TO DESIGN AN INNOVATION COCONUT PLUCKING ROD WITH ADVANCE MECHANISM

CHONG FEI MING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TO DESIGN AN INNOVATION COCONUT PLUCKING ROD WITH ADVANCE MECHANISM

CHONG FEI MING

A report submitted
In fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project report entitled “To Design an Innovation Coconut Plucking Rod with Advanced Mechanism” is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

APPROVAL

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

Signature : .....

Supervisor's Name : .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

Coconut is one of the industrial crop in Malaysia and it has a great influence on the social economic of the Malaysia. This industry requires new invention in the harvesting method which not only to fulfill its mass distribution around the world but also able to consider the safety to the user and reliability. It is usually seen that the cultivators used the traditional method such as climbing method or pole method in the harvesting of coconut. The purpose of this project was to design a coconut plucking rod and proposed a mechanism system which to be cooperated with the existing rotary blade. The designing of the coconut plucking rod was carried out through the design methodology which provide a systematic approach and guidelines in produces a product. The concepts of design the coconut plucking rod is generated according to the customer requirements which translated into the engineering characteristics and generated the product design specifications. As a result of this study, a coconut plucking rod with a gear mechanism is selected as the final concept for the product. The mathematical and CAD analysis was carried out and showed that the mechanism system able to generate the required force and the structure of the rod able to support the applied force. By designing the coconut plucking rod, the users can pick the coconut with ease and low energy.

ABSTRAK

Kelapa merupakan salah satu tanaman industri di Malaysia dan ia mempunyai pengaruh yang besar terhadap ekonomi sosial Malaysia. Industri ini memerlukan ciptaan yang baru dalam cara penuaian kepala untuk memenuhi pengedaran massa di seluruh dunia tetapi juga untuk mempertimbangkan keselamatan untuk pengguna dan kebolehpercayaan. Petani biasanya menggunakan kaedah tradisional seperti memanjat ke atas pokok kelapa atau meggunakan galah untuk memetik kelapa.Tujuan projek ini adalah untuk mereka bentuk pemetik kelapa dan mencadangkan satu sistem mekanisme yang akan berfungsi dengan bilah berputar yang sedia ada di pasaran. Penghasilan reka bentuk pemetik kelapa telah dijalankan melalui kaedah reka bentuk yang memberi pendekatan yang sistematik dan garis panduan dalam menghasilkan produk. Konsep reka bentuk pemetik kelapa telah dihasilkan mengikut keperluan pelanggan yang diterjemahkan ke dalam ciri-ciri kejuruteraan dan menghasilkan spesifikasi produk. Hasil daripada kajian ini, pemetik kelapa dengan mekanisme gear dipilih sebagai konsep terbaik bagi produk. Analisis matematik dan CAD telah dijalankan dan menunjukkan bahawa sistem mekanisme mampu menjana tenaga yang diperlukan serta produk struktur dapat menyokong daya yang dikenakan. Dengan pemetik kelapa ini, pengguna boleh memetik kelapa dengan lebih mudah dan kos yang rendah.

ACKNOWLEDGEMENTS

I would like to acknowledge with much appreciation the crucial role of Dr. Mohd Asri bin Yusuff, who gave permission for me to complete my final year project under his supervision. He is willing to teach patiently and guide me well in these two semesters of my final year project. He gives a lot of advices and encouragement to lead me to a correct way to complete my project.

Next, many thanks go to my course mates. Throughout these two semesters, we are giving supports and helps to each other. I am very appreciate with their full effort of helping when I am encountered with problems.

Last but not least, I would like to express my gratitude towards my parents for their kind encouragement which help me in completion of this project. With their supports, finally I am able to complete my project smoothly.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBEREVATIONS

QFD	Quality Function Development
HoQ	House of Quality
CRs	Customer Requirements
ECs	Engineering Characteristics
CAD	Computer Aided Design

LIST OF SYMBOLS

V	=	pitch-line velocity
d	=	Gear diameter
n	=	Gear speed
W_t	=	Transmitted load
H	=	Power
T	=	Torque
L	=	Radius of gear
F_c	=	Force transferred by chain driver
r_s	=	Radius of sprocket

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Coconut is the one of the oldest agro-based industries in Malaysia. It ranks fourth in the industrial crop of Malaysia after the oil palm, rubber and paddy in terms of total cultivated area. Coconut contributes very little to the overall economy of Malaysia. Recent, the total area of coconut cultivation is declined as the result of the competition with the oil palm for land. However, coconut now still has a great influenced on the social-economic of the Malaysia as it involves 80,000 households. There is about 63% of the total coconut production is used for domestic consumption while the 37% is for export and industrial processing purposes (Sivapragasam, 2008). In the world production of coconut, more than 50% is processed to copra. While some portion is used to produce end-products of coconut such as desiccated coconut, coconut milk powder and activated carbon. The rest of the production is taken in the form of fresh coconut and tender coconut for domestic demand (Punchihewa and Arancon, 2001).

As the high demand on the coconut, the coconut harvesting method become an important matter to be consider to ensure the production able to fulfill the demand of the country. Harvesting of the coconut can be done in different ways which depend on the size of the tree. In many popular coconut cultivating countries, the traditional harvesting method is used to pick the coconut from the tree. This traditional method is done by a skilled and experienced picker who has to climb up 30 to 80 feet high above the ground with bare handed

or the aid of a rope and taps the nut with its harvesting knife to test its maturity (Abraham et al., 2014).

In Malaysia, Indonesia and Thailand the pig-tailed monkeys are trained to climb the coconut tree and throw down the ripe nut (Raffauf, 1985). According to the National Primate Research Center at the University of Wisconsin, Madison, a height-savvy money to pluck the fruit from the trees up to 80 feet is safer than a human. Other than that, the harvesting of coconut also have been done with the help of a curve knife which attached to a long bamboo pole. The ripe nut are cut from the trees and collected from the ground. Furthermore, another simple method to harvesting coconut is to wait the nuts fall to the ground by themselves then collected by farmer.

Nowadays, there are many invention of the coconut harvesting device to help the farmer in plucking the nuts. Most of the invention is in form of the climbing machine to ensure the safety of the pickers. On the other hand, there has a design of rotary blade which can be used for the plucking coconut. However, this new design of rotary blade do not have any mechanism to cooperate with it. Therefore, a mechanism to be designed to cooperate with this rotary blade for the coconut harvesting purpose.

1.2 Problem Statement

Coconut plays a very important role in the economy of many developing countries. Unfortunately in spite of its mass distribution around the world, the coconut harvesting is still done without consider the safety and reliability which can lead to the casualties. Most of the coconut harvesting in cultivating countries is done by trained, skillful and experienced picker. The job of coconut picking is risky and unglamorous cause the number of coconut tree climbers has declined sharply in recent years as many young people is not interesting in this work. Therefore, the alternative method to pluck the coconut is done by a knife that

attaches to the long bamboo pluck. This method requires a lots of energy and causes the picker get tired easily. Recent, there has been an array of coconut palm climbing devices developed to assist and claim the safety during harvesting. However, there is still an acute shortage of trained coconut climbers for harvesting activities (Mani and Jothilingam, 2014). Furthermore, the coconut palm climbing devices is considered expensive for the smallholders who unable pay for the high cost. Therefore, a cheap and effective technology of coconut plucking device is required to allow the coconut harvesting process become easier and solve the problem of shortage of skilled picker.

There was a rotary blade that has been designed specialized for plucking the coconuts. This rotary blade is used the rotary mechanism to pluck the nut. However, there was lacked of the designing of the pole to operate with the rotary blade from the ground. Therefore, the designing of the pole is required to complete this equipment.

1.3 Objectives

The objectives of this project are:

1.3.1 To design a coconut plucking rod with advance mechanism.

1.3.2 To propose a mechanism system which to be cooperating with the existing rotary blade.

1.4 Scope of Project

This project focuses primarily on designing the coconut plucking rod with advance mechanism and how it cooperates with the existing rotary blade. The design of the coconut plucking rod is emphasized on the coconut tree which tall less than 5m. The analysis on the design will be done by CAD software. However, other aspects such as the production and marketing of the coconut plucking rod are not covered in this project.

1.5 Expected Result

This project is to design a coconut plucking rod with advanced mechanism which allows the user to pick the coconuts easily. A mechanism system with the ability to transmit the rotating mechanical to be proposed which to be cooperating with the existing rotary blade.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Research on the coconut tree have been done in order to understand its characteristics during the designing of the coconut pluck rod. The purpose on studying the harvesting method is a way to understand and generate some ideas on designing coconut pluck rod. The others harvesting tool in the market also have been identified. The characteristic of the material also been emphasized in this literature studies. Next, the design process also have been explained in this chapter for acting as a guideline in designing of the coconut pluck rod.

2.2 Morphology of Coconut Palm

Coconut palm which also known as cocos nucifera is a monocot perennial member of the Arecaceae (palm family), typical cultivated in the tropical countries. Coconut is particularly important to many tropical countries as it are part of the daily diet of many people. Its usefulness as well as its adaptability to various ecological conditions made it favours by worldwide. (Ohler, 1999). In many domestic and industrial have use its different parts for different purpose such as the oil extracted from its kernel are commonly used in cooking; the shredded kernel is sold as desiccated coconut used in food and confectionary. The coconut water obtain from the young nuts is a refreshing beverage. The husk and shell can be used for furnishing and decorating. Other than that, coconut wood also have being used for house building and other uses such as tool handles. Therefore, coconut is known for its great versatility.

The coconut palm can reach up to 25m in height and sometimes can reach about 30 which depends on the ecological conditions and age. It is topped with a terminal crown of leaves up to 4 meters long. Its trunk is smooth, columnar and light grey-brown with a mean diameter of 30-40cm at breast height. Leaves is in pinnate shaped with 4 to 7 m long and can reach to 1.5 wide at the broadest part (Orwa et al., 2009).

Figure 2.1 Coconut plams (Cadiz, n.d.)

Inflorescence can be divided into two which are male and female axillary flowers. Male flowers small and numerous on the upper part while female flowers are much larger than the male with spherical structures. However, the female flowers fewer and once in a while completely absent. Fruit avoid and size can up to 15 to 25cm or more in green or yellowish. It is composed of a thick fibrous mass and inner wall lined by white endosperm matter and a milky fluid containing cytokinins (Santos et al., 1996).

Figure 2.2 Inflorescence (Cadiz, n.d.)

2.3 Harvesting

The coconut palm average able to produce 12 inflorescences in one year. However, some of the inflorescences are likely to abort into fruit brunches and some of them may fail which are depended on the ecological conditions (Thampan, 1989). Consequently, the frequency of the harvest vary among countries and even among provinces within the same country. In some areas of India, Sri Lanka and Philippines, the harvesting is done six times of a year. In Kerala, the harvesting could be done at 45 to 60 interval. The recommended harvesting cycle is every 45 days for practical and economic reasons. In the properly managed farm, two or three brunches of coconut could be harvested from each palm by following this cycle. This harvesting cycle has been found that can yield to a good number of mature nuts with high copra and oil recovery (Punchihewa and Arancon, 2001).

The harvesting coconut is carried out in different method which depends on the size of the grove and the products desired. The producers of certain countries, especially from Pacific do not harvest their coconut. The mature nuts are just left to fall on the ground and gathered them up by the farmer at regular intervals. In such harvesting method where the crop is normally for direct consumption and not highly commercialized. This method may

cause the lost for huts where that impact damage to the nuts may occur (Raffauf, 1985). There are two common methods of harvesting coconuts which are the pole and climbing method.

2.3.1 Pole Method

The pole method of harvesting is common method used in the region of many countries. This harvesting is done from the ground with the help of a knife attached to the end of a long bamboo pole. The bamboo is normally about sixteen feet long. The ripe nuts are cut from the palms and collected from the ground immediately. Sometimes the unripe nuts may also harvested due to mistake of the farmers. The dwarf varieties are the easiest to harvest by using this method.

Figure 2.3 Pole method (Michael, 2015)

2.3.2 Climbing Method

The climbing method is used when the tall varieties of coconut palm grow to a height beyond the reach of the cutting pole. This method normally for the palm is about 30 feet to 80 feet high about the ground (Raffauf, 1985). The harvesting is done by a skilled and

experienced climber who reach to the top of a coconut tree and taps the nut with its harvesting knife to test its maturity. A number of climbing methods have been found and the most of the climber uses the rope harness encircles the trunk which allow the climber to move up and down the palm. Climbing also done by cutting notches on the trunk and is generally done barefoot. Once the climber reach the crown, examines the maturity of the nut bunches and cut down it. At the same time, climber also clean up the top of trees such as removes the dry leaves, sheaths and spathes.

There are many invention of palm climbing device in helping the harvesting operations to ensure the safety of the climbers. This device is more efficient as compared with manual climbing. There are around 80 tress are harvested in a day. This also have increase the safety of the climbers and prevent them from falling down from the tree. In research station and seed farms, the gadget could be useful for breeding purposes.

Figure 2.4 Climbing method (Nethrapalli, 2005)

2.3.3 Trained Monkey

There is a third harvesting method which only practiced in Thailand, Malaysia and Indonesia. This method involves a trained monkeys to climb up the palms and throw down the ripe nuts. According to the National Primate Research Center at the University of

Wisconsin, Madison, a height-savvy money to pluck the fruit from the trees up to 80 feet is safer than a human.

Figure 2.5 Trained Monkey (Wlnograd, 2016)

2.4 Limitation of Harvesting Method

Even though both of the pole and climbing method require the experienced and skilled labour to perform safely and efficiently, but each has own advantages and disadvantage. It has been observed that the climbing method is slower and more expensive as compared with the pole method. A man able to cover at least 250 trees a day while the climber can hardly cover about 50 trees (Punchihewa and Arancon, 2001). Therefore, the harvesting using bamboo poles is generally faster, efficient and less dangerous. On the other side, the harvesting by climbing method can inspect the crown of the palm for pest and disease attack. However, the cutting of notches in the trunk is not suitable for timber purpose and fractures serve as entry points for pests. Harvesting coconuts by using trained monkeys is considered efficient and cost effective especially in the countries where there is shortage of skilled labour.

2.5 Harvesting Tools in the Market

2.5.1 Motorized Cutter

Motorized Cutter or known as CANTAS is harvesting tool which developed by The Malaysia Palm Oil Board. This machine is able to harvest the fresh fruit bunches at the height less than 4.5m. According to Fancy Power Sdn. Bhd. (n.d.), CANTAS drive by a 2-stroke petrol engine with a special designed chisel and C-shape of sickle. This machine uses the rapid chopping concept of cutting edge to provide the faster harvester and more efficient in productivity.

Jelani et al. (2008) found that this technology could double the productivity and increase the profits. Trials carried out on Cantas revealed that the productivity of the machine was 560 to 750 bunches per day while the manual harvesting is only 250 to 350 bunches per day. The productivity of Cantas is about to two or three times for human harvesters. Furthermore, this technology would be able to reduce 50% of the labour requirement in the harvesting operation. The most important of the invention of this technology is to overcome the labour shortage problem which the oil palm industry are facing.

Figure 2.6 Motorized cutter Cantas (Etani, 2015)

2.5.2 Mechanical Harvesting Machine

Shaking principles were used as the mechanism in designing the olive harvesting machines during the past decades. (Ravetti, 2008). The trunk shakers was one of the designed harvesting machine. The shaker could use to shake the main trunk or each scaffold branch. As the result the fruit unattached and fall on the net or into a collecting device. This harvesting machine able to use in any shape of tree, but it will function better with a tree of 70-100cm high of trunk and scaffold branches in 40 to 50 degree angle. However, Castro-Garcia and et al. (2009) stated that the damage on the tree configuration and fruit are the major constraints to the adoption of mechanical harvesting. Fruit mechanical harvesting had about 35% of fruit bruising. Other than that, it had three times of fruit with broken skins as compared to hand harvested fruit.

On the other hand, this shaking principles also had been designed as shaker rake. This equipment powered by 12V battery and consists a converter. It provided the user with 4 to 8 times faster in harvesting as compared with manual harvesting. It was cost effective due to it zero fuel consumption and low maintenance cost. This equipment ease to use and the most important is not damage on the tree and fruit.

Figure 2.7 Mechanical harvesting machine (Pellenc, n.d.)

2.5.3 Clip and Pick Fruit Picker

This picker was designed to harvest the difficult reach fruits and nuts such as avocado. This equipment utilized the U-shaped cutting blade which fixed at the end of the pole. After the cropping of the nuts, the nuts straight dropped directly into the bag (Betherlehem, n.d.). This mechanism provides handpicked quality produce without causing the damage on the fruit. The telescopic aluminium pole allow to extend from 2.4m to 4.8m.

Figure 2.8 Clip and pic fruit picker (Sears, n.d.)

2.5.4 Rotary Blade Picker

Rotary blade picker is a plucking tool which particular designed for helping the farmer in coconut harvesting. This tool is used the rotary mechanism to cause the coconut falls into the ground. It consists of few components such as frame, gear system, pulley system and rotary blade (Nur, 2015). The frame is made from mild steel which acted as the support for whole system. The gear and pulley system is the transmission system of this tool. The movement is transmitted from the power source through the gear system and pulley system to cause the rotary blade rotates. The rotary blade is designed to make from mild steel instead

of carbide after the consideration of the application of the tool. The tool is a new design for the coconut plucking tool which used the concept of pole method. However, the advanced mechanism is added to the product in order to bring the convenient to the farmers during harvesting.

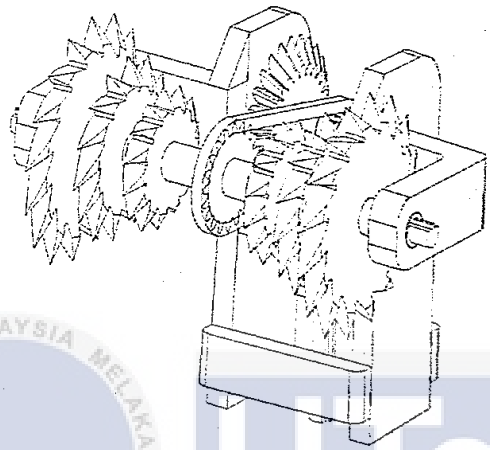


Figure 2.9 Rotary blade (Nur, 2015)

2.6 Material of Plucking Pole

Bamboo is the common material which used as the coconut plucking rod due to its naturarity. Bamboo is classified as a grass and not a wood. It is one of the fastest growing plants on Earth with a recorded of growth rates of 100cm in 24 hours. However, this is dependent on the soil cand climatic condtions as well as species (Dassoxtr, n.d). Most typical growth rate of bamboo is in the range of 3cm to 10cm per day. Primarily growing in warmer climates region and vast fields in Asia. Its steams are ready for harvesting within 5 years. Bamboo properties make it suitable for a wide range of application such as construction, textiles, wood and paper industries. Due to its flexibility, bamboo is also widely used as pluck rod as well as coconut pluck rod. Even though the bamboo is used in many application but without any protective treatment, most of the bamboo only have an average natural durability of less than 2 years (Schoder, 2014).

Figure 2.10 Untreated bamboo pole (Schoder, 2014)

Other than that, the PVC pipe and stud pine also is used as the coconut pluck rod due to light in weight and ease to get from market.

