STRUCTURAL DESIGN AND MECHANISM ANALYSIS OF OIL PALM HARVESTER

MICHELLE WONG KHAI SHING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MICHELLE WONG KHAI SHING

This report is submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Structural Design and Mechanism Analysis of Oil Palm Harvester" 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 & Innovation).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother and father.

ABSTRACT

Plantation of oil palm becomes focus in Malaysia as it is the top contributors of the economy. In order to match the supply of oil palm fruit with demand, different harvesting methods and tools are used in oil palm estate such as the motorized cutter named Cantas. Although it can reduce the harvesting time and the number of labors involved in harvesting process, the tight arrangement of oil palm fronds and long manually adjusted harvesting pole may cause the inconvenient to the labors. Therefore, this project studies the design of a circular cutter and automatically adjusted telescopic pole with rotational mechanism. It is designed onto an oil palm harvester so that it can reach the oil palm tree with maximum height of 4m. This project is done according to the product development process in designing a product. The concept development of harvester is based on the scientific study on the limitations, customer requirement and engineering characteristics of existing harvesters. It is followed with the selection of best design of harvester that can solve the problems that faced by labors in existing harvester. Different analysis and calculations are also carried out in term of rotational speed, deflection and bending moment for different components in the oil palm harvester. After the selection of suitable materials and dimensions for each component, the design of harvester is done with the aid of CAD software in form of part detail design, orthographic view and exploded view. The automatically adjustable telescopic pole is designed in this project to replace the manually adjusted harvesting pole. Besides, the vibration method in vertical direction that used in the sickle of existing harvester is replaced by circular cutter with rotational harvesting mechanism.The17cm diameter of inclined teeth circular cutter with rotational mechanism and 3.7m maximum length of telescopic pole with automatically controlled are designed in this project and it could facilitate the harvesting process. With the rotational cutting mechanism, the harvester is not restricted by reaching constraints which was experienced in conventional harvesters. Labors no longer need to find the suitable position to insert the sickle in the middle of fronds with tight arrangement, they can easily reach and harvest the oil palm FFB from the bottom of the bunches with the support of automatically controlled telescopic pole.

ABSTRAK

Perladangan kelapa sawit menjadi fokus di Malaysia kerana ia adalah penyumbang utama untuk ekonomi negara. Bagi memastikan sumber buah kelapa sawit dapat memenuhi permintaan, kaedah dan alat penuaian yang berbeza telah digunakan dalam ladang kelapa sawit seperti pemotong bermotor yang dinamakan Cantas. Walaupun ia boleh mengurangkan masa dan bilangan buruh yang terlibat dalam proses penuaian, susunan pelepah kelapa sawit yang sempit dan batang penuai yang panjang serta dilaraskan secara manual boleh membawa kesukaran kepada buruh dalam proses penuaian. Oleh itu, projek ini mengkaji reka bentuk pemotong bulat dan batang teleskopik yang diselaraskan secara automatik dengan menggunakan mekanisme putaran. Ia juga direka dalam penuai kelapa sawit supaya ia dapat mencapai pokok kelapa sawit yang ketinggiannya maksimum 4m. Proses pembangunan produk digunakan di dalam projek ini untuk mereka bentuk produk penuai kelapa sawit. Pembangunan konsep bagi penuai adalah berdasarkan kajian saintifik mengenai batasan, keperluan pelanggan dan ciri-ciri kejuruteraan daripada penuai sedia ada. Projek ini diikuti dengan pemilihan reka bentuk penuai yang terbaik dan dapat menyelesaikan masalah yang dihadapi oleh buruh dalam penuai sedia ada. Analisis dan pengiraan yang berbeza juga dilakukan dari segi kelajuan putaran, pesongan dan momen lentur bagi komponen yang berbeza dalam penuai kelapa sawit. Selepas pemilihan bahan dan dimensi yang sesuai bagi setiap komponen, reka bentuk penuai dilakukan dengan perisian CAD dalam bentuk lukisan secara terperinci, pandangan ortografik serta lukisan bertaburan.Batang teleskopik yang diselaraskan secara automatik telah direka di dalam projek ini bagi menggantikan batang penuai yang dilaraskan secara manual. Di samping itu, kaedah getaran dalam arah menegak yang digunakan dalam sabit penuai sedia ada juga digantikan oleh pemotong bulat yang berfungsi dengan mekanisme putaran. Pemotong bulat bergigi cenderung dengan 17cm diameter yang berfungsi menggunakan mekanisme putaran dan batang teleskopik dengan 3.7m maksimum panjang yang diselaraskan secara automatik telah direka dalam projek ini dan ia dapat memudahkan proses penuaian. Dengan menggunakan mekanisme putaran dalam pemotong, penuai kelapa sawit dapat mencapai pelepah kelapa sawit yang sempit dengan lebih senang dan dapat menuai tandan kelapa sawit dari bahagian bawah bersama dengan sokongan batang teleskopik yang dikawal secare automatik.

