20%	0.7893	81.8 PPM	10.2 um
Cr	0.08	0.08%	8.76%	0.8242	26.2 PPM	18.6 um
Mo	0.073	0.07%	11.10%	2.441	42.0 PPM	69 um
K	0.073	0.07%	15.80%	0.2298	40.9 PPM	5.0 um

The XRF machine works in a process where it can automatically analyzed results into the software installed in the computer. The process of XRF are briefly described as:

1. A solid sprocket sample was irradiated with high energy x-rays from a controlled x-ray tube.
2. When an atom in the sample was struck with an x-ray of sufficient energy (greater than the atom's K or L shell binding energy), an electron from one of the atom's inner orbital shells was dislodged.
3. The atom regained stability, filled the vacancy left in the inner orbital shell with an electron from one of the atom's higher energy orbital shells.
4. The electron dropped to the lower energy state by releasing a fluorescent x-ray. The energy of this x-ray is equal to the specific difference in energy between two quantum states of the electron. The measurement of this energy is the basis of XRF analysis.

In the meantime, a survey was done on the website for the sprocket sell in the market for the materials that they are using for their product. From the survey, majority of the company are using 1023 Steel, 1045 Steel, and also 7075-T6 aluminium alloy. There is a reason for the selection of those materials by each company which are the aluminium materials used for lighter weight, high performance motorcycle riding, ease and low cost interchangeability while the steel materials used for greater strength and longer use period.

Furthermore, in order to produce a new invention product, some other specifications also being surveyed so that the product quality will be the same as the original sprocket sell in the market which include technical specifications and performance specifications. The technical specifications for the sprocket production will include the surface treatment, heat treatment, and quality control or mechanical testing. Besides that, the information regarding lifetime and the warranty provided for the original sprocket sell in the market will be used as the performance specifications. All these information are really useful and helpful, so that the new slip-on sprocket production has the same quality or almost the same as the original sprocket used in the world. The surveyed results for the specifications of the motorcycle sprocket are shown in Table 7 below.

Table 7. Technical and performance specifications of motorcycle sprocket

	Specifications	Company			
		A	B	C	D
Technical	Materials used	1045 Steel	1023 steel/1045 Steel	Aluminum7075 - T6	1045 Steel
	Surface treatment	Sandblasting & polishing	Sandblasting & polishing	Anodized	Sand Blasting & polishing
	Heat treatment	High frequency quenching Carburization	High frequency quenching Carburization	High frequency quenching Carburization	High frequency quenching Carburization
	Quality control / Mechanical testing	Tensile strength, yield stress, impact testing, pressure testing, metallographic, magnetic particle flaw inspection		Tensile strength, yield stress, impact testing, pressure testing, metallographic, magnetic particle flaw inspection	
Performance	Life time	15000 km	15000 km	10000 km	20000 km
	Warranty	1 year	2 years	1 year	2 years

4.5.1 Surface Treatment

In every manufacturing process, surface treatment is one of the important phase that need to be performed in order to produce a quality product which satisfy all the mechanical criteria and aspects. Surface treatment is a process being used to alter or modify the surface of manufactured item in order to satisfy the property required. There are many purposes for the finishing processes which include resistance against corrosion, tarnish, chemical, and wear. Besides that, it helps to improve hardness, modify electrical conductivity, appearance, wettability or adhesion, solderability, remove burrs and other surface flaws and also control friction of the surface. Sometimes, in order to restore original dimensions to salvage or repair an item, these techniques may be considered for manufacturing process. In producing the slip-on sprocket, there are three types of surface treatment being used by the manufacturing companies which include **sandblasting, polishing and anodizing**.

Sandblasting is a cleaning and etching process at a surface with the presence of very fine bits material propelled at high velocity. There are three different parts involved to setup the sandblasting process which include air compressor, blaster nozzle and also the abrasive itself. A workstation is highly needed in order to hold the piece of glass for etching and small object cleaning where the workstation will act as a collector to gather up excess dust. There are two main primary function of sandblasting process which include to either carve or etch designs or words into glass similar material and also clean the surface from clinging materials above it.

On the other hand, **polishing** is a process used a chemical action or rubbing materials in order to create a smooth and shiny surface until the surfaces leave a significant specular reflection. Polishing is able to reduce diffuse reflection to minimal values in some materials including glasses, black or transparent stones and also metals. The surface of an unpolished materials usually looks like valleys and mountains under a thousand times magnification and this polishing process ensure that those rough surfaces are worn down until they are flat or nearly flat by using repeated abrasion method. The process of abrasives polishing starts with coarse surface until fine surface.

Moreover, **anodizing** is an electrolytic passivation process used to increase the thickness of the natural oxide layer on the surface of metal parts and usually it is done on the aluminium materials product. There is a recommending layer thickness for anodizing process following the area of application of certain products behavior as shown in Table 8 below. Anodizing is used to maintain the products as:

- A new appearance.
- Corrosion resistance enhancer.
- Dirt repellant surface creator that satisfies stringent hygiene requirements.
- Decorative surface creator with durable color and gloss.
- An electrical insulating coating to the surface.
- A base provider for the application of adhesives or printing inks.