2.7 Design Process

The design process is a systematic activity and a set of guidelines that helps to produce a successful product to satisfy that encompasses product, process, people and organization. It enable the designers to follow the systematic approach to design and help them guide their creativity and technical problem-solving skills to a satisfactory end (Haik and Shahin, 2011).

There are various forms of the systematic design process. Basically, they include the same following basic principles:

a) Requirement

b) Product concept

c) Solution concept

d) Embodiment design

e) Detailed design

2.7.1 Customer Requirement

Identifying the needs of the customer is the critical step in the design process. However, it is important to establish who the customers are before the needs of customer is defined. Customers of a product mean here not only the end users, it include everyone who will deal with the product at some phase during its lifetime (Haik and Shahin, 2011). One of the example is the product must attractive the seller to agree to advertise and market it. Customers usually define their needs by using their own expressions with many dimensions to be satisfied simultaneously. The needs sometimes may conflict for the same product. Defining all the needs and achieve at a reasonable compromise according to priority and feasibility. Knowledge of the customer needs is a must requirement in order to ensure the design product able to satisfy the customer and have the competitive with the products in the market.

2.7.2 Market Analysis

The identification of the customer requirement can be done in different ways. Either directly approach to the customer as stated in section 2.6.1 or find an opportunity in the market by identifying the need for new or improved product. Designer must know what is already available in the market and what they can offer to the customers. The following sources may consult to gather all the relevant information and determine market availability:

a) Technical and trade journals

b) Abstracts

c) Research reports

d) Technical libraries

e) Catalog of component suppliers

f) U.S patent office

g) The internet

The information gathered not only can save the time and money and may become an available design solution and the hardware to accomplish the goal. The creativity should be directed generating alternatives once the designer defined what is in the market.

2.7.3 Specifications

Specifications is a statement which made at the early stage of design process. It details the requirement of the products that required to meet in order for the product to be successful. It ensures that all relevant factors are accounted for and all stakeholders are heard from. The designer requires to list all pertinent data and parameters that tend to control the design and guide it towards the desired goal. It shows the limits on the acceptable solution but it should not defined in too narrow way, this may lead to eliminate the acceptable solution. However, it also cannot be too broad till cause the designer no direction to satisfy the design goal.

2.7.4 Conceptualization

The conceptualization is a process of generating alternative solution to the stated goal. The designer must review the market analysis and task specifications in this stage as he is in the process of creativity and innovation. A series of alternative solution is produced by free-hand sketches in this stage. However, the alternatives do not need to state the detail but are recorded as possibilities to be tested.

2.7.5 Concept Evaluation

Once the concepts are generated, they need to be evaluated to ensure that the solution is finally adopted is the one of the meets the product design specifications. Evaluation

implies both comparison and decision making. An excellent technique to guide for making the best decision regarding these alternatives is the scoring matrix. This method uses evaluation criteria derived from the PDS to compare design concepts. This method is an iterative evaluation that tests the completeness and understanding of requirements, quickly identifies the strongest concept.

2.7.6 Embodiment Design

Once the concept design has been finalized, the embodiment design is take place where the designed product begins to take shape. This stage will begin to illustrate a clear definition of part such as how it will look. How it interfaces with others part in the product assembly. However, the details of the product such as dimension and tolerances do not include in this stage. A new technologies may come out to replace the old ones which exact same concept in this stage. Therefore, this stage is separated from the concept design and the detailed design.

2.7.7 Detailed Design

Once the synthesis phase of the design has been completed, the analysis phase begins which now as detailed design. The solution is essence to test against the physical laws. The manufacturability of the product also required to analysis to ensure it usefulness. A product may satisfy the physical laws but cannot be manufactured, it is considered as useless product, vice versa. A concept to be altered or redefined then reanalysed in this stage. Therefore, the design is constant shifted between the analysis and synthesis as this stage is put it iterative sequencing with the original synthesis phase. Analysis starts with estimation and follow by ordering of magnitude calculation.

2.8 Mechanism

In term of engineering, mechanism is defined as n the rigid bodies that connected by joints in order to accomplish a desired force or motion transmission. It is a device used to the transfers of a force and motion from a source to a desired output. Mechanisms normally involved of moving components such as gear trains, cam, belt and chain drivers as well as linkages.

2.8.1 Sprockets and Chain

Sprockets and chains is a method for transferring rotating motion from one shaft to another. The sprocket is a profiled wheel with teeth that mesh with a chain. The ratio of its diameter is related to the speed of the system. This mechanism are usually used on bicycles, camshafts and motorcycles to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track. One of the advantages of this mechanism is it provide direct drive with no slippage.

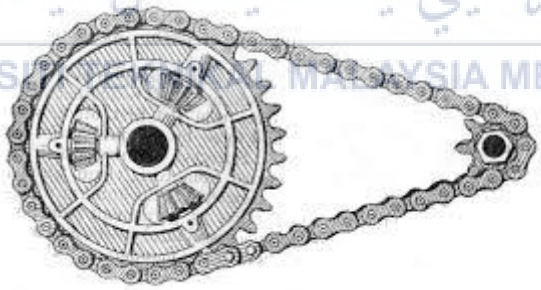


Figure 2.11 Sprockets and chain (Sclater and Chironis, 2001)

2.8.2 Gear Trains

A gear is a wheel with evenly sized and spaced teeth machined and formed around its perimeter. Gear train involves two or more gears to transmit motion from one shaft to another and gearing is a system of wheels or cylinders with meshing teeth. Gears are knowns

as versatile mechanical components as it capable of performing many different kinds of power transmission or motion control such as changing rotational speed, changing rotational direction and multiplication or division of torque or magnitude of rotation (Sclater and Chironis, 2001).

Gears can be divided as either external gears or internal gears. External gears have teeth on the outside surface of the wheel while internal gears have teeth on the inside surface of a ring. Figure show the example of the external and internal gear. Examples of external gear are spur gears bevel gears, helical gears, and herringbone gear. An internal gears as shown in Figure 2.12 is a variation of the spur gear except that its teeth are cut on the inside of a ring rather than on the outside. Internal gears usually drive by a pinion.

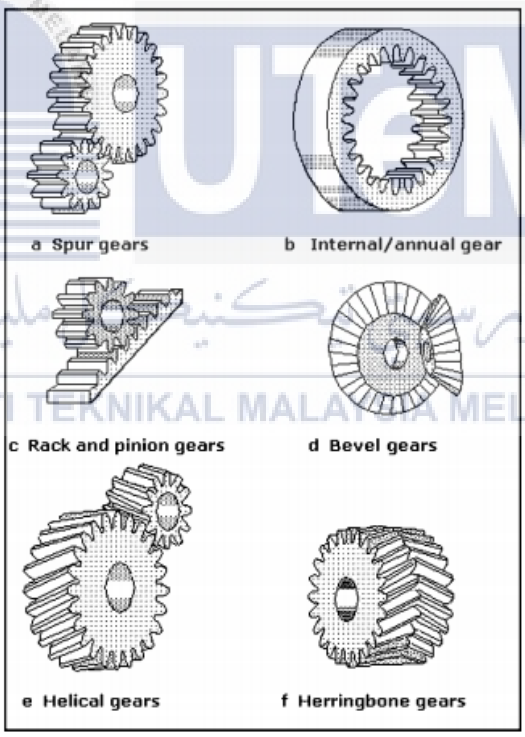


Figure 2.12 Example of the external and internal gear (Sclater and Chironis, 2001).

2.8.3 Cam Mechanisms

A cam is a mechanical component capable of transmitting motion to a follower by direct contact. In a cam mechanism, the cam is the driver and the driver member is called as

follower. The follower can remain stationary, translate, oscillate or rotate which depend on the desired output. Figure 2.13 illustrates the general form of a plane cam mechanism. It consists of two shaped members A and B with connected by a third body, C. in this case, either body A or body B can be the driver, while the others body become the follower. The any change is made in the relative positions of bodies A and B, point 1 and 2 are shifted.

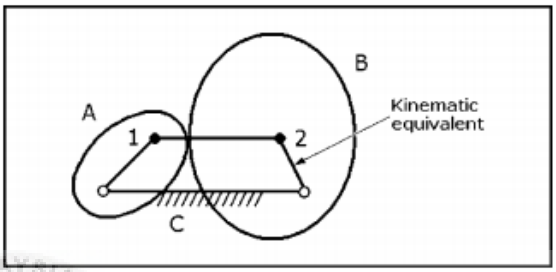


Figure 2.13 General form of a plane cam mechanism (Sclater and Chironis, 2001).

2.8.4 Pulleys and Belts

As same as sprockets and chain mechanism, pulleys and belts system also transfer rotating motion from one shaft to another. A belt is used to link two or more shafts mechanically in parallel. Pulleys without teeth are depended on the frictional forces of connecting belt to transfer torque. If the pulleys with different size are used, the mechanical advantage and velocity ratio are gained. The velocities of pulleys are inversely proportional to their diameters. One of the disadvantages for this mechanism is slippage may occurred. However, there was a type of belt known as timing belt may use to prevent this problem

Figure 2.14 Pulleys and belts (Sclater and Chironis, 2001).

2.9 Bevel Gears

Bevel gears are gears where the axes of the two shaft intersect and the tooth-bearing faces of the gears themselves are conically shaped. They are widely used due to their suitability towards transferring power between nonparallel shafts at almost any angle or speed. American Gear Manufacturing Association (AGMA) has developed standard for the design, analysis and manufacture of bevel gears. For any general design employing gears, the first thing that need take into consider is to understand all of the conditions under which the gears will operate. The most important are the anticipated loads and the speed that will affect the design of the gear. The other concerns that need to take into account are the operating environment, lubrication, life of operation and assembly processes (Brown, 2009).

The bevel gear are available in straight, spiral or hypoid shape. The bevel gear with no profile shifted tooth is a standard straight bevel gear. Table 2.1 is the formula that used to design a standard straight bevel gears according to Figure 2.15.

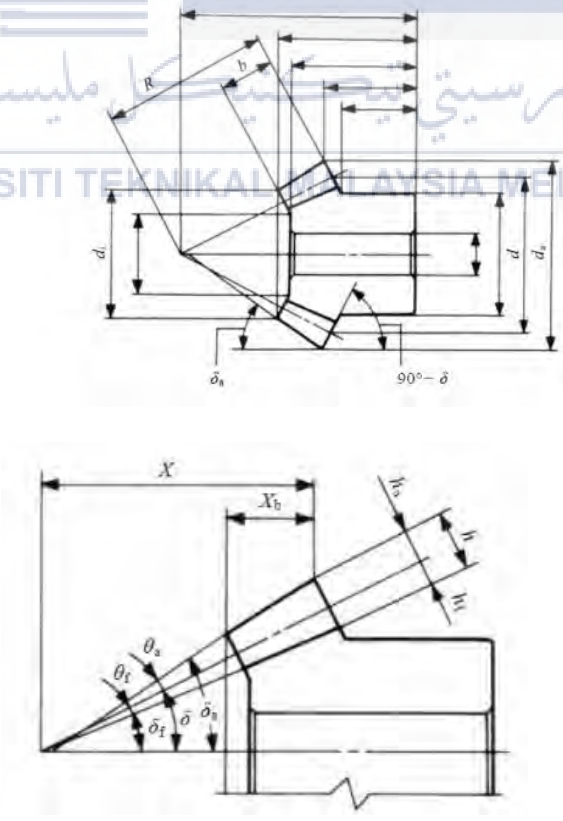


Figure 2.15 Dimension and angles of bevel gear

Table 2.1 The formula for standard straight bevel gear

No.	Item	Symbol	Formula
1	Shaft angle	Σ	Set Value
2	Module	m	
3	Reference pressure angle	α	
4	Number of teeth	z	
5	Reference diameter	d	zm
6	Reference cone angle	δ_1	$tan^{-1}\left(\frac{sin\,\Sigma}{\frac{z_2}{z_1}+cos\,\Sigma}\right)$
		δ_2	$\Sigma-\delta_1$
7	Conde distance	R	$\frac{d_2}{2sin\delta_2}$
8	Facewidth	b	It should not exceed R/3
9	Addendum	h_{a1}	$2m-h_{a2}$
		h_{a2}	$0.54m+\frac{0.460m}{\left(\frac{z_2 cos\delta_1}{z_1 cos\delta_2}\right)}$
10	Dedendum	h_f	$2.188m-h_a$
11	Dedendum angle	θ_f	$\tan(h_f-R)$
12	Addendum angle	θ_{a1}	θ_{f1}
		θ_{a2}	θ_{f2}
13	Tip angle	δ_a	$\sigma+\theta_a$
14	Root angle	δ_f	$\sigma+\theta_f$

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology for designing the coconut plucking rod with advanced mechanism. The design methodology is a systematic activity and a guidelines that helps to produce a successful product to satisfy that encompasses product, process, people and organization. It also draws on reliability study where the process enhance the dependency on the system applied adequately in harvesting of coconut. Figure 3.1 shows the systematic design process which are important for any design, irrespective of domain. The design process includes the identify customer requirement, product design specification, conceptual design, concept evaluation, embodiment design and detail design.

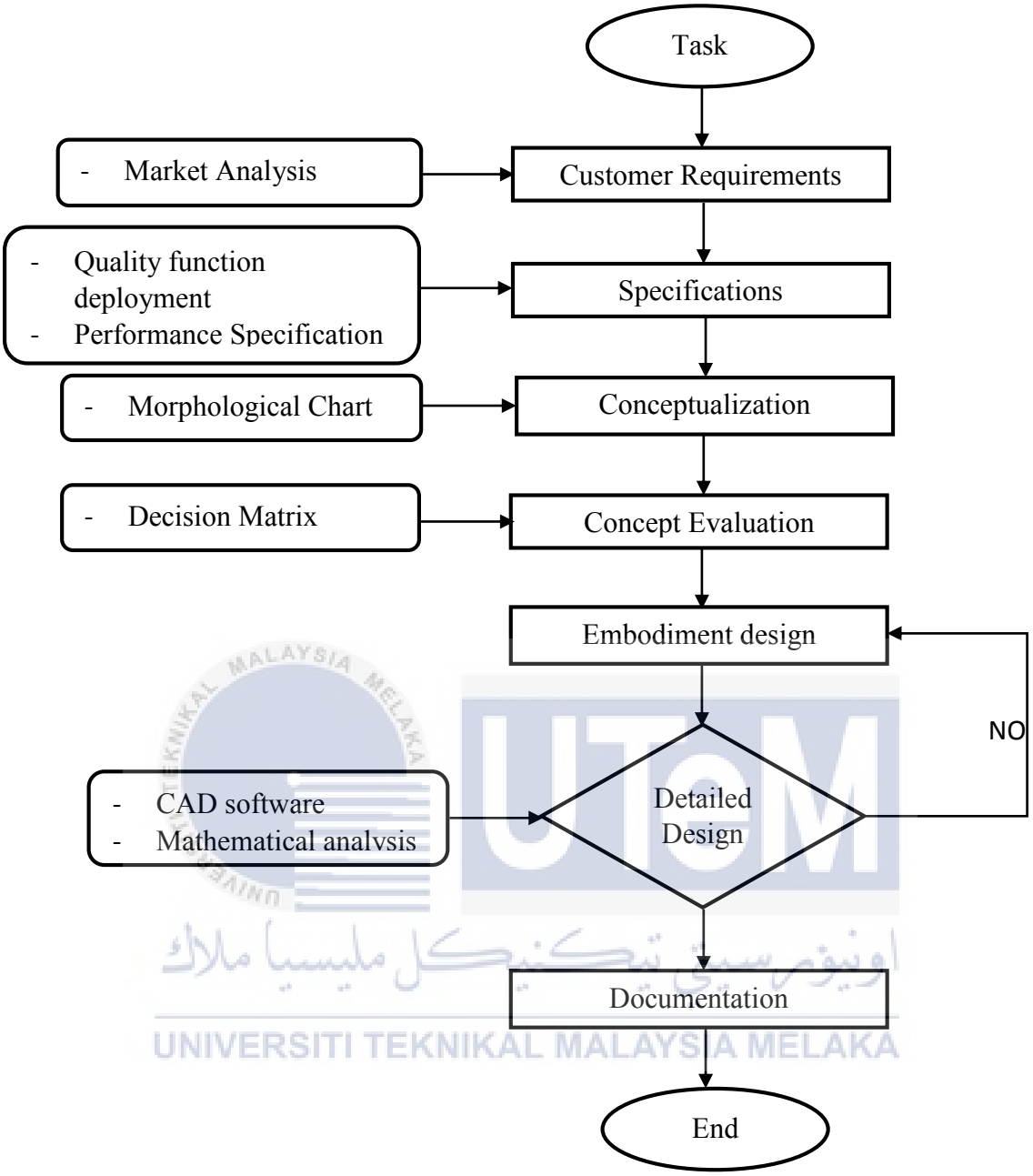


Figure 3.1 Flow chart of design process

3.2 Customer Requirements

As mention in the section 2.6.1, the knowledge of the customer needs is a must requirement in order to ensure the design product able to satisfy the customer and have the competitive with the products in the market. In this research, the voice of the customer was obtained through the marketing analysis.

3.2.1 Market analysis

Market analysis was done through the different sources with the aims to gather all the relevant information and determine the market opportunity. Information was gathered from the different sources such as journals, patent, research reports as well as book. Through the market analysis, the problem statement was defined. After that, a strategy was developed for the search process. Next, the relevant information was organized and checked.

3.3 Specifications

3.3.1 Quality Function Deployment

Quality function deployment (QFD) is a planning tool that defines a list of delights, wants and needs of the customers to translate them into engineering characteristics in the initial step of the product development process. The relationships are explored between the quality characteristics which expressed by the customer and substitute quality requirements expressed in engineering terms with the application of QFD. House of quality is the basis tool of the management approach of quality function deployment. It is a systematic and graphical method that used to translate the customer requirements which obtained from marketing research and benchmarking data, into technical requirements. Figure 3.2 is the house of quality which consists the information on Whats (CRs) and Hows (ECs). The Whats

represent customer needs and expectations while HOWs is the quality characteristics. In the middle part of the house of quality is defined that relationships between what the customer wants and how those wants are to be realized. Qualitative correlations are identified between the various Hows. Competitive assessment and importance ratings are developed as a basis for risk assessment when making decisions relative to trade-offs and compromises.