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LIST OF ABBEREVATIONS

ABS	Acrylonitrile Butadiene Styrene
AC	Alternative Current
BOM	Bill of Material
CAD	Computer Aided Design
CATIA	Computer Aided Three Dimensional Interactive Application
DC	Direct Current
DOSM	Department Of Statistics Malaysia
FELDA	Federal Land Development Authority
FFB	Fresh Fruit Bunches
GI	Galvanized Iron
HAVS	Hand Arm Vibration Syndrome
HOQ	House of Quality
MPOB	Malaysia Palm Oil Board
MPOC	Malaysia Palm Oil Council
PDS	Product Design Specification
PKO	Palm Kernel Oil
PM	Pugh Matrix
QFD	Quality Function Development
RM	Ringgit Malaysia

LIST OF SYMBOL

C_s	=	Critical Speed
d	=	Diameter
E	=	Young's Modulus
I	=	Moment Inertia
L	=	Length
M	=	Bending Moment
n	=	Rotational Speed
P	=	Load
p	=	Power
r_i	=	Inner Radius
r_o	=	Outer Radius
T	=	Torque
v	=	Velocity
Z	=	Section Modulus
σ	=	Stress
Δ	=	Deflection

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Oil palm is one of the most rapidly expanding equatorial crops in the world and Malaysia is one of the largest oil palm producing countries in Southeast Asia (Koh and Wilcove, 2008). Oil palm is firstly introduced as an ornamental plant to Malaysia in 1870 and the first commercial planting of oil palm took place in Tennamaran Estate in Selangor in 1917. An oil palm fruit is grown in large bunches with weight of 10kg to 50 kg where each bunch has up to 2000 fruits. The oil palm fresh fruit bunches (FFB) need to go through some processing unit operations before it produces as a palm oil product. There is difference in the level of mechanization for each unit of operation. However, the most important and primary stage is harvesting of oil palm FFB from oil palm tree.

At earlier stage, the traditional method was used in harvesting process. The oil palm harvesting involved the cutting of FFB by harvester and allowing it to fall to ground by gravity. It was done manually as the chisel in Figure 1.1(a) was used for young palms while the sickle in Figure 1.1(b) was used for taller palms. However, this manually harvesting operation led to the bruise or damage on oil palm fruits. This method was also extremely inefficient because of the height of palm tree and difficulty to access to fruit.

(a)

(b)

Figure 1.1(a) Chisel for young palm and (b) Sickle for tall palm

Realizing the problem, a motorized cutter which named as Cantas has been invented and developed by Malaysia Palm Oil Board (MPOB). The Cantas which shown in Figure 1.2 can be used to cut the frond and FFB from oil palm tree efficiently as it is powered by a 1.3 hp petrol engine (Jelani et al, 2008). The vibration method is used in designing the operational mechanism of Cantas whereby the vibration action is transferred to vertical direction so that the cutting operation can be performed vertically. Cantas not only reduces the involvement of labor in harvesting process, it also increases the productivity of oil palm with the harvesting capacity of 500 to 700 bunches per day. By comparison, the manual harvesting will only harvest 200 to 300 bunches of oil palm fruits per day (MPOB, 2016). However, there are limitations on the cutter and mechanism of the oil palm harvester. Hence, this project will focus in designing and analyzing of an oil palm harvester for better operational efficiency.