Table 8. Recommending layer thickness for anodizing process

Layer thickness	Area of application
25 µm	When surfaces are exposed to severe stress in the form of corrosion or abrasion
20 µm	Great or normal stress outdoors (eg. Transport & construction industries
15 µm	Severe abrasion, indoors and outdoors in dry and clean atmospheres
10 µm	Normal stress indoors
3-5 µm	Protective anodizing before machining, short period of etching

4.5.2 Heat Treatment

Heat treatment is a process to alter the mechanical and physical properties of metals by controlling heating and cooling processes without changing the product shape. Welding and forming which lead to heat or cool the metal in the manufacturing processes are sometimes lead to heat treatment without any intention. Heat treatment process is usually done to increase the strength of material, but sometimes it may be used to modify certain manufacturability objectives which include improve formability, improve machining and restore ductility after a cold working operation. Therefore, this heat treatment process can help to improve product performance by increasing strength or other desirable characteristics instead of helping other manufacturing process. In sprocket manufacturing process, the familiar heat treatment processes are **high frequency quenching** and also **carburization**.

High-frequency quenching (HFQ) is a process to harden the surface of iron and steel machine details. The process begin with a rapid heating of the hardened surface in the pulse regime by a high-frequency field with subsequent rapid self-quenching of the heated layer by heat transfer to cold deep layers of the metal. Endurance and other features of metal, firmness, augments durability of such detail in several times increases with the formation of superfine strengthening structures including carbides and martensites. There are several advantages of HFQ which include brittleness reduction due to particle dispersion and plastic core, local hardening possibility, energy inputs reduction for heating, lack or significant decrease in war page and also possibility of external and internal surfaces hardening.

In the meantime, **carburization** is a process of making harder material where steel or iron absorbs carbon released during the metal heating process in the presence of carbon bearing material including carbon monoxide or charcoal. The affected area can vary in carbon content depending on the amount of time and temperature. They are both directly proportional in relations where longer carburizing times and higher temperatures lead to the increasing of carbon diffusion depth. The higher carbon content on the outer surface becomes hard via the transformation from austenite to martensite when the iron or steel is cooled rapidly by quenching, while the core remains soft and tough as a ferritic and/or pearlite microstructure.

4.6 Manufacturing process and testing

The manufacturing process will take place by the PETROCLAMP Company and the product design is according to the engineering detail drawings of slip-on sprocket as shown in Fig. 29 above. Most of the critical processes take place in this manufacturing process will be followed by a specific quality control process. The detail plan of manufacturing processes for the slip-on sprocket are explain below in Fig. 32 from the beginning of the process which is wax pattern injection until the last process which is packaging and delivery. The testing required during the manufacturing process will be handled by the PETROCLAMP Company while the product testing and analyzing the performance of slip-on sprocket on the real motorcycle will be handled after the final product has produced.