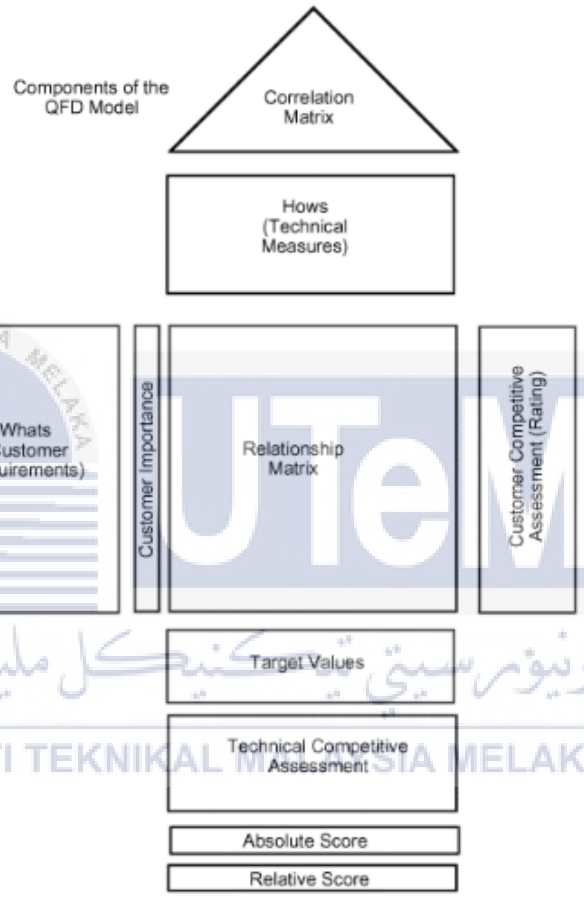


Figure 3.2 HOQ of configuration (Squires, n.d.)

3.3.2 Performance Specification Method

The aim of setting the performance specification is to make an accurate specification of the performance required by the coconut pluck rod. It is important to have the specific requirements of performance for the coconut pluck rod to fulfil the demand and need. The

specifications of the product were summaries from the literature study on the harvesting method and product in the market.

3.4 Conceptualization

Conceptualization is a process to generate alternative solution to the stated goal. A series of alternative solution will generate by free-hand sketches based on the criteria that to be developed in the morphological chart.

3.4.1 Morphological Chart

A morphological chart is a visual way to present the essence product functionality and explore alternative means and combinations of achieving that functionality. There can be a number of possible solutions for each element of product function. The chart enables these solutions to be expressed and provides a structure for considering alternative combination.

The process to develop a morphological chart includes three step:

a) Define the features or sub-function that are essential to the product.

b) Identify all the possible solutions for each features.

c) Sketch a chart that contains all the possible sub-solution.

3.5 Concept Evaluation

The concepts are evaluated once they have been done. Evaluation of these conceptual design is to determine which of the solution is adopted and meets the product design specifications. The decision matrix method will be used as the tool to evaluate the conceptual design.

3.5.1 Decision Matrix Method

Decision matrix method or also known as Pugh method is a tool for concept selection. It compares the alternatives design with respect to multiple criteria of different levels of importance. Comparison of the scores generated gives insight into the best alternatives.

In order to construct a decision matrix, the criteria for comparison will be defined. A set of weight will be generated to define the relative importance of the criteria. An existing product is set and used as the datum. After that, computed the total score. The highest score of the alternative will be the best solution in this study.

3.6 Embodiment Design

Embodiment design is the connector between the conceptual design and detailed design. This stage included a more detailed analysis on the selected concept such as definition of layout, preliminary form design, preliminary production information, materials and process selection and industrial design. The main purpose is to establish concept development to refine concept sketches as a distinct stage in the design process by identifying the steps and rules employed.

3.7 Detail Design

In detail design, it includes the complete manufacturing drawings with dimensions, tolerances, material selection and manufacturing details. The activities in detail design phase are as follow:

i. Complete the selection and sizing of the component with refer to engineering standard.

ii. Making decision on the basic cost and manufacturing capacity.

iii. Documentation of the engineering drawing of each component with subassembly and assembly drawing.

iv. Complete the bill of materials list on each individual component in the product with the estimated product cost.

v. Final design of the product.

3.8 Design Tool

Design tool can be an object or media as well as computer program which can be used to design a drawing. There are several tools to be used for the production of the design from the basic sketch up to the specific design. The design tolls to be used in this project are:

i. Sketch drawing

ii. Solidworks software

3.9 Result Analysis

Result analysis to be done in order to provide the detail of every single data. The analysis can be done in mathematical model of the structure and run the simulation on the parts of the system. There are some assumptions or theoretical aspects to be made in some case to complete the analysis and get the result.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter describes about the process of the development on the coconut plucking rod design. The development of the coconut plucking rod design is obtained through a series of systematic design methodology.

4.2 Customer Requirements

4.2.1 Research analysis

Based on the research and analysis from the sources such as journal as well as internet article, there are different mechanism used in the harvesting of fruit. However, most of the harvesting equipment are not available for plucking the coconut. There do not have any specialized equipment for plucking coconut in term of the pole. Normally, the labours use the pole method or climbing up the tree to do the plucking process manually. According to the research, it also shows that by using the pole method, a man able to cover at least 250 trees a day as compared with the climbing method. However, this method only suitable for the coconut palm which height not more than 15m. Harvesting by the pole method required a larger force. Therefore, the labour's hand will get tired easily.

There are the lists of customer requirements that identified through the research and view that have been made:

i. Light in weight

ii. Easy to use

iii. Low in cost

iv. Long lifetime

v. Safe to operate

vi. Low maintenance

vii. Less energy to function

viii. Ease to maintenance

ix. Quality material

The customer requirements have been clarified by using the objective trees as shown in Figure 4.1.

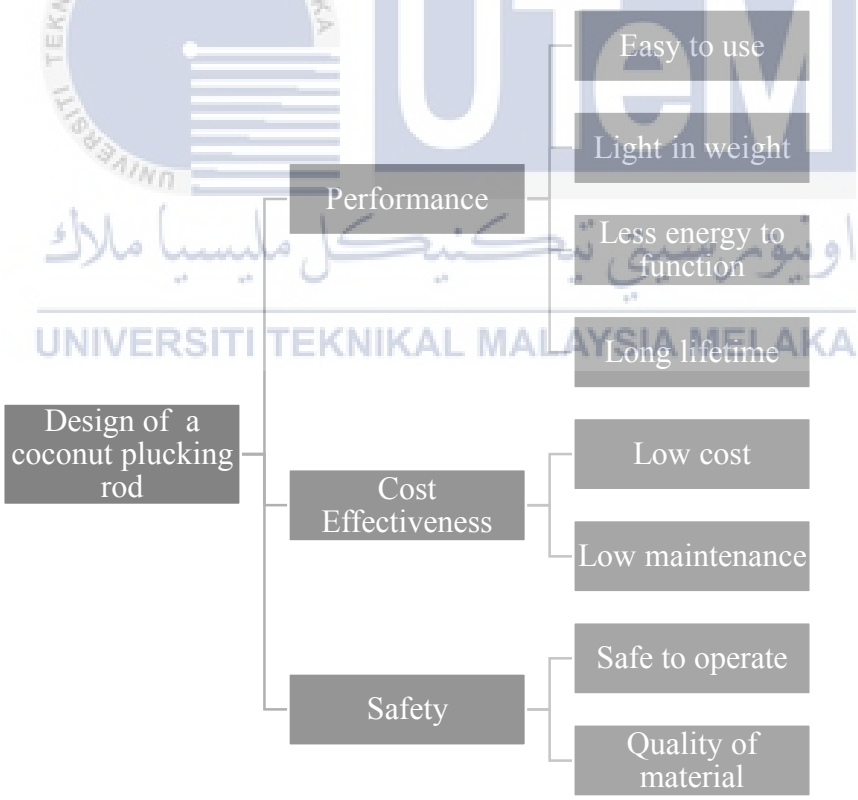


Figure 4.1 Objective tree of customer requirements

4.2.2 Survey

The information that gathered from the interview with the coconut farmer is to define the current harvesting method and also the difficulties that faced. As the result, the farmer is using the ladder and rope to pluck the coconut from the tree. The rope is tied on the nut to avoid it from free falling to the ground that may cause the damage to the nut. The tool that used is normally is 6 to 10m in length. The weight of the tool is less than 1kg which always can use up 1 to 3 years.

The difficulties that faced by the labours are they required large energy during the harvesting of the coconut. Another difficulty is about safety where the labours have to climb up the tree by using ladder made from the wood. The criteria that will be considered during buying a new coconut pluck tool is the cost.

Figure 4.2 Interview session with coconut labour

Figure 4.3 Coconut farm

4.2.3 Relative Importance of the Customer Requirements

The relative importance of the customer requirements for designing a coconut plucking rod is determined by using the digital logic method and the weight method. The weight factor is important to identify the essential and priority of product design specifications in the designing of the coconut plucking rod. Table 4.1 shows the application of the digital logic method to determine the relative importance of customer requirements.

Table 4.1 Determination of relative importance of customer requirements by using digital logic method

Customer	**Decision Number**													
Requirements	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Light in weight	1	1	1	1	1	0	1							
Easy to use	0							0	1	0	1	0	1	
Low cost		0						1						1
Long lifetime			0						0					0
Safe to operate				0						1				
Low maintenance					0						0			
Less energy to function						1						1		
Quality of material							0						0	

Customer	**Decision Number**													
Requirements	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Light in weight														
Easy to use														
Low cost	1	1	0	0										
Long lifetime					0	1	0	1						
Safe to operate	0				1				1	0	1			
Low maintenance cost		0				0			0			0	1	
Less energy to function			1				1			1		1		1
Quality of material				1				0			0		0	0

Table 4.2 Weighting factor for customer requirements

Customer Requirements	Positive Decision	Weighting factors, α
Light in weight	6	0.21
Easy to use	3	0.11
Low cost	4	0.14
Long lifetime	2	0.07
Safe to operate	4	0.14
Low maintenance cost	1	0.04
Less energy to function	7	0.25
Quality material	1	0.04
Total	**28**	**1.00**

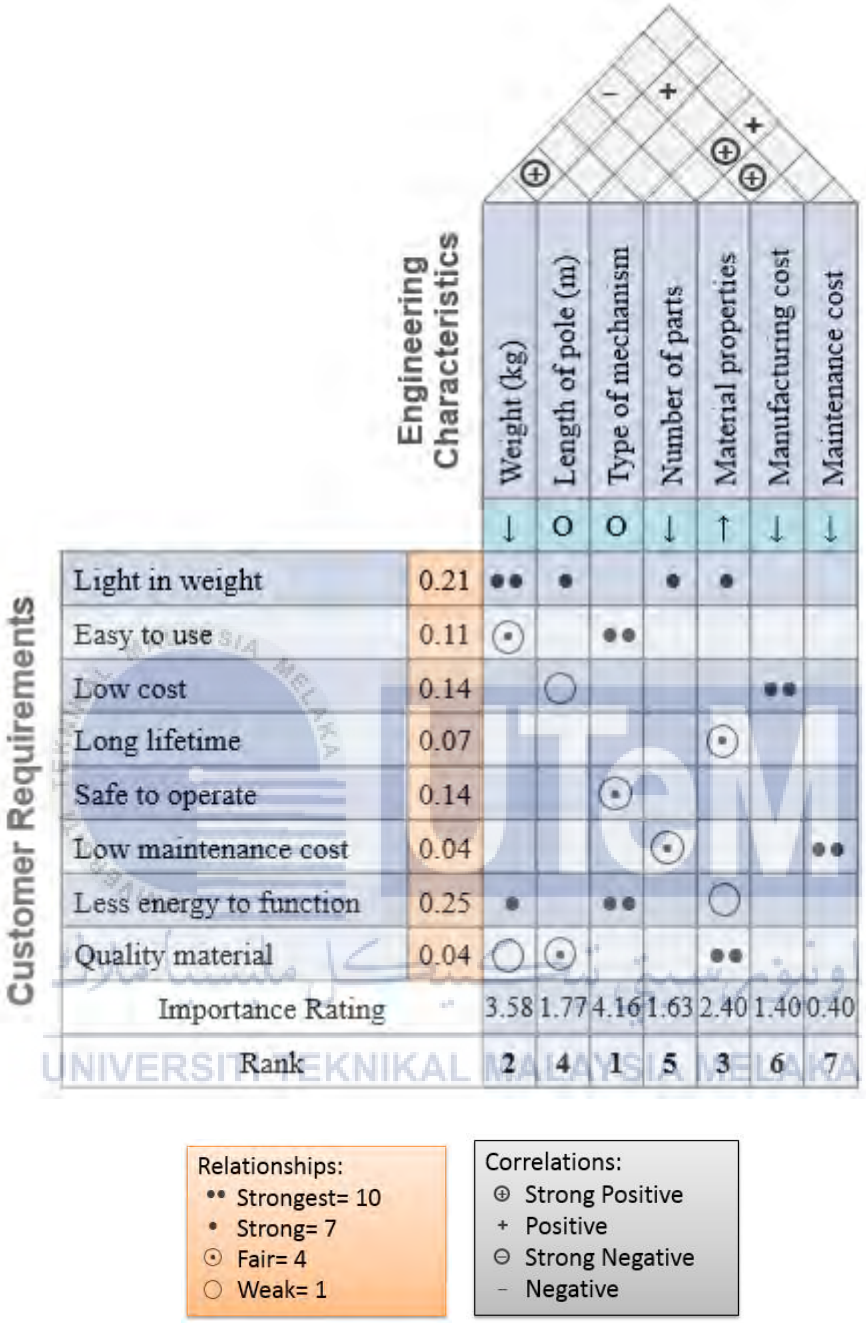
According to the weighting method as shown in Table 4.2, the priority in the designing of the coconut plucking rod is less energy to function and it follows by light in weight. The cost and safety of the coconut plucking rod also are the important specifications that need to consider during the designing of the product. However, the maintenance cost and the quality material of the product are the less important specifications to be considered.

4.3 Specifications

4.3.1 Quality function deployment

The house of quality method is employed to translate the customer requirement into engineering characteristics and to determine the essential product specifications which as shown in Table 4.3. The importance rating of the customer requirements is based on the weighting factor that obtained in the previous section.

Table 4.3 House of quality for coconut plucking rod



Based on the house of quality analysis, the type of mechanism is the priority to be emphasized during the concept generation of the product. It is followed by the weight, material properties and length of pole as these characteristics have high impact of the use of energy. The number of part and manufacturing cost are the moderate important

specifications to be considered in the designing of coconut pluck rod. However, the maintenance cost is the less important in this study.

4.3.2 Performance Specification Method

Product design specifications (PDS) are used for analysis and design the conceptual design with the aim to achieve a specified degree of performance, safety, efficiency as well as a common standard of good design practice. There have seven product design specifications which are performance, weight, length of pole, material, operating mechanism, product cost and safety are considered in the development of the coconut plucking rod. Table 4.4 is the summarized for the product design specifications for coconut plucking rod.

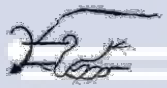
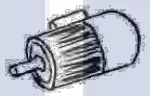
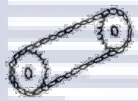
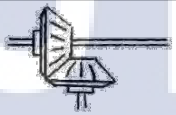
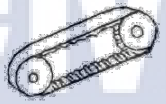
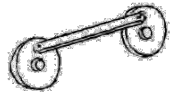
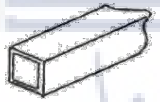
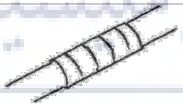
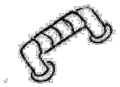
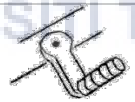
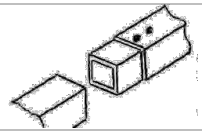
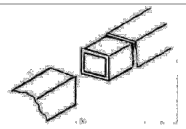
Table 4.4 Product design specifications for coconut plucking rod

Criteria	Specifications
Performance	• Cooperate with the existing rotary blade to harvesting coconut
Weight	• Light weight (Less than 5kg)
Length of pole	• 5m
Material	• Strength • High durability
Operating Mechanism	• Simple mechanism • Easy to operate
Product cost	• Low fabrication cost • Low maintenance cost
Safety	• Should not have effect to the coconut palm • User friendly

4.4 Conceptualization

4.4.1 Morphological Chart

Table 4.5 Morphological Chart

CRITERIA	IDEA 1	IDEA 2	IDEA 3	IDEA 4
Power Source				
Type of Transmission Mechanism				
Shape of Rod				
Hand Grip				
Rotating Handle				
Connection of the rod				

4.4.2 Conceptual Design

There are five concept designs that generated based on the criteria in the morphological chart. The designs focus on the transmission mechanism with the function to transmit the mechanical power from the bottom of the rod to the rotary blade. The shape of the rod, the handle grip, rotary handle and connection of the rod also have been selected after the consideration of the mechanism.

4.4.2.1 Concept 1

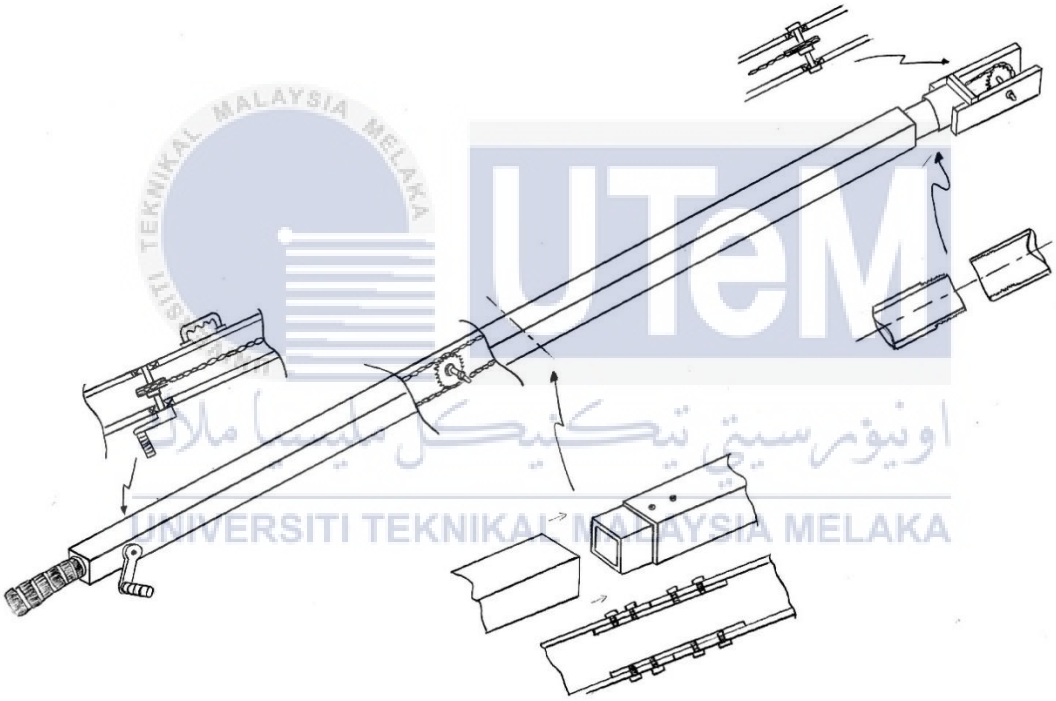


Figure 4.4 Sketch view of concept 1

The main mechanism used in this concept is chain drive where the mechanical power is transmitted from one place to another as shown in Figure 4.4. This type of chain is known as roller chain. The power is conveyed by a roller chain, passing over a sprocket gear, with the teeth of the gear meshing with the holes in the links of the chain. The rotating of the handle at the bottom of the rod cause the gear to turn, and this pulls the chain putting

mechanical force into the system. Other than the driver and driven gear, there has another two gear are placed in the middle of the driver and driven gear to assist and guide the transmission of the mechanical power as the mechanical power is required to transmit in a long distance. This concept allows no slip during the chain driver, hence the perfect velocity ratio is obtained. Since the chains are made of metal, therefore they occupy less space in width as compared with a belt drive. However, the production cost of chain is relatively high and it needs accurate mounting and careful maintenance.