Figure 1.2 Motorised cutters, Cantas

1.2 PROBLEM STATEMENT

Production in the agriculture field becomes focus in Malaysia as it can lead to many advantages especially in economy of the country. Being one of the biggest producers and exporters of oil palm fruit, Malaysia aims to fulfil the growing global need. The rise in demand of oil palm fruits increases the work load of labour in oil palm estate as the harvesting of oil palm FFB is the vital stage of overall process. Although the motorized cutter, Cantas can reduce the harvesting time, the harvesting process of oil palm fruits normally still associated with high prevalence of ergonomic injuries (Ng et al, 2013). One of the reasons is the difficulty in cutting some of the fronds and brunches of oil palm, as the fibre bundles consist of cellulose. Labors might need to use some energy to shove the fronds and brunches physically during the harvesting of oil palm fruits. The tight arrangement of oil palm fronds and FFB on the tree also causes the difficulty in placing the sickle accurately.

During the harvesting process, the Cantas conserves the energy of labours and increases the productivity of oil palm fruits. However, the manually adjusted pole in the oil palm harvester causes the inconvenience to the labours as they need to change the height of poles manually due to various height of oil palm tree. The length of the pole is considered too long if they need to carry it for whole day long. Besides, they need to find a suitable position during harvesting process so that the oil palm FFB could be harvested accurately. Therefore, an oil palm harvester will be designed and analysed to solve these problems and provide higher operational efficiency.

1.3 PROJECT OBJECTIVES

The objectives of this project are as follows:

1. To design a circular cutter with rotational harvesting mechanism onto an oil palm harvester.
2. To develop a structure of automatically adjustable telescopic pole in the oil palm harvester.

1.4 SCOPE OF PROJECT

The scope of this project is emphasizing on the design of circular cutter and automatically adjustable telescopic pole onto an oil palm harvester that used to harvest oil palm FFB effectively. The oil palm harvester is designed for palm tree with maximum height of 4m. Besides, the operational mechanism of the cutter and telescopic pole are analysed in this project. The CAD work in designing the oil palm harvester is presented in CATIA V5R20.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In order to design an oil palm harvester with better mechanism, some researches on the oil palm tree and its fresh fruit bunches (FFB) are carried out. The history and invention of oil palm harvester since the early stage of a century are also studied. Different harvesting methods used in Malaysia as well as its mechanism are determined as it is a way to generate some ideas on designing the oil palm harvester. Other harvesting and cutting tools are also identified and studied in term of its components and mechanism. Besides, the definition of terms in product development process are also determined and studied in this chapter.

2.2 HISTORY OF OIL PALM

Elaeis Guineensis, commonly known as oil palm is originated from the tropical rain forest region of West Africa since 5000 years ago. The late 1800s, archeologists discovered that there is evidence of its use as an essential food crop and even being buried with people in Egyptian tombs. Besides, oil palm is also considered as one of the earliest traded commodities in Egypt. As the result of the British industrial revolution and the expansion of oversea trade, the oil palm is expanded significantly in the international market and also became a substantial part of the world global economy.

In early of the 1870s, oil palm is first introduced as an ornamental plant in Malaysia by a Scotsman named William Sime and an Englishman named Henry Darby (Green Palm Sustainability, 2016). According to Malaysian Palm Oil Council, the first planting of oil palm tree in Malaysia is located at Tennamaran Estate, Selangor in 1917. After that, the developments and cultivations of oil palm are increased at a rapid race in 1960 as the FELDA's smallholder stimulated the schemes of replanting of old rubber estate with oil palm. By 1982, Malaysia emerged as the largest palm oil producer in the worlds with 56% of world production and 85% of world exports of palm oil. In 2004, Malaysia also developed 4.49 million hectares of land for the cultivation of oil palm and this led to 17.73 million tons of palm oil and 2.13 tons of palm kernel oil (MPOC, 2010).