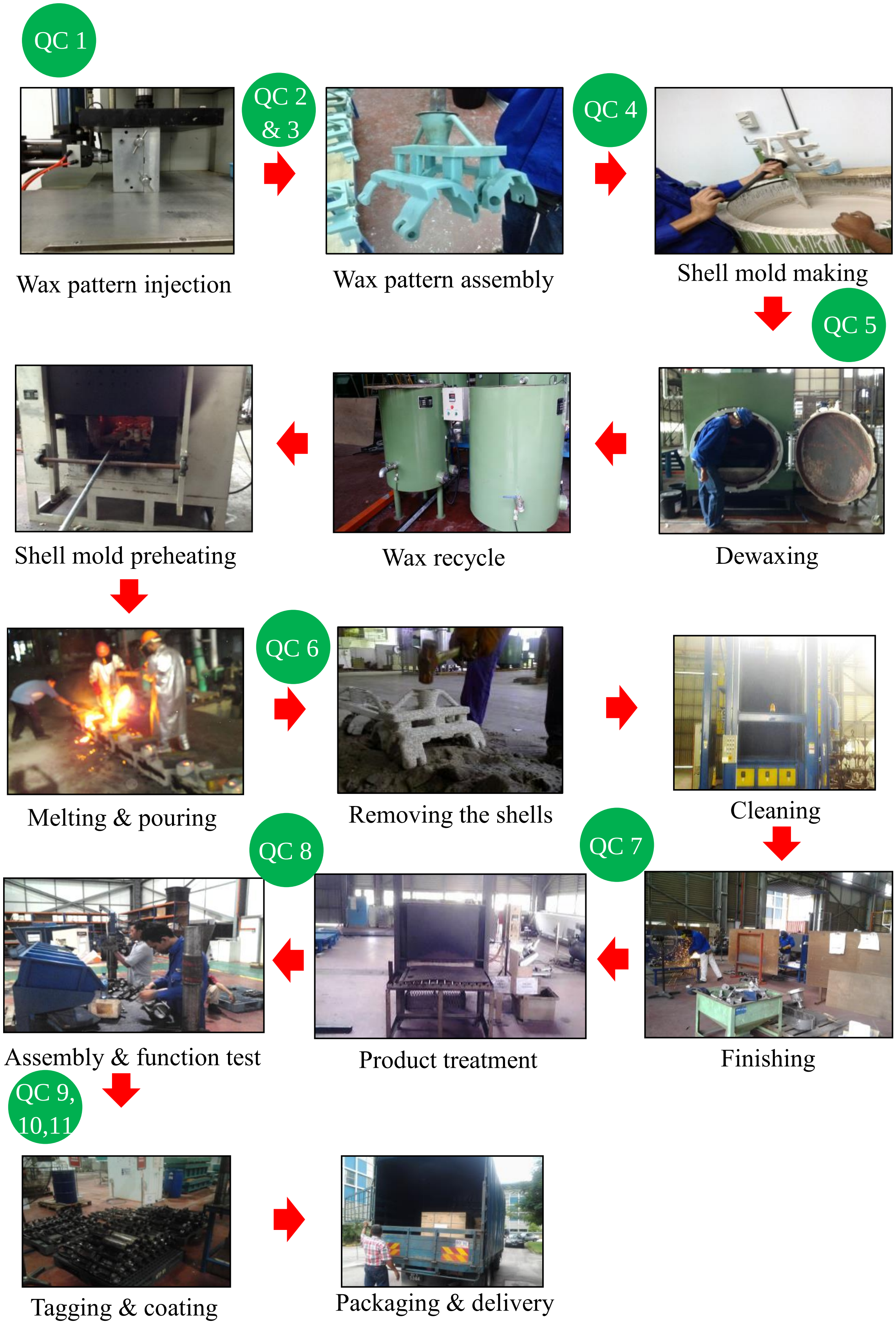


Figure 32. Planned manufacturing process for slip-on sprocket production

The quality control processes that take place in this manufacturing process of slip-on sprocket include:

- **QC 1:** Raw material receiving inspection
- **QC 2:** Wax die inspection
- **QC 3:** Wax pattern and sprue inspection
- **QC 4:** Wax tree inspection
- **QC 5:** Environmental and tree inspection
- **QC 6:** Molten steel chemical composition inspection
- **QC 7:** Casting inspection
- **QC 8:** Dimension inspection
- **QC 9:** Machining inspection
- **QC 10:** Assembly function test inspection
- **QC 11:** Performance test

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In a nutshell, the slip-on sprocket β – prototype design was improved from the existing slip-on sprocket by using reverse engineering method. The original 36 teeth sprocket and 40 teeth sprocket were used to measure the critical dimensions by using coordinate measuring machine (CMM). Design for manufacturing (DFM) took place in this project in order to reduce the manufacturing cost by analyzing the sprocket to design only 1 mold for the production of slip-on sprocket which is 10 teeth/unit. The drawing process was done completely by using CATIA software and 3D prototype printing process was performed in order to analyze the assembly configuration of the improved slip-on sprocket design onto most types of 36 teeth motorcycle sprocket. This new design of slip-on sprocket fitted successfully onto 36 teeth sprocket of Honda Wave, Modenas Kriss and Yamaha LC. The improved design of slip-on sprocket also shown a positive result of assembly testing with no gaps exist between the interlocking of chains and the 40 teeth slip-on sprocket. The project has been continued with the early stage of manufacturing process which is mold and die preparation for the slip-on sprocket by PETROCLAMP Company. The engineering detail drawings had been submitted for their reference to design the mold and die of each quarter unit of slip-on sprocket consist of 9 teeth inner slot and 10 outer teeth. Therefore, this project has achieved the three main objectives which include to perform calculation and analysis for the β – prototype design improvement by using reverse engineering method, to examine β – prototype to suits all motorcycle make instead for only Honda EX5 motorcycle and also to prepare mold and die designation of β – prototype for slip-on sprocket.

5.2 Recommendation

This Design Improvement of Existing Slip-on Sprocket project shall be continued with the manufacturing process of the real product. Collaboration with PETROCLAMP Company should be followed up in order to produce the real slip-on sprocket. All the mechanical testing should be tested on the final product of slip-on sprocket which include tensile testing, impact testing, pressure testing, lateral load, axial load, pull out force, cyclic testing and also deformation testing. In the meantime, performance testing is also required for the slip-on sprocket product in order to prove that this new invention is compatible and aligned with the performance of 40 teeth sprocket sell in the market. The performance testing required are speed result, torque result, and acceleration result of the motorcycle driven with the slip-on sprocket on the rear part of motorcycle.

All of the future works should be expedited in order to complete this invention and to make the development of the slip-on sprocket successful. Once the 36 – 40 teeth of slip-on sprocket product is produced successfully and hit the market, the development of the slip-on sprocket design should be continued with another project scope in terms of teeth number, for example 36 – 42 teeth of slip-on sprocket, 38 – 42 teeth of slip-on sprocket and 40 – 44 teeth of slip-on sprocket so that the farmers, flood victims and torque booster users will find it easy to have this new technology invention for their interest.

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