4.4.2.2 Concept 2

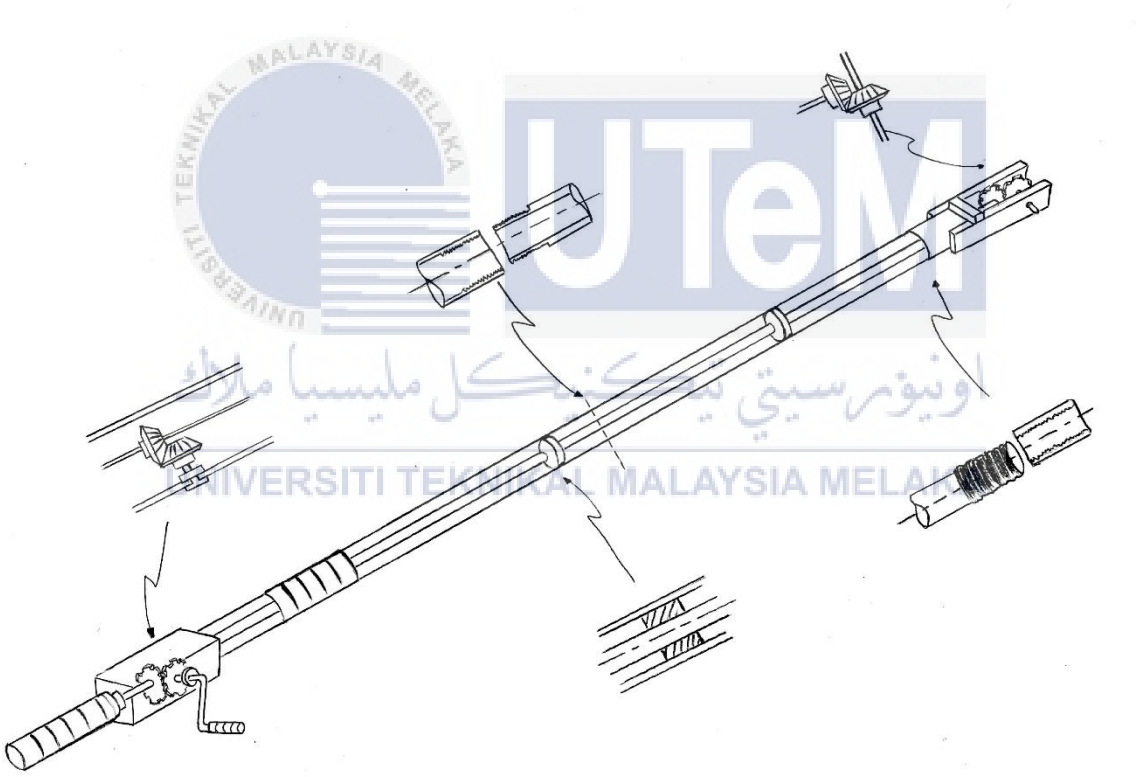


Figure 4.5 Sketch view of concept 2

In this concept, the bevel gears are used as the transmitted of the mechanical power. The main function of the bevel gear is to change the direction of the shaft's rotation. The gears are mounted on shaft at 90 degrees. The rotating of the gear cause the shaft also rotate

and transmits the mechanical power form the bottom of the rod to the top of the rod. At the top of the rod, the bevel gears also have been used to change the direction of the shaft's rotation, which to cause the blade of the cutter to rotate. However, the gears must mount precisely during the installation to ensure it can function well. The bearing used must be capable of supporting significant forces.

4.4.2.3 Concept 3

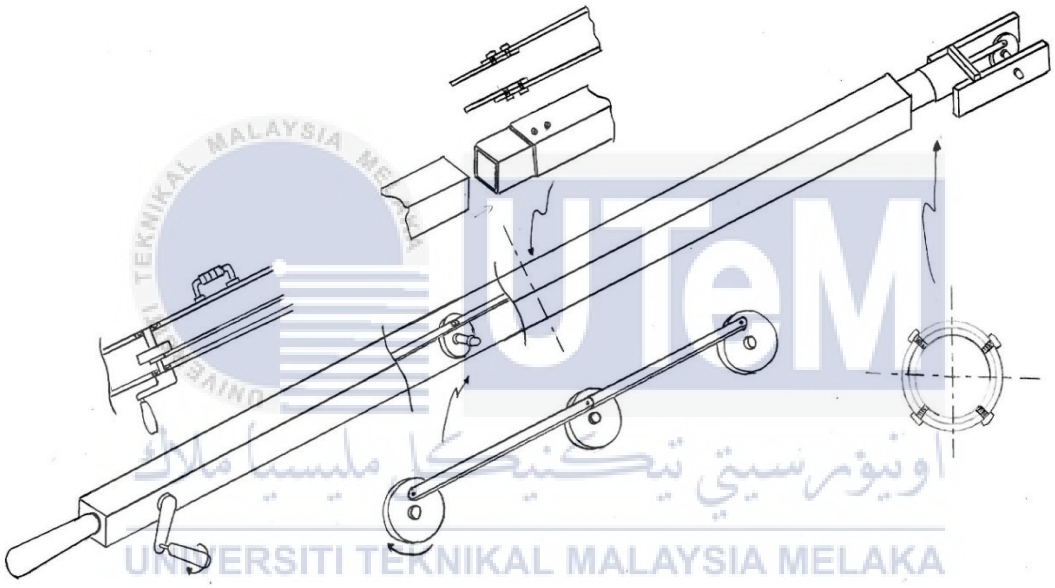


Figure 4.6 Sketch view of concept 3

The crank mechanism is used in the design of concept 3 as the design is to transmit rotary mechanism from the bottom to the top of the rod. The connecting rods connect to the driver and driven as shown in Figure 4.6. While rotating the handle manually will cause the driver to rotate together. At the same time, the connecting rods transmit the motion of the driver to the driven and allow the blade to rotate. The installation of this mechanism is very difficult and not ease for maintenance.

4.4.2.4 Concept 4

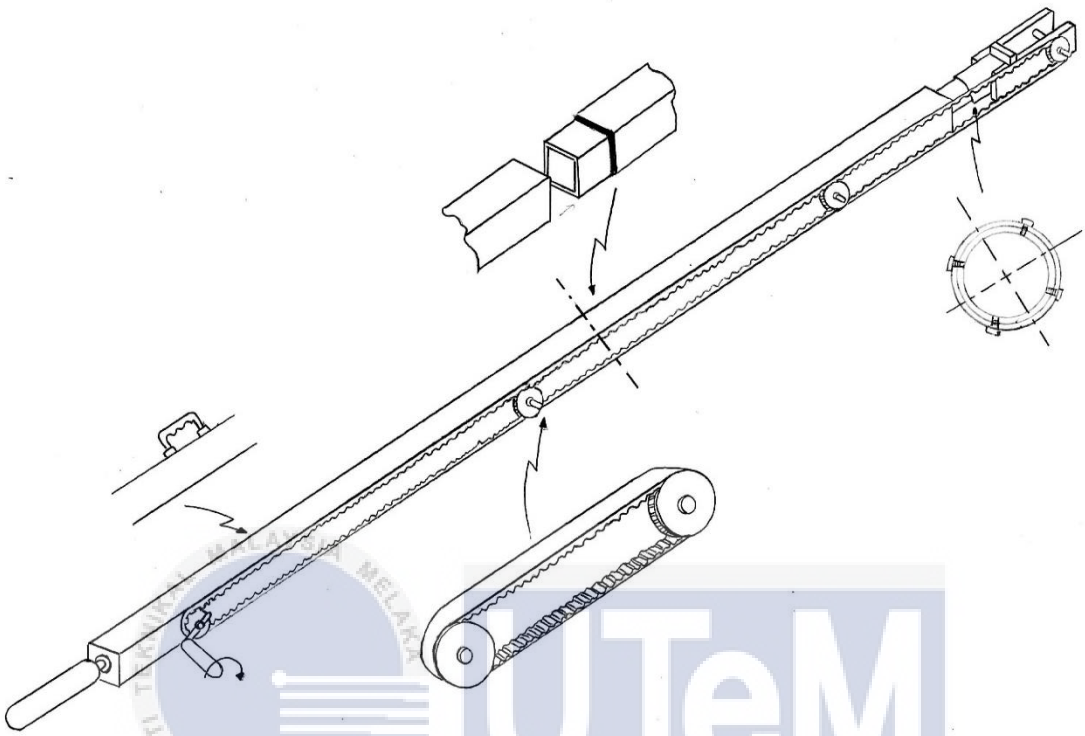


Figure 4.7 Sketch view of concept 4

This concept is designed based on the fishing rod concept. The belt drive acts as the transmission system of the power. The source of power for this design is manually. The rotation of the handle causes the pulley to rotate and the power transmits through the belt. There also will have few pulley to guide the transmission of the power. In this concept, the timing belt is used to avoid for slipping. Belt driver is less expensive than chain drives for low ratio application and require no lubrication. Since the belt driver is mounted on the side of the rod, it is not easy for storage and can get damaged easily.

4.4.2.5 Concept 5

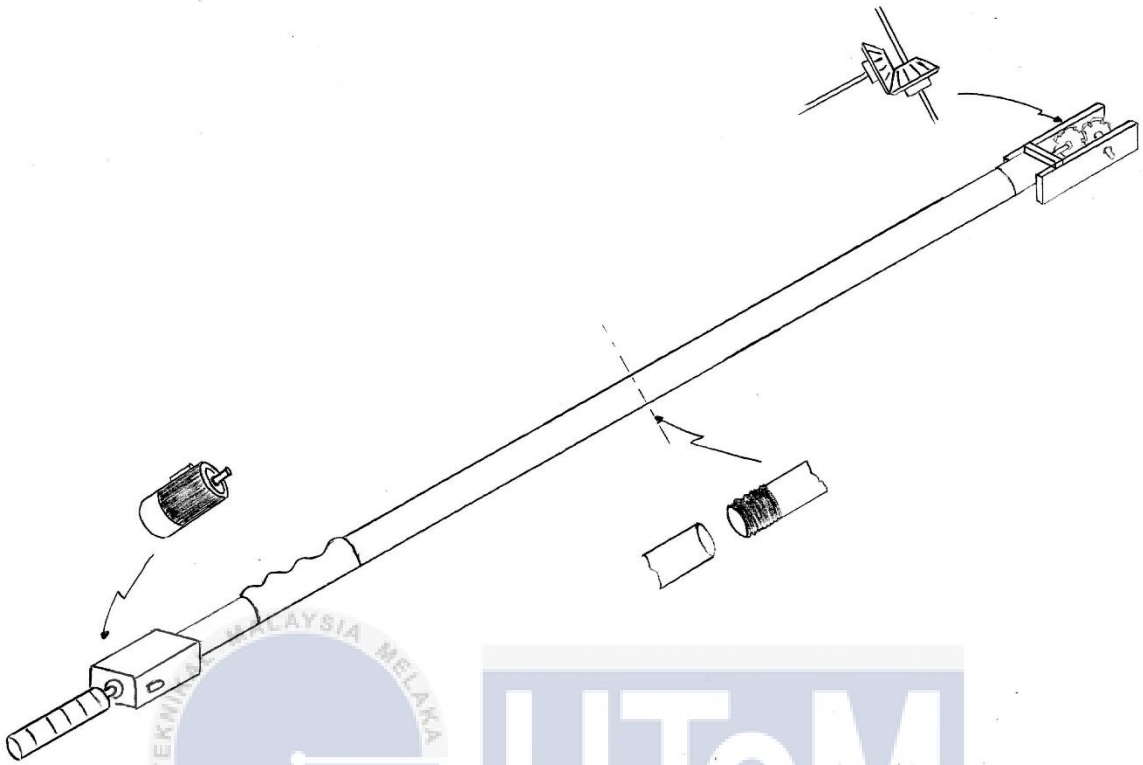


Figure 4.8 Sketch view of concept 5

This design is different from the other concepts as it used the electric motor as the power source. The motor rotates and rotational mechanism is transmitted through the shaft to the top of the rod. At the top of the rod, the bevel gears are used to change the direction of the shaft's rotation and cause the cutter blade to rotate. The bearings are mounted inside the rod to assist and guide the shaft to rotate smoothly. This concept is simple to use and manufacturing. However, the electric motor is heavier and not easily portable and consideration must be made for the correct electrical supply and voltage.

4.5 Concept Evaluation

The five concept designs have been evaluated by using decision matrix method as shown in Table 4.5 to select the best concept design of coconut plucking rod.

4.5.1 Decision Matrix Method

There are six criterias to be concerned which are performance, installation, cost, ease of maintenance, ease of manufacture and safety in the effort to determine the best concept. The conceptual design 4 set as datum and compares with other concepts based on +, -, and = scale.

Table 4.6 Concept design evaluation using the matrix method

Conceptual Design / Criteria	1	2	3	4	5
Performance	+	+	+	|	+
Installation	-	+	-	D	+
Cost	=	=	=	A	-
Ease of maintenance	-	+	-	T	=
Light in weight	-	=	-	U	-
Safety	+	+	+	M	+
Addition	2	4	2	-	3
Subtraction	3	1	3	-	2
Total	-1	3	-1	-	1

Note: plus (+): better than; equal (=): average; minus (-)

Based on the concept evaluation above, Concept 2 is selected as the best concept as it scores the highest rating among five conceptual designs.

4.6 Material Selection

In the material selection, there are a few parts that have been considered in order to meet the criteria of the product. The parts are included rod, gear housing, gear housing cover, bevel gear and shaft. However, the others part such as ball bearing, seal ring, bolt, rotary handle and rotary blade are considered as standard part which material is based on supplier.

4.6.1 Rod

The length of the rod is designed with 5 meters long. It is made from aluminum as it has a high strength and light in weight, which are met with the criteria requirements of the product design. This material also has relatively good corrosion resistance. Based on the standard measurement provided by the supplier, the outer diameter of the aluminum pipe to be used in this design is 34.93mm with the thickness of 1.47mm. The length of aluminum that available is about 8 feet. Therefore, two aluminum tubes will be used and connected by using the threaded method to achieve the requirement of the product. The product specifications are shown as Table 4.7 as below.

Table 4.7 Part specifications of rod

Part Specifications	
Material	: Aluminum 6061-T6
Dimension	: 34.93mm OD x 31.98mm ID x 2.95mm wall thickness
Properties	: High strength, light weight, good corrosion resistance, resistance to stress cracking

4.6.2 Gear Housing

The material that is applicable and suitable for the manufacture housing is aluminum. Rather than plastic and porcelain-enamel, aluminum is chosen due to high strength and also

can withstand high impact from hard materials. Table 4.8 is the specifications of the gear housing.

Table 4.8 Part specifications of gear housing

Part Specifications	
Material	: Aluminum
Dimension	: 120mm x 100mm x 68mm
Properties	: High strength, light weight, good corrosion resistance, resistance to stress cracking

4.6.3 Gear Housing Cover

Gear housing cover is made from the ABS as it function is to cover and protect the components in the gear housing. The cover is designed with ABS with the purpose for allowing the user who can carry out the maintenance of the gear system easily. Table 4.9 is the specifications of the gear housing cover.

Table 4.9 Part specifications of gear housing cover

Part Specifications	
Material	: ABS
Dimension	: 124mm x 104mm x 2mm
Properties	: Resilient, hard to tear and resists abrasions.

4.6.4 Bevel Gear

Plain carbon steel is selected as the manufacture material for bevel gear as this coconut plucking rod design involves low duty service. Other than that, the plain carbon steel also low in price which meet the requirements of the product. The size of the bevel gear is selected according to the required torque to pluck coconut and the standard size provided by the vendor. Table 4.10 shows the specifications of bevel gear.

Table 4.10 Part specifications of bevel gear

Part Specifications	
Material	: Plain carbon steel
Properties	: High strength, good machinability and least expensive

4.6.5 Shaft

Aluminum is used for the shaft as it is among of the good choice for coconut plucking rod. The aluminum has high in strength to weight ratio. The part specifications of shaft are shown in Table 4.11.

Table 4.11 Part specifications of shaft

Part Specifications	
Material	: Aluminum
Dimension	: 15mm OD x 13mm ID x 1mm wall thickness
Properties	: High strength, light weight, resistance to stress cracking

4.6.6 Rod Support

Rod support is made from the aluminum due to its specifications such as high strength and light in weight. The part specifications for rod support as shown in Table 4.12.

Table 4.11 Part specifications of rod support

Part Specifications	
Material	: Aluminum
Dimension	: 35mm OD x 31mm ID x 2mm wall thickness
Properties	: High strength, light weight, resistance to stress cracking

4.6.7 Rod Support Cover and Hand Grip

PVC is used as the material of the rod support cover and hand grip as it is among of the good choice for coconut plucking rod. PVC has extremely good tensile strength and is

readily available and cheap. The part specifications of rod support cover and hand grip are shown in Table 4.13.

Table 4.13 Part specifications of rod support cover and hand grip

Part Specifications	
Material	: PVC
Properties	: High , good tensile strength

4.7 Result Analysis

This section is focused on the analysis of the coconut plucking rod design. There have two types of the analysis methods to be used which are theorem equation analysis and CAD analysis. The analysis is emphasized on the mechanical power transmission system of the coconut plucking rod and the strength of the structure. The analysis is done to ensure that the design of the coconut plucking rod able to meet the requirements of the design specifications and function well.

4.7.1 Design Analysis by Using Theorem Equation

In this design, the coconut plucking rod has employed a transmission system to transmit the input power from one end of the rod to the other end with the purpose to generate torque and pick the nut. This transmission system is included two set of bevel gears where one is allocated at the gearbox while another is attached to the structure of rotary blade. Figure 4.9 is shown the transmission system of the coconut plucking rod.

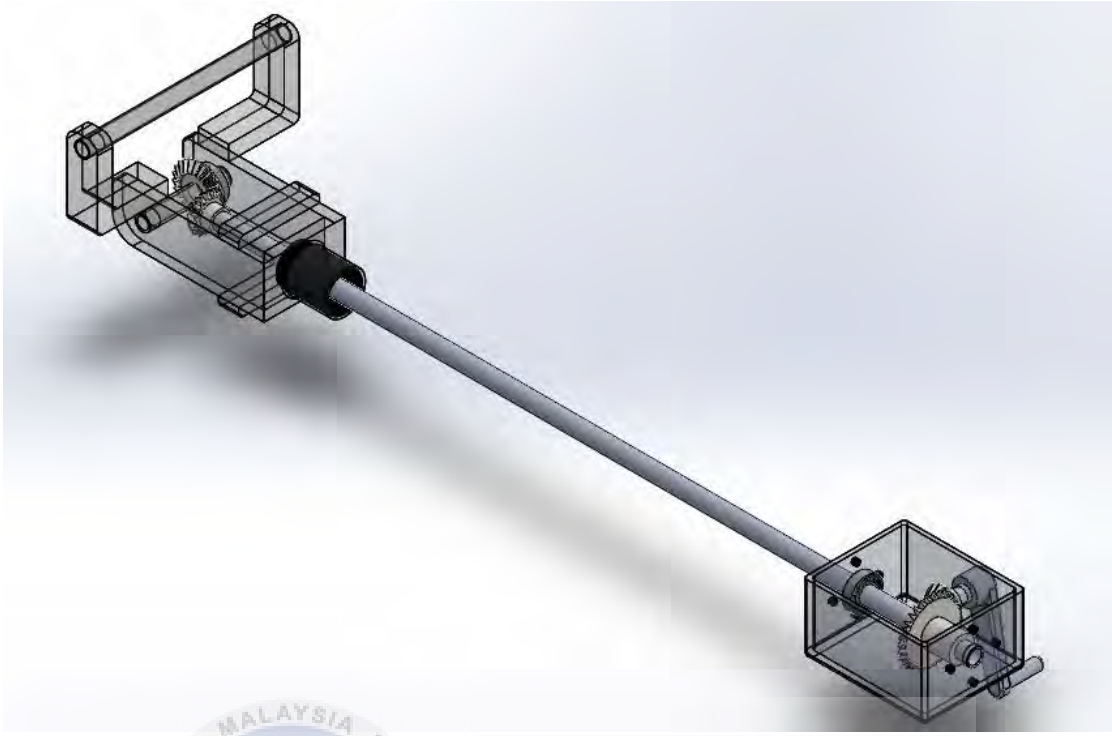


Figure 4.9 Transmission system of the coconut plucking rod.