According to the Department of Statistic Malaysia, the top contributors in the agriculture sector Malaysia for the year 2015 were Johor, Pahang, Sabah, Sarawak, and Perak with the total share of 71.6 % as shown in Figure 2.1. However, the oil palm in Sarawak, Perak, and Negeri Sembilan were the main catalyst for national agriculture's growth (DOSM, 2016). Today, the oil palm becomes the most important commodity crop and plays an important position in the economy of Malaysia. As the main producers and exporters of oil palm, Malaysia has to fulfill the global needs for oils and fats sustainability.

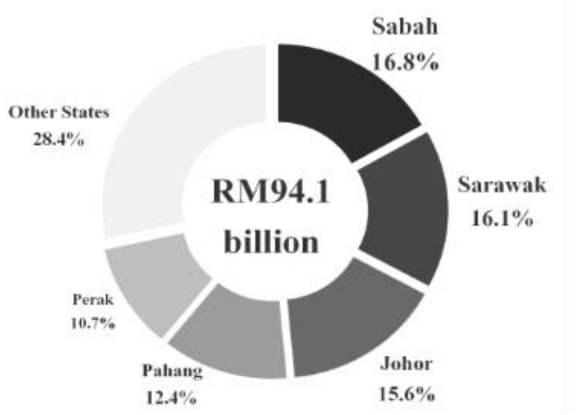


Figure 2.1 Percentage share of agriculture by state in 2015

(Source: Department of Statistic Malaysia, 2016)

2.3 OIL PALM TREE AND ITS FRESH FRUIT BUNCHES (FFB)

Oil palm is one of the most important plantation crops in Malaysia. Every part of the oil palm tree is very useful for economic and domestic purpose while the oils are importance in domestic, industrial and pharmaceutical preparations. Oil palm trees grow very well and produce a lot of FFB in hot weather and rains at a great deal. Therefore, it is suitable to plant at Malaysia where tropical climate with high temperatures and high humidity throughout the year.

2.3.1 Oil Palm Tree

An oil palm tree plants and grows from a seed. Those seeds are kept in room with hot temperature so that it will germinate faster within 90 to 100 days. Those seeds that germinated will then replant in a small container. After 4 to 5 months, a leaf with two points (bifid leaf as shown in Figure 2.2) will grow up and the young seedling will be transplanted into a nursery. After the young seeding stays in a nursery for one year, it will be moved to the palm grove (Food and Agriculture Organization of United Nations, 1990).

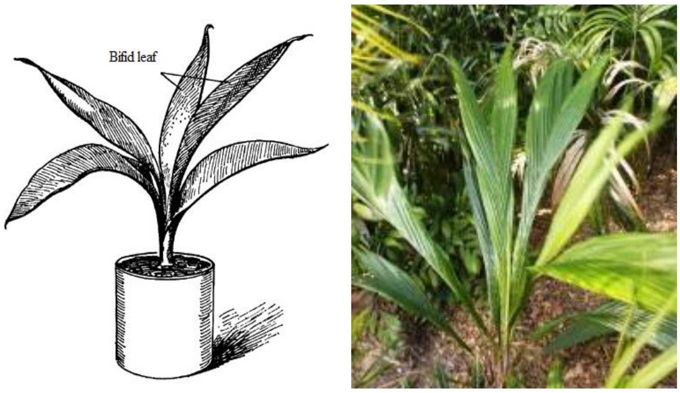


Figure 2.2 Seedling with bifid leaf

(Source: The oil palm, 1990)

Oil palm tree has no branches but it has trunk and leaves. The trunk can be named as stripe, which is a stem of the palm. Oil palm tree in Figure 2.3 starts to grow fruits after 30 months of field planting and it produces oil palm fruits for the next 20 to 30 years. This shows that the oil palm tree has a longer economic life span. For the oil palm tree with 25 years old, it is capable of growing up to 20 meters and more in height, depending on the age and vigor of the trees.