The transmission of the torque from the input power to the output is analyzed to ensure that the coconut plucking rod able to meet the requirements of the design. According to Nur (2015), the force which required to pluck a nut is 100N. Based on this requirement, the design of the bevel gear is selected by referring to the standard provided by manufacturer. Standard straight bevel gears with no profile shifted tooth is used in the design. The shaft is attached to 90 degrees. Figure 4.10 shows the illustrate diagram of bevel gear set.

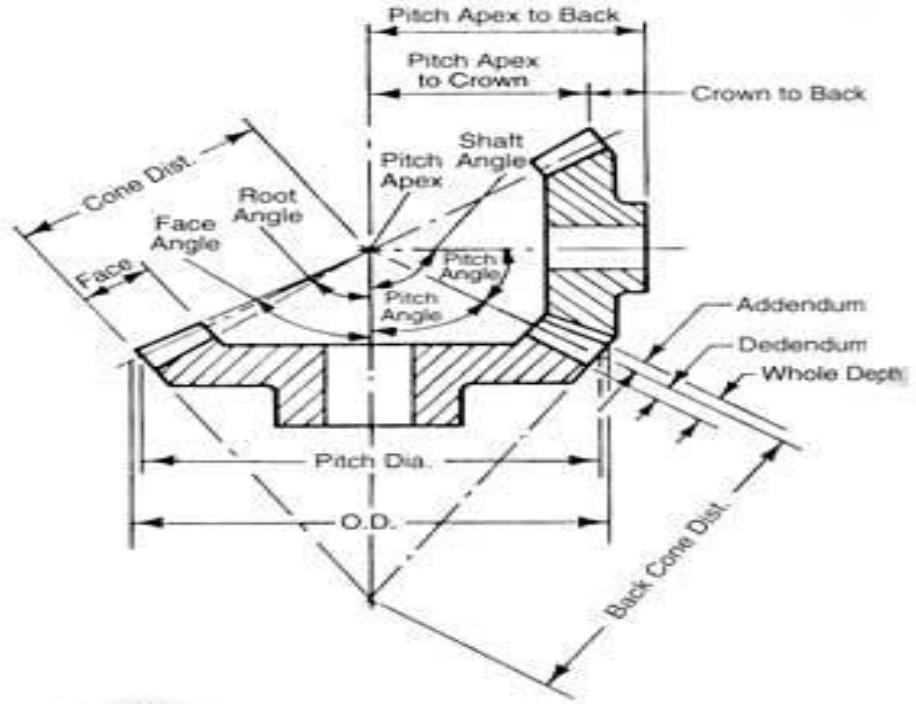


Figure 4.10 Illustrate diagram of bevel gear set

The bevel gear set that is allocated at the gearbox of the coconut plucking rod which module is set as 2 while the pressure angle is 20 degree. The parametric of the first bevel gear set is shown in Table 4.14.

Table 4.14 Parametric of the first bevel gear set

No.	Item	Symbol	Pinion, G_1	Gear, G_2
1.	Shaft angle	Σ	90°	
2.	Module	m	2	
3.	Reference pressure angle	α	20°	
4.	Number of teeth	z	15	30
5.	Diametral pitch	d	30	60
6.	Pitch angle	δ	26.57°	63.43°
7.	Face width	b	11.5	
8.	Addendum	h_a	3.41301	3.41227
9.	Dedundum	h_f	4.26343	4.26251

In term to calculate the transmitted load of the gear, the pitch-line velocity according to the average pitch radius is defined:

$$V = \pi dn/12$$

where V = pitch-line velocity, m/s

d = gear diameter, mm

n = gear speed, rev/min

The gear diameter is referred to the diametral pitch of pinion, G_1 which is 30mm and the gear speed is 120rpm.

$$V = \frac{\pi(30)(120)}{60000} = 0.188m/s$$

By assuming the input power as 100N, the transmitted load is

$$W_t = \frac{H}{V}$$

where W_{t1} = Transmitted load of first bevel gear set, N

H = Power, N

$$W_{t1} = \frac{100}{0.188} = 531.91N$$

The torque generates on the pinion gear, G_1

$$T_1 = W_{t1} \times L_1$$

where T_1 = Torque of pinion gear, N.m

L_1 = Radius of pinion gear, m

The radius of the pinion gear is 0.015m

$$T_1 = 531.91N \times 0.015m = 7.97$$

The resultant torque at gear, G_2

$$T_2 = W_{t1} \times L_2$$

where T_2 = Torque of gear, G_2, N.m

L_2 = Radius of gear, G_2, m

The radius of the gear, G_2 is 0.03m

$$T_2 = 531.91N \times 0.03m = 15.96N.m$$

The second set of bevel gear which allocated at the rotary gear also attached in 90 degree. The module is set as 2 and pressure angle is 20 degree which same as the first bevel gear set. The parametric of the second bevel gear set is shown in Table 4.15.

Table 4.15 Parametric of the second bevel gear set

No.	Item	Symbol	Gear, G_3	Gear, G_4
1.	Shaft angle	Σ	90°	
2.	Module	M	2	
3.	Reference pressure angle	α	20°	
4.	Number of teeth	z	16	24

5.	Diametral pitch	dp	32	48
6.	Pitch angle	δ	26.57°	63.43°
7.	Face width	b	10	
8.	Addendum	h_a	3.96639	3.9664
9.	Dedundum	h_f	4.95355	4.95356

The torque transmits from the gear, $\boldsymbol{G_2}$ to the pinion, $\boldsymbol{G_3}$ is same which 15.915N.m. Therefore, the transmitted load for the second gear set, W_{t2} is

$$W_{t2} = \frac{T_3}{L_3}$$

where T_3 = Torque of gear, G_3, N.m

L_3 = Radius of gear, G_3, m

The torque of gear, G_3 is 15.96N.m and the radius is 0.016m.

$$W_t = \frac{15.96N}{0.016m} = 997.5N.m$$

The resultant torque at gear, G_4

$$T_4 = W_{t2} \times L_4$$

where T_4 = Torque of gear, G_4, N.m

L_4 = Radius of gear, G_4, m

The radius of the gear, G_4 is 0.024m

$$T_4 = 997.5 \times 0.024m = 23.94N.m$$

Thus, the gear transmission system will generate 23.94N.m of torque to the rotary blade. In the design of the rotary blade, there was a chain and sprockets system to transmit the mechanical power to the cutter blade as shown in Figure 4.11.

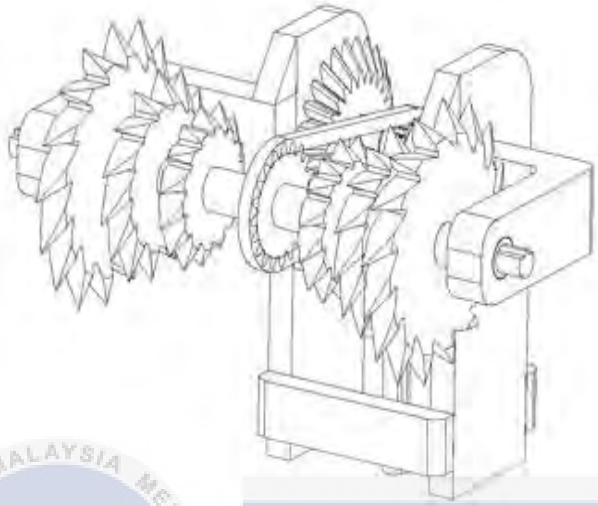


Figure 4.11 Chain and sprockets system in the rotary blade

Therefore the transmission of the power through the chain and sprocket system is calculated. Table 4.16 is shown the parameter of the each sprocket in the chain and sprockets system.

Table 4.16 The parameter of the chain and sprockets system

No.	**Item**	**Symbol**	**Sprocket, S_1**	**Sprocket, S_2**
1.	Number of teeth	z	10	20
2.	Pitch Circle (mm)	d	20	40
3.	Clearance (mm)	α	9.4	18.8
4.	Dedendum	h_f	8.75	17.5
5.	Addendum	h_a	11	22

The force transferred from the sprocket, S_1 to sprocket, S_2 is

$$F_c = \frac{T_{s1}}{r_{s1}}$$

where F_c = Force transferred by chain drive, N

T_{s1} = Torque of sprocket, S_1, N.m

r_{s1} = Radius of sprocket, S_1, m

The torque of sprocket, S_1 is transmitted from the gear system and same as gear, G_4 which is $23.94N.m$. The radius of sprocket is 0.001m.

$$F_c = \frac{23.94N.m}{0.01m} = 2394N$$

The resultant torque on the chain drive is

$$T_{s2} = F_c \times r_{s2}$$

where T_{s2} = Torque of sprocket, S_2, N.m

r_{s2} = Radius of sprocket, S_2, m

The radius of sprocket, $S_2$is 0.02m. Therefore,

$$T_{s2} = 2394N \times 0.02m = 47.88N.m$$

As the three cutter blade with different size are attached at the same shaft as sprocket, S_2, thus they will have the same value of torque. The largest diameter of the cutter blade is 18cm while the smallest diameter of the cutter blade is 15cm. In order to determine the generated torque is great enough to pick the nut, the transmitted force on the largest cutter blade is calculated.

$$F_{cutter} = \frac{T_{resultant}}{r_{cutter}}$$

where F_{cutter} = Force transmitted to pick the nut, N

$T_{resultant}$ = Torque of largest cutter, N.m

r_{cutter} = Radius of largest cutter, m

The torque drive the largest cutter is 47.88N.m and the radius is

$$F_{cutter} = \frac{47.88N.m}{0.09m} = 532N$$

The force generated on the largest cutter blade is 532N which is able to pick the nut from the coconut tree as the force measured to pick a nut is 100N. However, this force will change depend of the input force and input speed of the user.

4.7.2 CAD Analysis

This section is discussed about the analysis that carried out on the critical part of the coconut plucking rod. This analysis examines the strength of the coconut plucking rod either able to withstand the load or fail under the load by using the Solidworks software. The part of the design that to be analysis is the rod which is the main structure of the coconut plucking rod as it tend to bend or deform when a load is applied at the end of the rod. The rod is made up of aluminum 6061-T6 due to its properties as it has high in strength to weight ratio. Table 4.17 shows the properties of the aluminum 6061-T6.

Table 4.17 Properties of aluminum 6061-T6

Name:	**Aluminum 6061-T6**
Model type:	**Linear Elastic Isotropic**
Default failure criterion:	**Max von Mises Stress**
Yield strength:	**2.75e+008 N/m^2**
Tensile strength:	**3.1e+008 N/m^2**

In the analysis of the rod, one end of the rod is fixed while the other end is applied to a force of 30N which is shown in Figure 4.12. The force includes the weight of the rotary blade with 1.5kg and the weight of the nut with 1.44kg which is the average weight of the coconut.

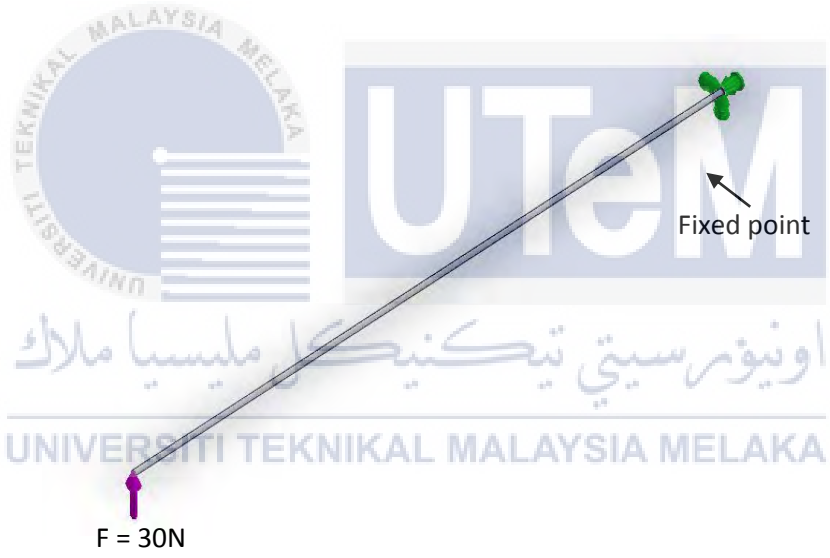


Figure 4.12 Default configuration of the rod

As the result of the analysis, the maximum stress is occurred the area near the fixed end of the rod. The maximum stress on the rod is 82MPa when subjected to a 30N load. The yield strength of the aluminum material is 275MPa. Therefore, the safety factor of the rod is about 3.35.

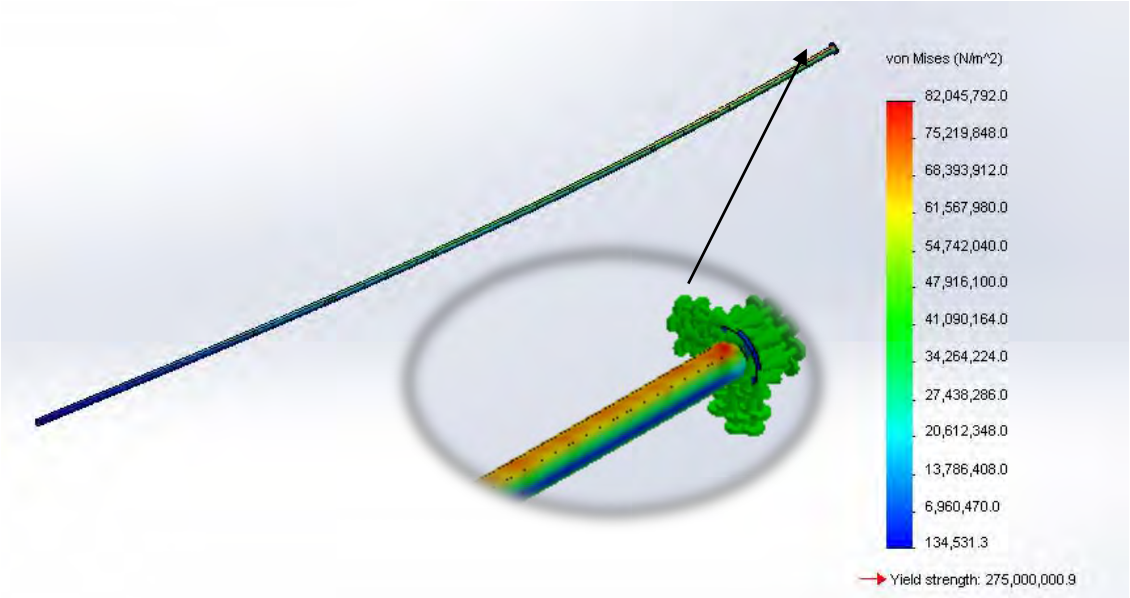


Figure 4.13 Von Misses Stress of the rod

Based on the software analysis, the displacement of the rod also can be obtained as shown in Figure 4.15. The maximum displacement of the rod when subjected to 30N is 0.52m. The maximum displacement occurs at the end of the rod where the force was applied. However, the deformation at the fixed end of the rod is the minimum.

Figure 4.14 Displacement of the rod

4.8 PRODUCT STRUCTURE

The completed design of the coconut plucking rod have been done by using Solidworks software and 3D model have been generated for the purpose of visualizing the structure of the design.

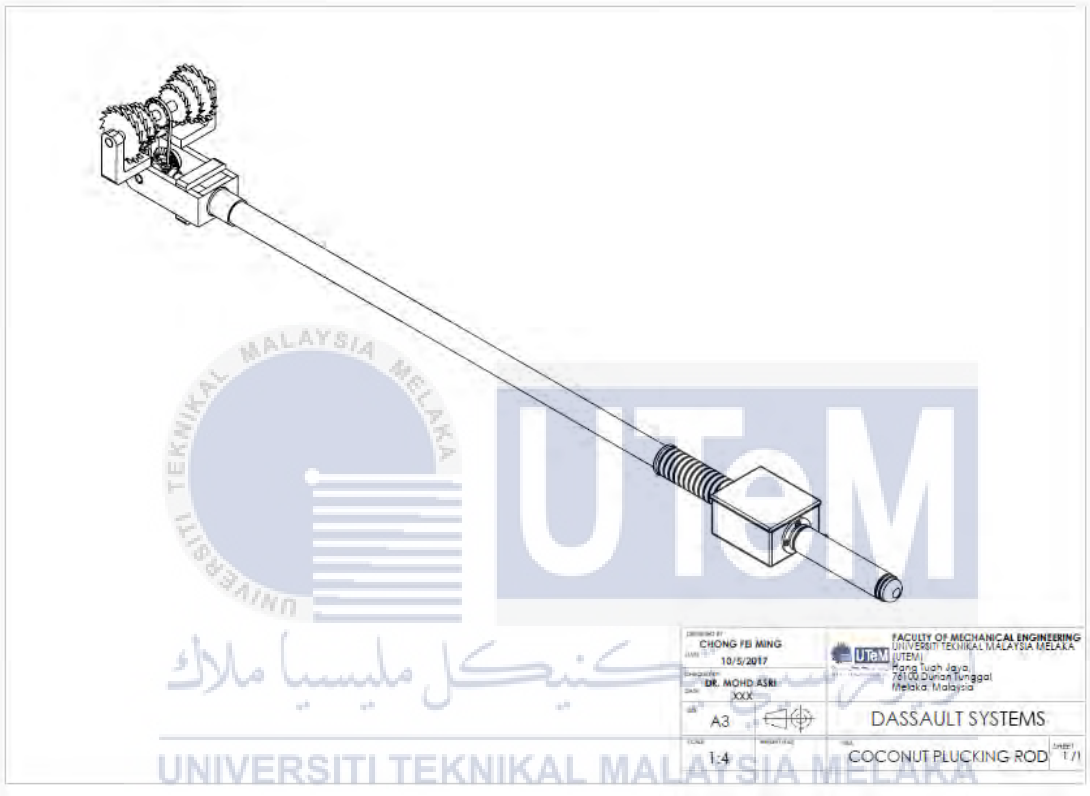


Figure 4.15 Structure of coconut plucking rod

The details regarding to the design were attached in the report as appendix B1-B2 with the exploded drawing; whereas other drawings (appendix B3-B18) were the specific sub-system and components that consisted in the overall system.

4.8.1 Product Structure Tree

Product structure tree shows the overall compilation of the product. Product structure tree for coconut plucking rod is divided into four sub-assembly which are rod sub-assembly, gear box sub-assembly, bevel gear set sub-assembly and rod support sub-assembly.

Figure 4.16 shows the sub-assembly of the rod sub-assembly. It consists three types of components where are aluminum rod, ball bearing, and hand grip. The ball bearing is attached inside and end the end of aluminum rod to guide the shaft and ensure it rotates smoothly.

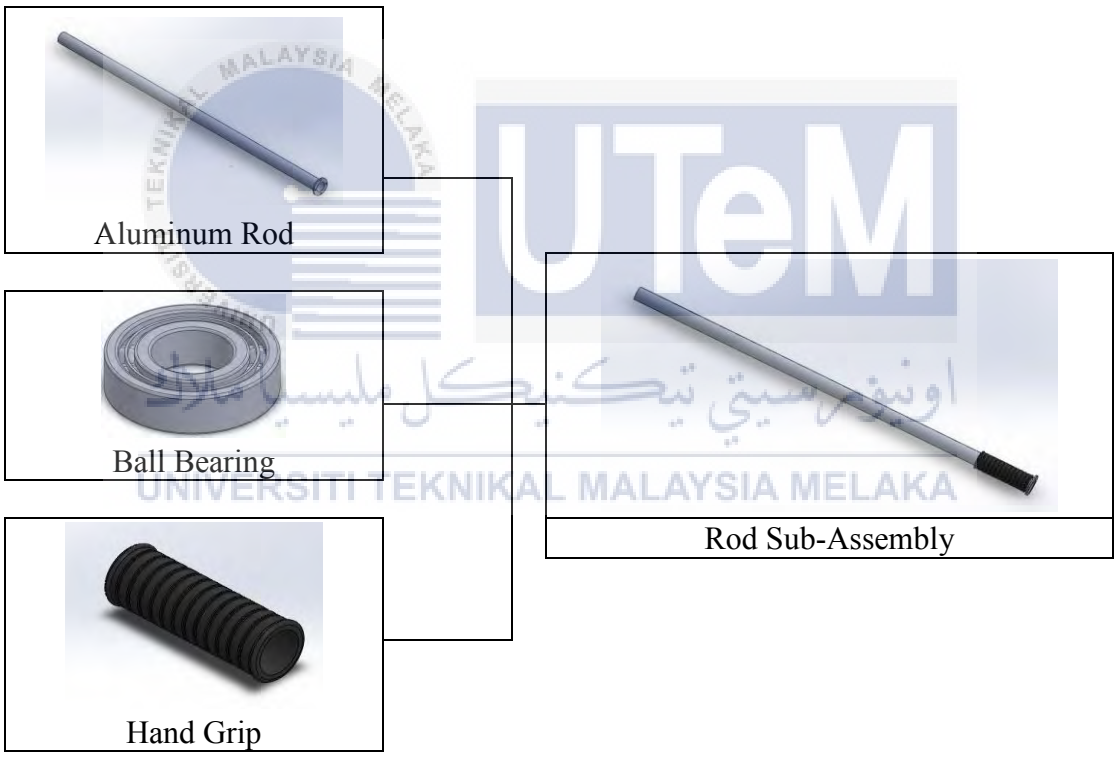


Figure 4.16 Rod sub-assembly

The gearbox sub-assembly is shown in the Figure 4.17 where it includes the pinion, gear, long shaft, ball bearing, gear housing, gear housing cover, short shaft, rotary handle and sealing ring. This sub-assembly is the important part of the designing on the coconut plucking rod as it used to transmit the mechanical power.

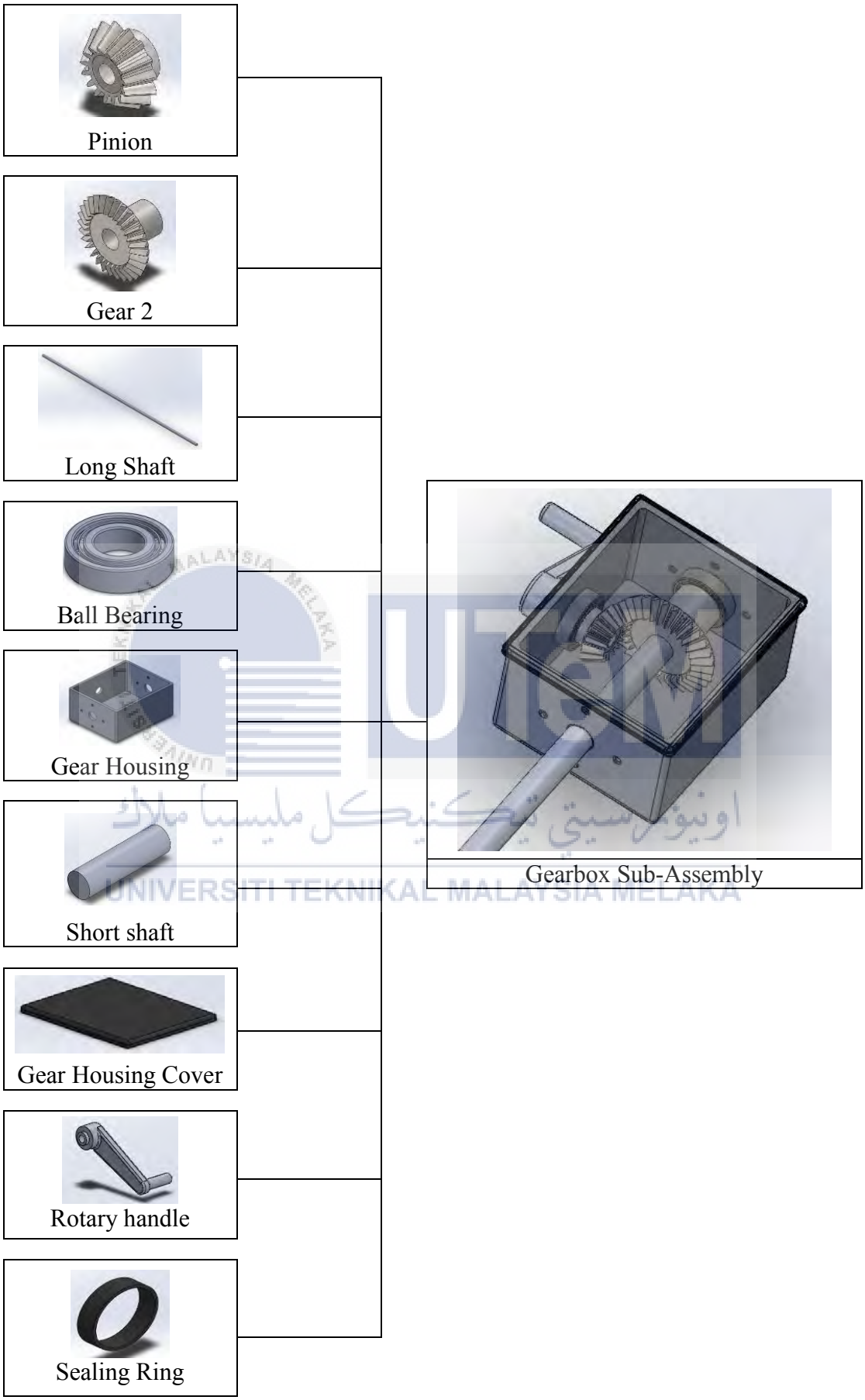


Figure 4.17 Gearbox sub-assembly

The bevel gear set sub-assembly is the bevel gear set which allocated at the structure of rotary blade to transmit the torque for picking the nut. The gear 3 is attached to the long shaft while the gear 4 is attached to the shaft of the rotary blade. The assembly of the bevel gear set is shown in Figure 4.18.

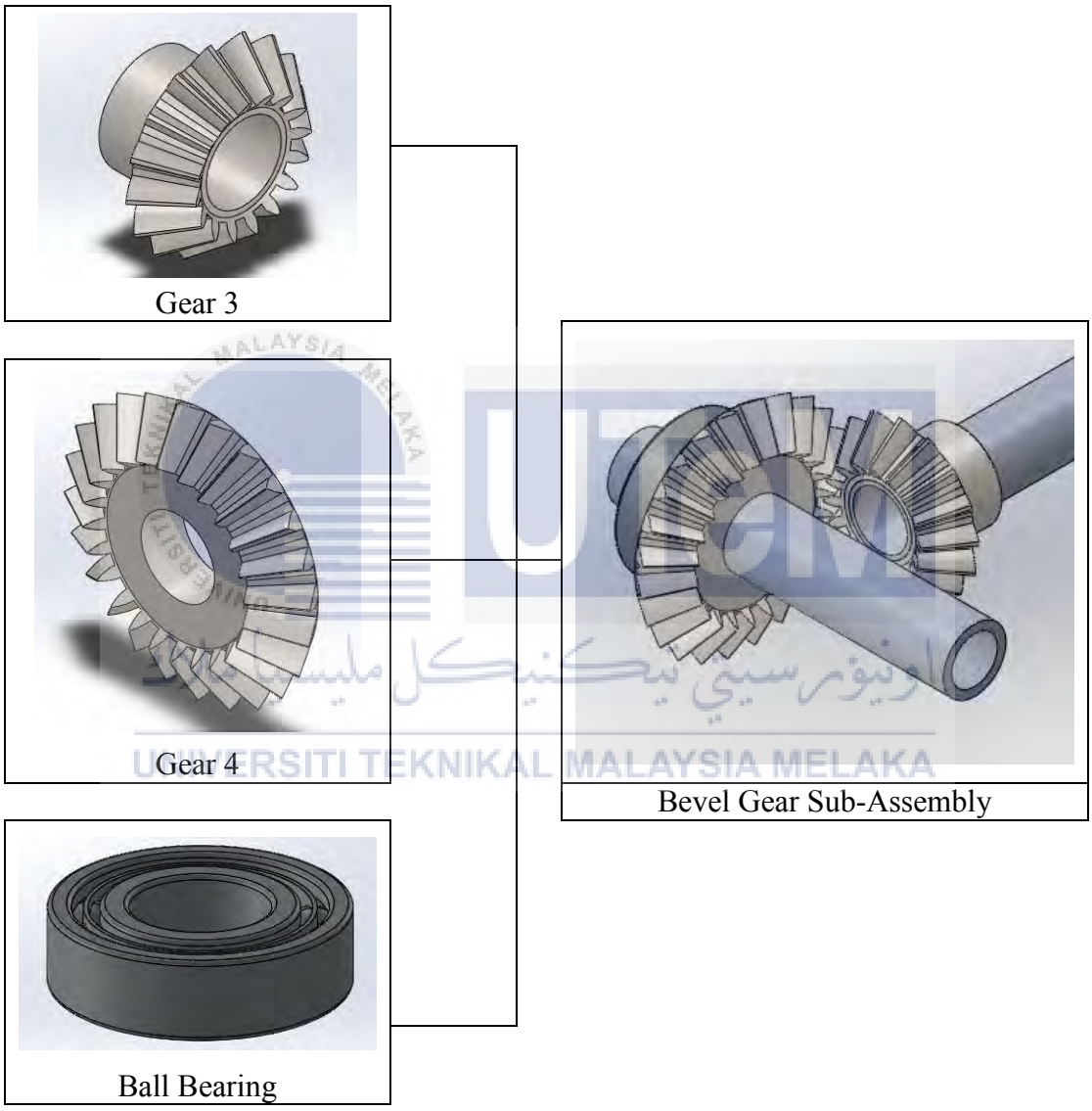


Figure 4.18 Bevel gear set sub-assembly

Figure 4.19 shows the rod support sub-assembly as it consists two components are rod support and support cover. This part is designed to allow the user to support the coconut plucking rod by using the other parts of the body such as the waist or tight.

Figure 4.19 Rod support sub-assembly

4.8.2 Detailed of Structure Modelling

The detailed of structure modelling is to show the close-up of the connection of the parts in the coconut plucking rod design. As mention in the material section, the length of aluminum rod that provided by the manufacturer is about 8 feet. In order to achieve the requirements of the product which is 5m long of coconut plucking rod, two aluminum rod will be used and they are connected by using the threaded method as shown in Figure 4.20.

Figure 4.20 The connection between the aluminum rod

The connection between the rotary blade and the rod also by using the threaded method as shown in Figure 4.21

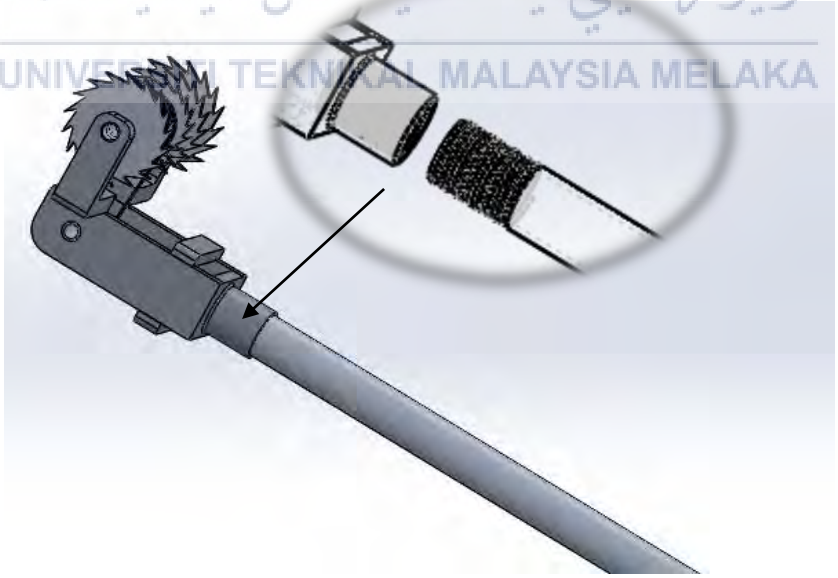


Figure 4.21 The connection between the rotary blade and the rod

Bolted joint is used to join the aluminum rod to the gear housing. This method also applied at the joining of the support rod and the gear housing. Figure 4.22 and Figure 4.23 illustrate the both joining part.

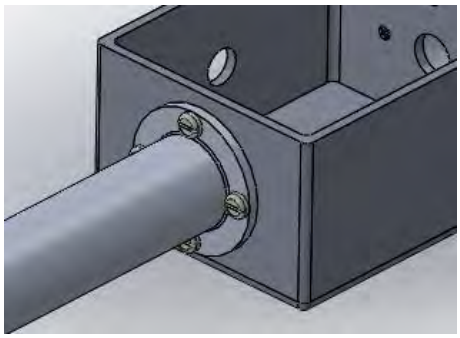


Figure 4.22 Bolted joint of aluminum rod and gear housing

Figure 4.23 Bolted joint of support rod and gear housing

4.9 Product Costing

The product cost is one of the important factors in order to evaluate and produce a high quality product with low cost. Cost estimations are represented in a general form that involved a detailed breakdown of manufacturing parts that associated with cost of material, production and assembly. The parts of coconut plucking rod are divided into two categories which are customized parts and standard parts. The customized parts are the parts that made according to specific design while the standard parts are purchased directly from the

manufactured or supplier. The gear housing, gear housing cover, rod, long shaft, short shaft, rod support, rod support cover and hand grip are considered as customized part. However, the ball bearing, bevel gear set, rotary handle, sealing ring and bolt are considered as standard and purchased part.

4.9.1 Cost of customize parts

In this section, the manufacturing process of the customize part is defined and shown in Table 4.18. The cost of the customize parts are represented in term of the material cost and the production cost. The cost of materials and production processes are based on the current price in the market.

Table 4.18 Manufacturing cost of customize parts

Part	Material	Process	Cost Per Part (RM)		
			Material	Production	Total
Gear housing	Aluminum 356.0-T6	Permanent Mold Casting	34.64	15.65	53.79
		Machining	-	3.50	
Gear housing cover	ABS	Injection Molding	0.64	2.60	3.24
Rod	Aluminum 6061-T6	Extrusion	19.50	45.50	73.50
		Machining	-	8.50	
Long Shaft	Aluminum	Extrusion	2.86	22.50	25.36
Short Shaft	Aluminum	Extrusion	1.20	5.50	6.60
Rod support	Aluminum	Extrusion	3.50	6.50	19.00
Rod support cover	PVC	Injection Molding	0.20	2.65	2.85
Hand Grip	PVC	Injection Molding	0.15	2.65	2.90
Total cost of customize part					187.24

4.9.2 Cost of standard part

For the standard part, the price of each part is made based on the price provided by the supplier. Table 4.19 shows the price for each standard part.

Table 4.19 Cost of standard parts

Part	Material	Quantity	Cost per unit (RM/unit)	Total Cost (RM)
Ball bearing	Steel	5	5.00	25.00
Bevel gear set	Plain carbon steel	2	50.00	50.00
Sealing ring	Rubber	2	0.12	0.24
Rotary handle	ABS	1	25.00	25.00
Bolt	Low carbon steel	8	0.30	2.40
Rotary blade	-	1	150.00	150.00
Total cost of standard parts				252.64

4.9.3 Assembly Cost

Assembly cost is the cost that required to assemble all the parts into a complete product. Figure 4.9 shows the assembly process flow of the coconut plucking rod. By assuming the time to assembly the parts of the coconut plucking rod is 45mins. According to the Minimum Wages Policy, the operator cost is set as RM 900 per month which is RM4.33 per hour. The cost for assemble the product is

$$Cost\ of\ assembly = RM4.33 \times \frac{45mins}{60mins} = RM3.25$$

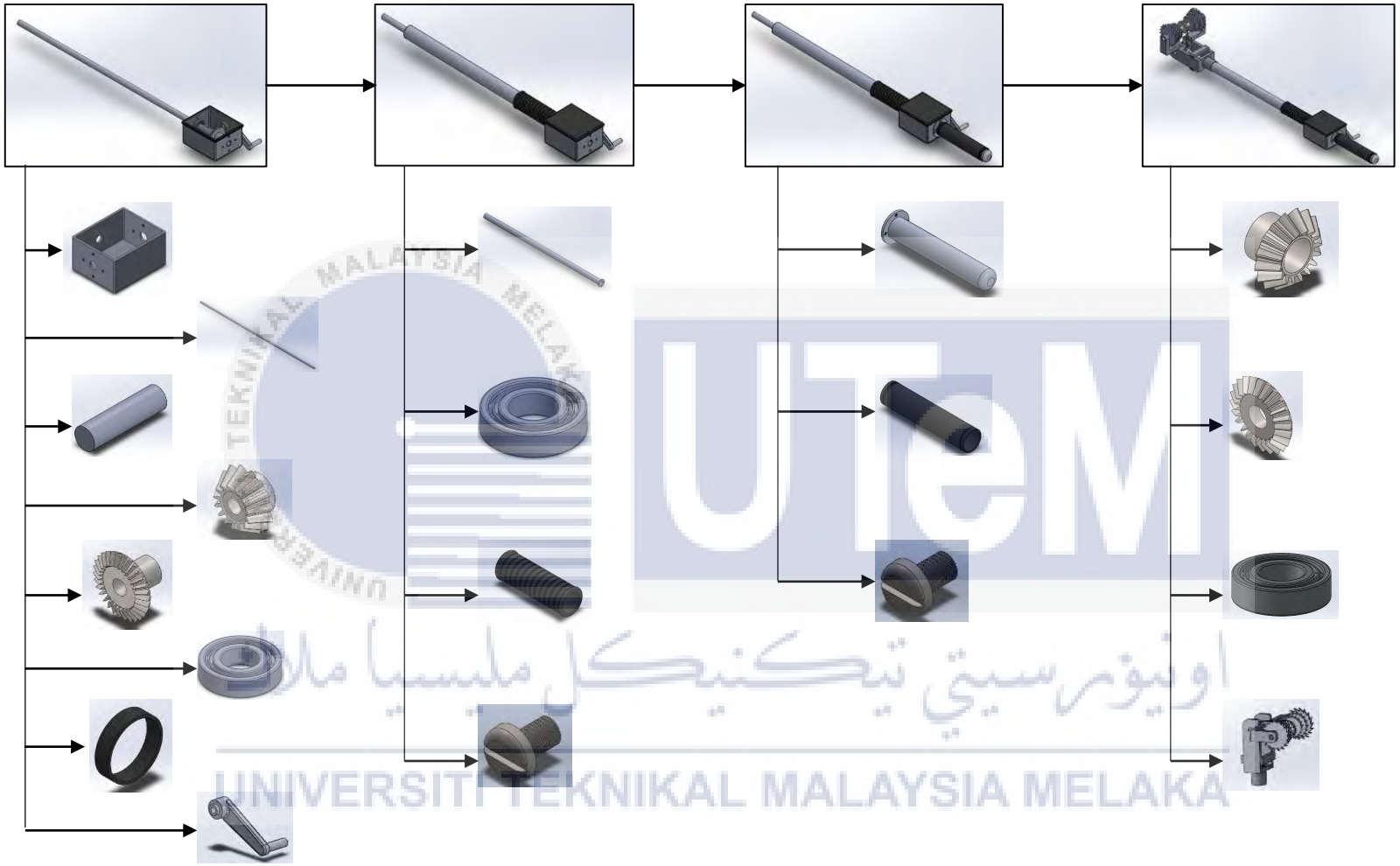


Figure 4.24 Assembly process flow

4.9.4 Total production cost

The total cost to produce a coconut plucking rod product is the sum of the cost of customize parts, cost of standard parts and cost of assembly.

$$Total\ production\ cost = Total\ cost\ of\ customize\ parts + Total\ cost\ of\ standard\ parts + Total\ cost\ of\ assembly$$

$$= RM187.24 + RM252.64 + RM3.25$$

$$= RM443.13$$

The total price to manufacture a coconut plucking rod is about RM443.13. However, this is an estimation price.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This inspiration for designing a coconut plucking rod originated from the fact that the coconut cultivating field does not have any invention of the equipment in the form of rod. It is usually seen that the cultivators used the traditional method such as climbing method or pole method in the harvesting of coconut. Even though there may some invention of the climbing machines in the market, it is considered high cost and the fear of the cultivators in the new technology. By conducting user study, market study and literature study, the customer requirements are defined. Based on the customer requirements, the QFD and PDS are generated. Various concepts of the designing of the coconut plucking rod are created. As a result, a gear system is selected as the mechanism to transmit the rotating mechanical from the power input to the cutter blade. The selected concept is illustrated in the CAD drawing to show the embodiment of the design. Mathematical analysis on the transmission system in the coconut plucking rod is done to ensure the generated torque and force able to pick the coconut from the tree. Moreover, analysis on the structure of the rod also have been done to define the factor of safety which is important to ensure the design is safe to use.

The goal of this project have been achieved through a series of design methodology which provide a systematic approach and guidelines that helps to produce a successful product to satisfy and meet the product specifications. At the end of this project, a coconut

plucking rod with advanced mechanism have been designed and the mechanism which used to transmit the rotating mechanism also have been proposed.

5.2 Recommendations

The designing of the coconut plucking rod in this project is focused on the smallholders of the coconut farm. Therefore, a manual and simple mechanism is suggested instead of the high technologies. However, the coconut plucking rod has a high potential in the market especially for the cultivation countries. Thus, high technologies system such as electric motor as the mechanism of the coconut plucking rod is recommended for the future study. The harvesting of the coconut by using the electric motor in the designing of the coconut plucking rod may help to improve the efficiency of the system.

REFERENCES

Abraham, A., Girish, M., Vitala, H. R., & Praveen, M. P. (2014). Design of Harvesting Mechanism for Advanced Remote-Controlled Coconut Harvesting, 7(October), 14651470.

Betherlehem, M. (n.d.). Manufacturing and engineering. [online]. Available at: http://bethlehemmotors.co.nz/manufacturing-and-engineering/ [Accessed on 2 December 2016].

Brown, M. D. (2009). *Design and analysis of a spiral bevel gear* (Doctoral dissertation, Rensselaer Polytechnic Institute).

Castro-Garcia, S., Rosa, U. A., Gliever, C. J., Smith, D., Burns, J. K., Krueger, W. H. & Glozer, K. (2009). Video evaluation of table olive damage during harvest with a canopy shaker. *HortTechnology*, *19*(2), 260-266.

Cadiz, R.T.(n.d.). Images from Platwise and partners for coconut(Cocos nucifera). [online]. Available at: http://www.plantwise.org/knowledgebank/DatasheetImages.aspx?dsID=11788 [Accessed on 29 November 2016].

Dassoxtr. (n.d.). Fused Bamboo for exterior use. [online]. Available at: https://www.greendepot.com/greendepot/assets/images/docs/DASSOXTR_Bamboo.pdf. [Accessed on December 2, 2016].

Etani. (2015). Cantas: Reach new performance height with Cantas. [online]. Available at: http://etani.com.my/index.php/machines/cantas-2/ [Accessed on December 2, 2016].

Fancy Power Sdn. Bhd. (n.d.). Manufacturer and Distributor of Cantas. [online]. Available at: http://www.sawitcantas.com.my/products.html. [Accessed on December 2, 2016].

Haik, Y., & Shahin, T. (2011). Engineering Design Process (Second Edi). Cenggage Learning.

Jelani, A. R., Hitam, A., Jamak, J., Noor, M., Gono, Y., & Ariffin, O. (2008). Cantas TM–A tool for the efficient harvesting of oil palm fresh fruit bunches. *Journal of Oil Palm Research*, *20*, 548-558.

Mani, A., & Jothilingam, A. (2014). Design and fabrication of coconut harvesting robot: COCOBOT. *Int. J. Innovative Res. Sci. Eng. Technol*, *3*(3), 8373–8381.

Michael. J. (2015). The basics of starting a new coconut plantation. [online]. Available at: http://traineeagriculturist.blogspot.my/2015/12/the-basics-of-starting-new-coconut.html. [Accessed on 2 December 2016].

Nethrapalli, I. (2005). Coconut harvesting. [online]. Available at: http://www.trekearth.com/gallery/Asia/India/South/Andhra_Pradesh/Nethrapalli/photo251872.htm. [Accessed on 5 November 2016].

Nur, I. (2015). Mereka bentuk dan membangunkan pemetik buah kelapa berinovasi.

Ohler, J. G. (1999). Modern coconut management: palm cultivation and products/Edited by Johan G.

Ohler. Orwa, C., Mutua, a., Kindt, R., Jamnadass, R., & Anthony, S. (2009). Cocos nucifera Arecaceae. *World Agroforestry Database*, *0*, 1–5.

Pellenc. (n.d.) Olive harvest tool. [online]. Available at: http://www.pellenc.com/agri/produits/olivion-shaker-rake/?lang=en. [Accessed on 6 November 2016].

Punchihewa, P. G., & Arancon, R. N. (2001). Post-harvest Operations. *INPhO-Post-Harvest Compendium.*, 56.

Raffauf, R. F. (1985). The book of edible nuts, Frederic Rosengarten, Jr. *Journal of Ethnopharmacology*. Retrieved on 20 October from http://doi.org/10.1016/0378-8741(85)90068-6.

Ravetti, L. (2008). *Guide to efficient olive harvesting*. Rural Industries Research and Development Corporation.

Santos, G. A., Batugal, P. A., Othman, A., Baudouin, L., & Labouisse, J. P. (1996). Manual on standardized research techniques in coconut breeding. *Roma: IPGRI*.

Schroder, S. (2014). Bamboo Preservation: Durability of bamboo. [online]. Available at: https://www.guaduabamboo.com/preservation/durability-of-bamboo [Accessed on 29 November 2016].

Sclater, N., & Chironis, N. P. (2001). *Mechanisms and mechanical devices sourcebook* (Vol. 3). New York: McGraw-Hill.

Sears. (n.d.). Barnel USA Z555P/B177Z 6-15' Telescoping Precious Fruit Picker. [online]. Available at: http://www.sears.com/barnel-usa-z555p-b177z-6-15'-telescoping-precious-fruit/p-07189936000P. [Accessed on 2 December 2016].

Sivapragasam, A. (2008). Coconut in Malaysia – current developments and potential. *2nd International Plantation Industry Conference and Exhibition (IPICEX2008), Shah Alam, Malaysia*, (November), 1–9.

Squires, T. (n.d.) Description of the QFD process. [online]. Available at: http://www.masetllc.com/products/418.shtml [Accessed on 5 December, 2016].

Thampan, P. K. (1989). *Handbook on Coconut Palm*. Oxford and IBH Publishing Co.Pvt Ltd., New Delhi.

Wlngrad, N. J., 2016. Did an abused monkey pick your coconut? [online]. Available at: http://www.huffingtonpost.com/nathan-j-winograd/did-an-abused-monkey-pick_b_8341554.html [Accessed on 30 November 2016].

APPENDIX A

APPENDIX A1

Table A1 Gantt chart for PSM 1

NO	TASK	WEEK													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Internet and library research														
2	Identify the problem statement and objective														
3	Preparation of progress report														
4	Submission of progress report														
5	Literature review														
6	Methodology														
7	Customer requirements identification														
8	Specifications definition														
9	Preparation of PSM I report														
10	Submission of PSM I report														

APPENDIX A2

Table A2 Gantt chart for PSM 2

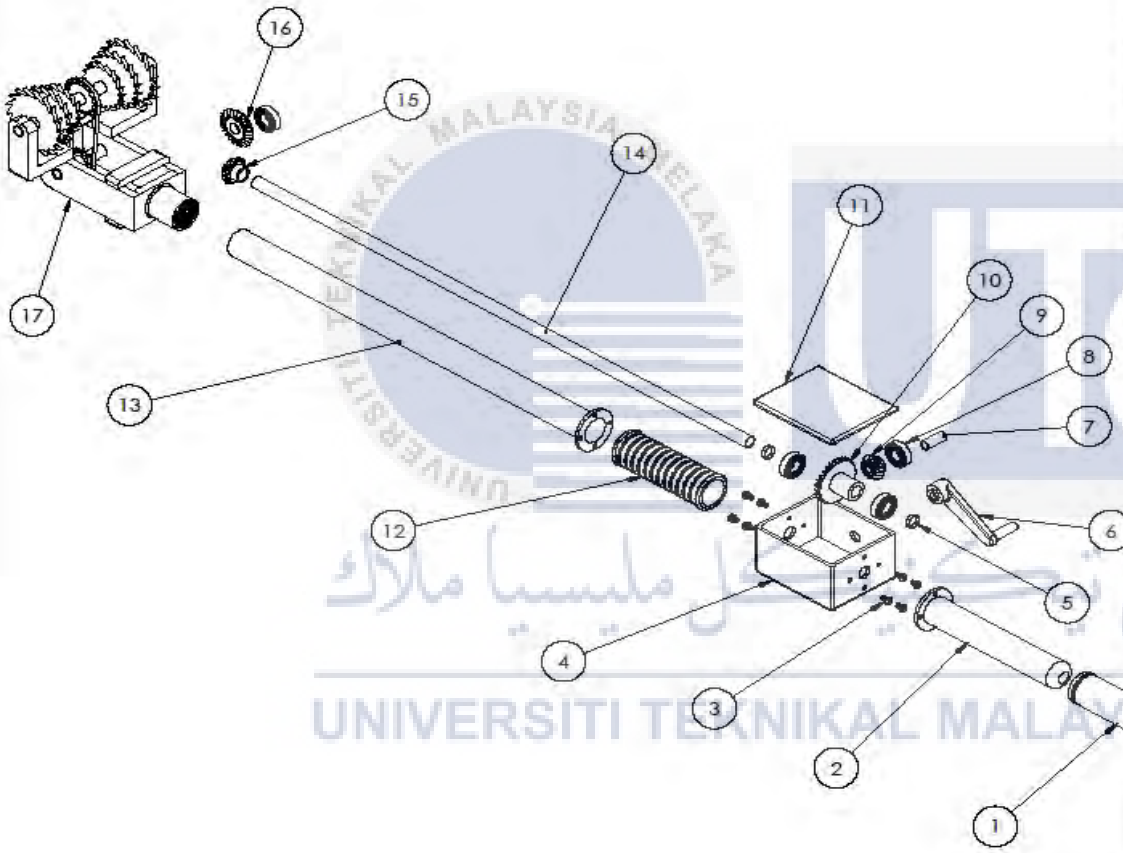
NO	TASK	WEEK													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Conceptualization and concept evaluation														
2	Embodiment design														
3	Details drawing for the design														
4	Design analysis														
5	Design improvement														
6	Design re-analysis														
7	Product costing														
8	Report writing														
9	Report submission														

APPENDIX B

APPENDIX B1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:4	WEIGHT (KG):	TITLE: COCONUT PLUCKING ROD SHEET: 1 /1

APPENDIX B2



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Rod Support Cover	Part	1
2	Rod Support	Part	1
3	Bolt	Part	8
4	Gear Housing	Part	1
5	Sealing Ring	Part	2
6	Rotary Handle	Part	1
7	Pinion Shaft	Part	1
8	Ball Bearing	Part	4
9	Pinion1	Part	1
10	Gear2	Part	1
11	Gear Housing Cover	Part	1
12	Hand Grip	Part	1
13	Rod	Part	1
14	Long Shaft	Part	1
15	Gear 3	Part	1
16	Gear 4	Part	1
17	Rotary Blade	Assembly	1

DESIGNED BY: CHONG FEI MING
DATE: 10/5/2017
CHECKED BY: DR. MOHD ASRI
DATE: XXX
SIZE: A3
SCALE: 1:5
WEIGHT (KG):

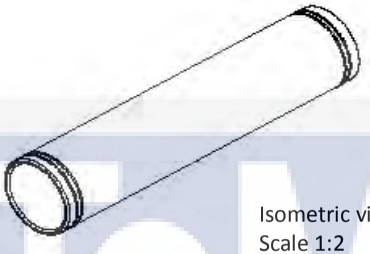
FACULTY OF MECHANICAL ENGINEERING
UNIVERSITI TEKNIKAL MALAYSIA MELAKA
(UTEM)
Hang Tuah Jaya,
76100 Durian Tunggal,
Melaka, Malaysia

DASSAULT SYSTEMS

TITLE: Exploded Drawing
SHEET: 1 /1

APPENDIX B3

Front view
Scale 1:2



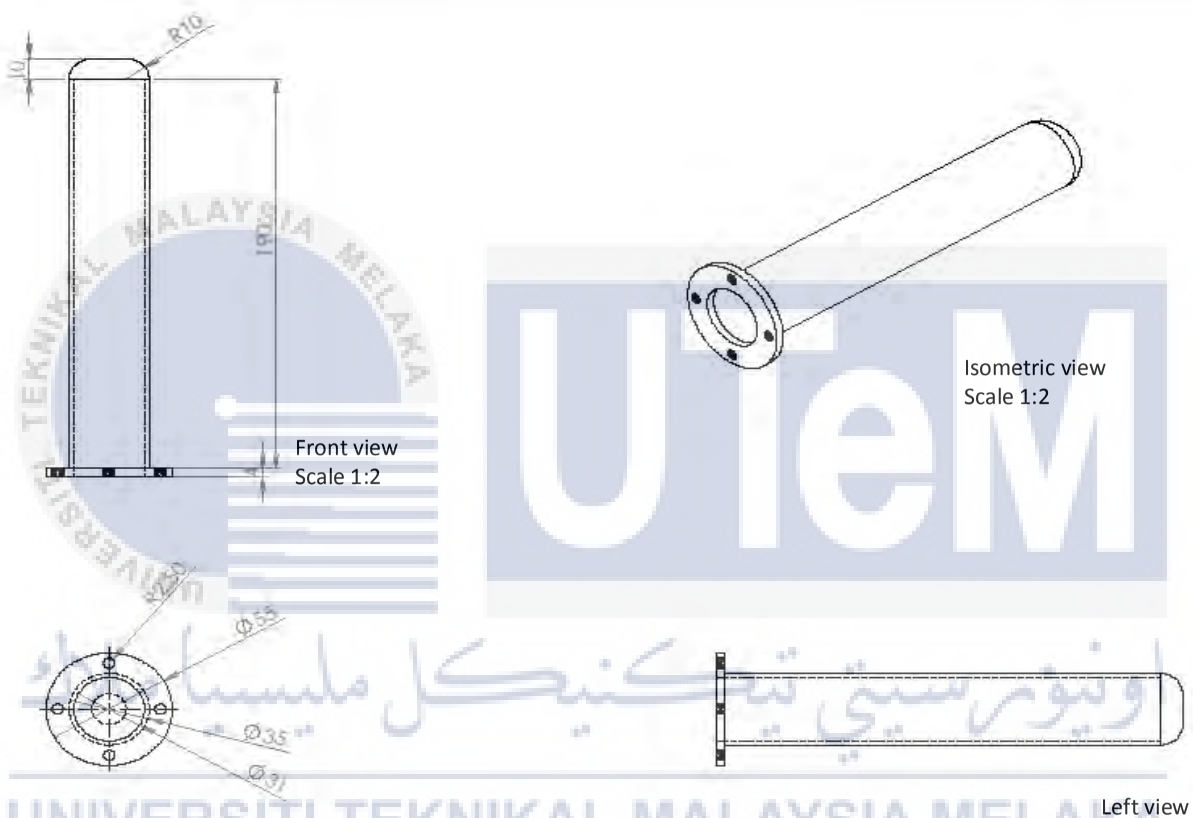
Isometric view
Scale 1:2

Top view
Scale 1:2

Left view
Scale 1:2

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:2	WEIGHT (KG):	TITLE: Rod Support Cover SHEET: 1 /1

APPENDIX B4



Front view
Scale 1:2

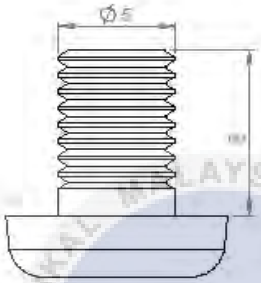
Isometric view
Scale 1:2

Top view
Scale 1:2

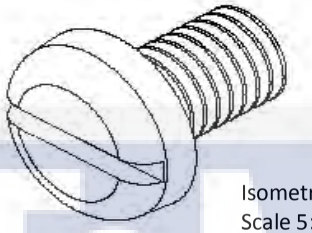
Left view
Scale 1:2

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:2	WEIGHT (KG):	TITLE: Rod Support SHEET: 1 /1

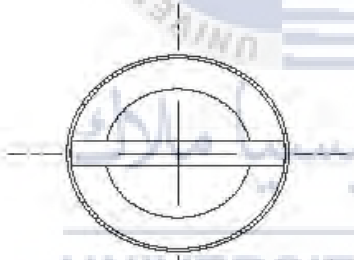
APPENDIX B5



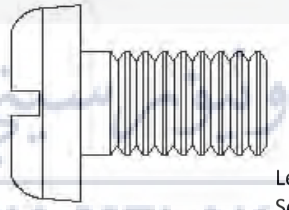
Front view
Scale 5:1



Isometric view
Scale 5:1



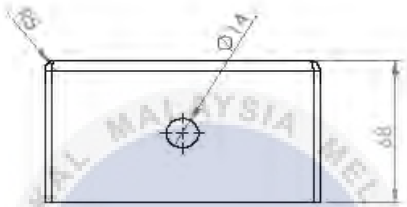
Top view
Scale 5:1



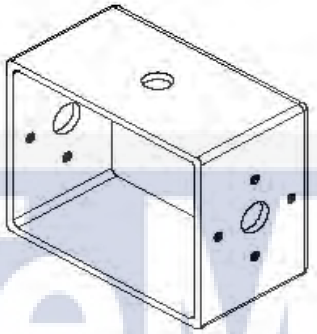
Left view
Scale 5:1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 5:1	WEIGHT (KG):	TITLE: Bolt SHEET: 1 /1

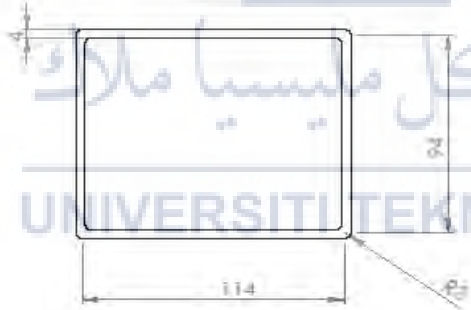
APPENDIX B6



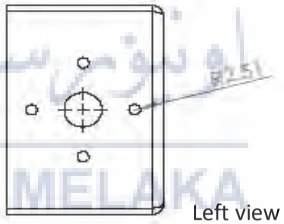
Front view
Scale 1:2



Isometric view
Scale 1:2



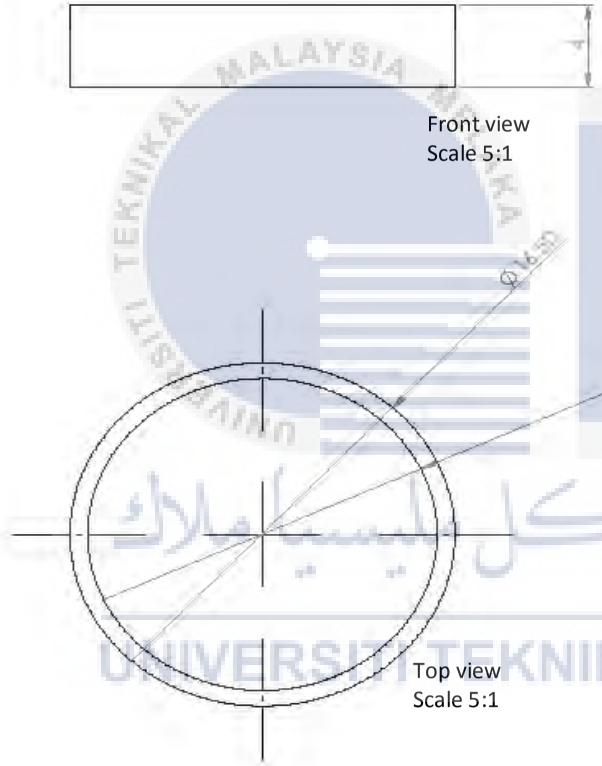
Top view
Scale 1:2

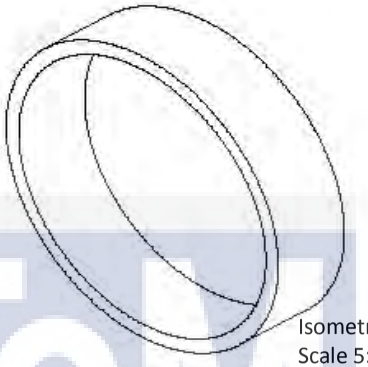


Left view
Scale 1:2

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017 CHECKED BY: DR. MOHD ASRI DATE: XXX		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:2	WEIGHT (KG):	TITLE: Gear Housing SHEET: 1 /1

APPENDIX B7

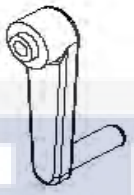




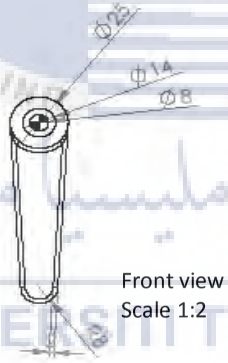
DESIGNED BY: CHONG FEI MING DATE: 10/5/2017 CHECKED BY: DR. MOHD ASRI DATE: XXX		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
SIZE: A3		DASSAULT SYSTEMS
SCALE: 5:1	WEIGHT (KG):	TITLE: Sealing Ring SHEET: 1 /1

APPENDIX B8

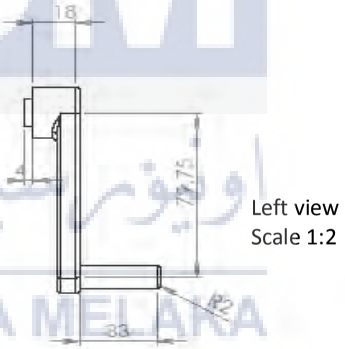
Top view
Scale 1:2



Isometric view
Scale 1:2



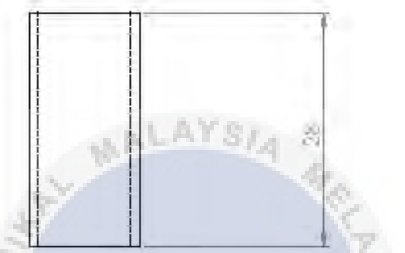
Front view
Scale 1:2



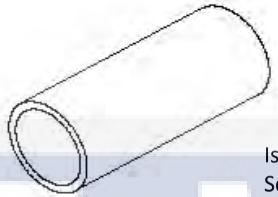
Left view
Scale 1:2

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017 CHECKED BY: DR. MOHD ASRI DATE: XXX		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:2	WEIGHT (KG):	TITLE: Rotary handle SHEET: 1 /1

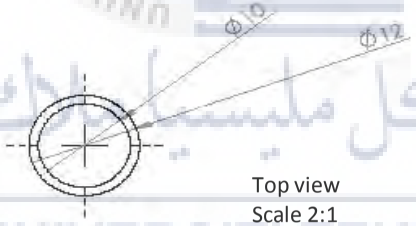
APPENDIX B9



Front view
Scale 2:1



Isometric view
Scale 2:1

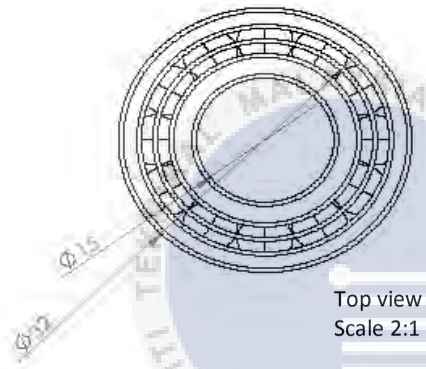


Top view
Scale 2:1

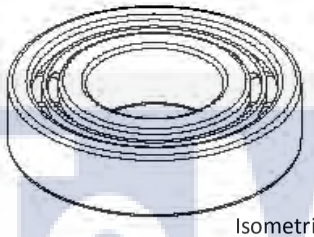
Left view
Scale 2:1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 2:1	WEIGHT (KG):	TITLE: Short Shaft SHEET: 1 /1

APPENDIX B10



Top view
Scale 2:1

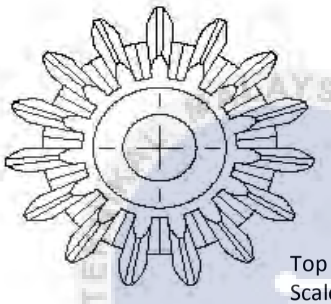


Isometric view
Scale 2:1

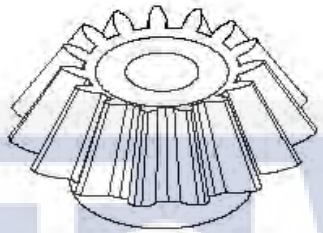
Front view
Scale 2:1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 2:1	WEIGHT (KG):	TITLE: Ball Bearing SHEET: 1 /1

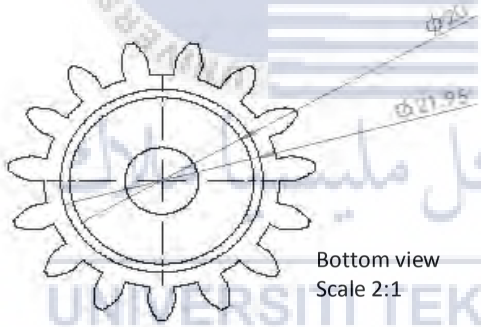
APPENDIX B11



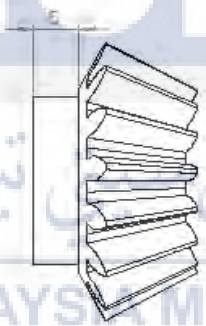
Top view
Scale 2:1



Isometric view
Scale 2:1



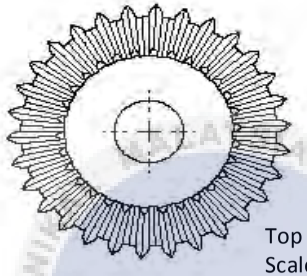
Bottom view
Scale 2:1



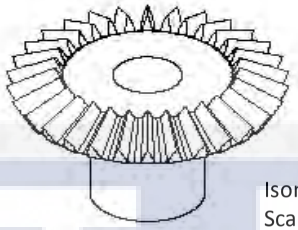
Left view
Scale 2:1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 2:1	WEIGHT (KG):	TITLE: Pinion SHEET: 1 /1

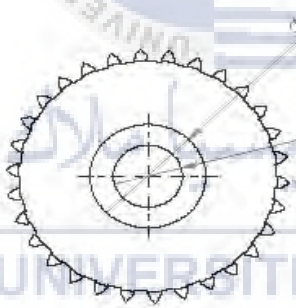
APPENDIX B12



Top view
Scale 1:1



Isometric view
Scale 1:1

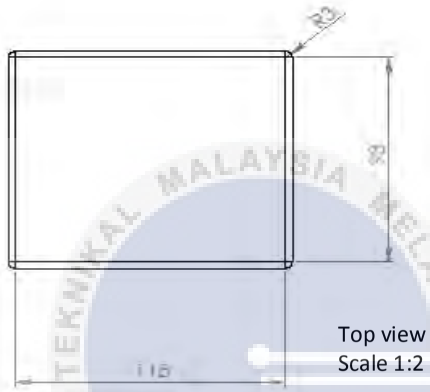


Bottom view
Scale 1:1

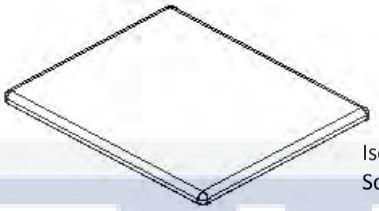
Left view
Scale 1:1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:1	WEIGHT (KG):	TITLE: Gear 2 SHEET: 1 / 1

APPENDIX B13



Top view
Scale 1:2



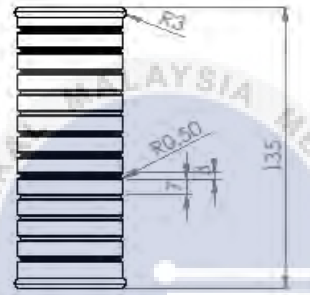
Isometric view
Scale 1:2

Front view
Scale 1:2

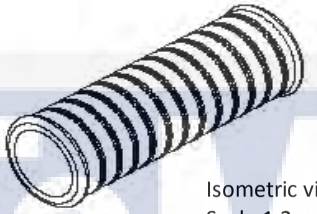
Left view
Scale 1:2

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:2	WEIGHT (KG):	TITLE: Gear Housing Cover SHEET: 1 /1

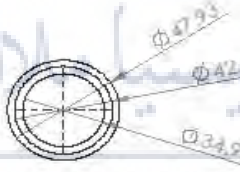
APPENDIX B14



Front view
Scale 1:2



Isometric view
Scale 1:2



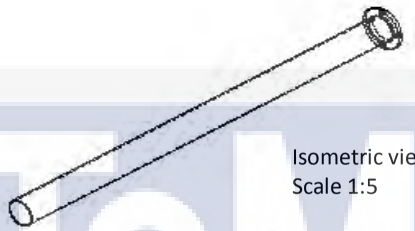
Top view
Scale 1:2

Left view
Scale 1:2

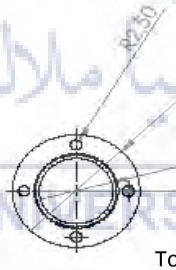
DESIGNED BY: CHONG FEI MING DATE: 10/5/2017 CHECKED BY: DR. MOHD ASRI DATE: XXX		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:2	WEIGHT (KG):	TITLE: Hand Grip SHEET: 1 /1

APPENDIX B15

Front view
Scale 1:5



Isometric view
Scale 1:5



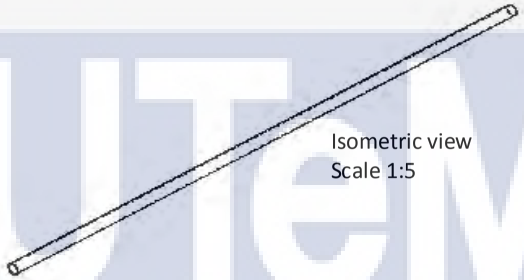
Top view
Scale 1:5

Left view
Scale 1:5

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:5	WEIGHT (KG):	TITLE: Aluminum Rod SHEET: 1 /1

APPENDIX B16

Front view
Scale 1:5



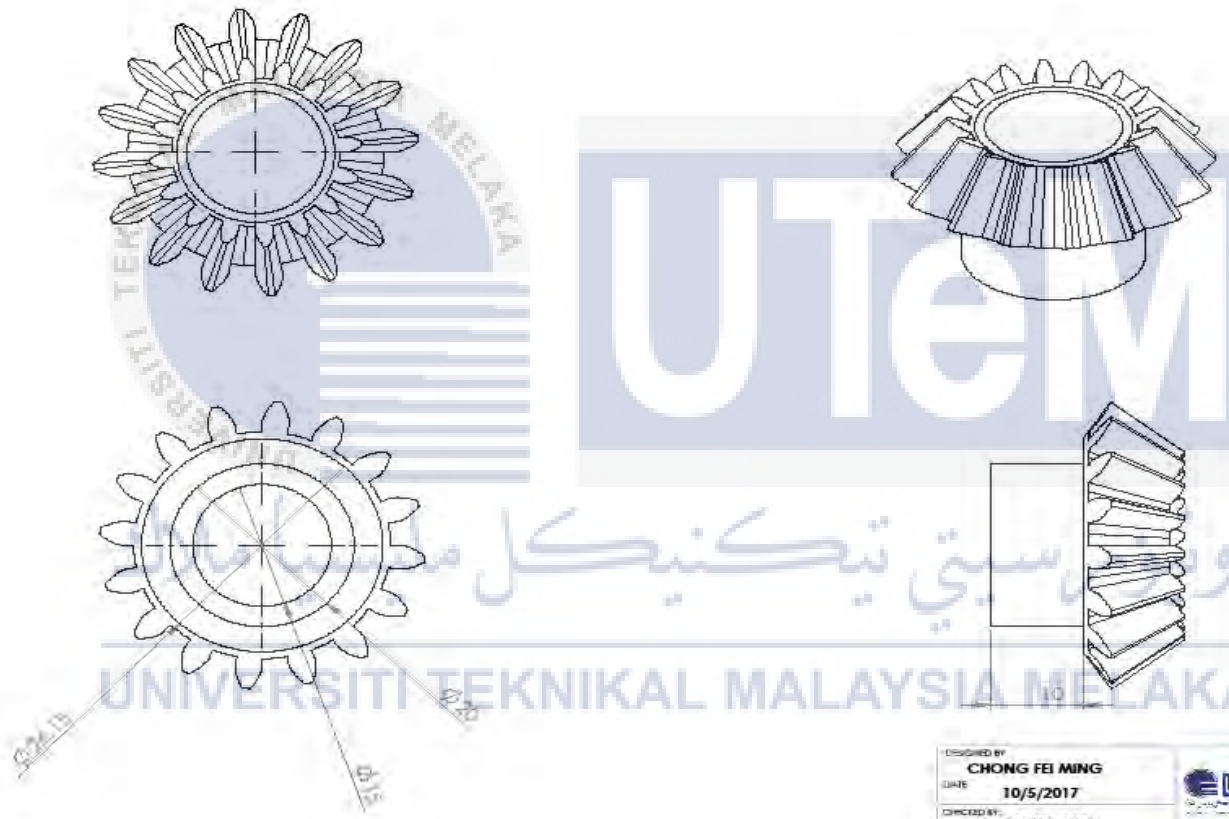
Isometric view
Scale 1:5

Top view
Scale 1:5

Left view
Scale 1:5

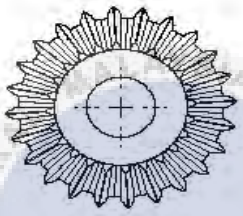
DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:5	WEIGHT (KG):	TITLE: Long Shaft SHEET: 1 /1

APPENDIX B17

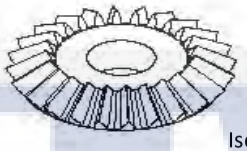


DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 2:1	WEIGHT (KG):	TITLE: Gear 3 SHEET: 1 / 1

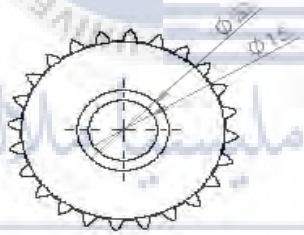
APPENDIX B18



Top view
Scale 1:1



Isometric view
Scale 1:1



Bottom view
Scale 1:1

Left view
Scale 1:1

DESIGNED BY: CHONG FEI MING DATE: 10/5/2017		FACULTY OF MECHANICAL ENGINEERING UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTEM) Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
CHECKED BY: DR. MOHD ASRI DATE: XXX		
SIZE: A3		DASSAULT SYSTEMS
SCALE: 1:1	WEIGHT (KG):	TITLE: Gear 4 SHEET: 1 /1