Figure 2.3 Oil palm trees

(Source: Amunisi News, 2016)

2.3.2 Fresh Fruit Bunches (FFB) of Oil Palm

Oil palm is a monoecious crop as both of the female and male flowers grow on the same tree. However, the flowers grow in different spikes and produce in different time. For several months, the oil palm will only produce male flowers. After few months, it will produce female flowers. The female flowers will be fertilized by male flowers and turned into a cluster of oil palm fruits. The oil palm grows in bunches and varies in weight from 10kg to 50kg as the FFB of oil palm consists of more than a thousand individual fruits. The oil palm FFB in Figure 2.4 is found to grow in three major stages from week 0 to 5, week 6 to 14 and week 15 to 14 (Kasim et al, 2014).

Figure 2.4 Oil palm fresh fruit bunches (FFB)

(Source: ArgiFarming, 2015)

2.3.3 Oil Palm Fruits

Oil palm fruits are naturally reddish in color as it is rich in carotenoids while the major component of its glycerides is the saturated fatty acid palmitic. Those fruits are viscous semi-solid at tropical ambient while solid fat in temperature climates.

They are similar in size to a small plum and almost spherical or elongated in shape as shown in Figure 2.5 (Kenneth, 2000). In detail, the individual fruit is range from 6g to 20g, as it consists of exocarp, mesocarp, endocarp, and kernel. The exocarp is the outer skin of oil palm fruits while mesocarp is the pulp that containing palms oil in a fibrous matrix. In addition, endocarp is a central nut that consists of shell and kernel is the resembling coconut oil that quite different from palm oil. The kernel contains the second oil which known as Palm Kernel Oil (PKO). Every component in the oil palm fruits has the health function for the human body. According to Obahiagbon (2012), trials have done on animals and humans based on the roles of oil palm in health. The β carotenes of the oil palm protect us against blindness and carcinogens. For tocotrienols, it can be used to produces inhibitory on breast cancer cells. The tocotrienol and tocophenols can be used as antioxidants to protect tissues from oxidative damage.

Figure 2.5 Oil palm fruits

(Source: Beiersdorf, n.d.)

2.4 HARVESTING METHOD USED IN MALAYSIA

As the main producers of oil palm in the world, the oil palm FFB harvesting and collection form a single largest direct cost in the oil palm production. There are sequences of processing steps which are designed to extract the oil palm from the FFB to oil product. The primary stage of the processing of oil palm is the harvesting process which involved the cutting of oil palm FFB from palm trees as well as pruning task. The harvesting process is carried out by cutting the exposed punch stalk while the pruning process is performed by cutting the oil palm frond that located at the trunk base. Each of the palm trees is visited for harvesting every 10 to 15 days as FFB ripen throughout the whole year.

2.4.1 Traditional Harvesting Method

A curved knife which attached to a long bamboo or aluminum pole or galvanized iron (GI) hollow metal pole is used in Malaysia. The knife can be categorized into two types which are chisel and sickle. For chisel, it is usually used for young and shorter palms which the height is within 0.5 meters to 3 meters above ground as shown in Figure 2.6. It can be done by slipping the chisel between the leaf and stem to cut off the FFB. It needs to throw the chisel at high speed to frond or FFB of oil palm. For sickle, it is used for taller palms which the height is over 3 meters as shown in Figure 2.7. The harvesting and cutting are done by slicing method by pulling the sickle downward.

In manual harvesting, a labor is required to move the body into suitable position by aligning it in the horizontal direction with the ripe FFB. Then, the harvesting is started by exerting push and pulls forces repeatedly using the pole. With the increase of tree height, the length of pole needs to be extended in order to reach the FFB on the tree. By using manual harvesting, the productivity is only 250 to 350 bunches per day.

Figure 2.6 Traditional harvesting methods with chisel

(Source: Indian Institute of Oil Palm Research, n.d.)

Figure 2.7 Traditional harvesting methods with sickle

(Source: Henkel, 2013)

However, the harvesting of oil palm FFB manually will cause the damage of oil palm fruits as it is allowed to drop onto the ground by gravity. Although the traditional process is simple, it is inefficient and tedious. The manual labour harvesting is also associated with high prevalence of ergonomic injuries especially waist problem as the labors need to forcefully pushing and pulling during harvesting. The intensity of the lifting manually had increased with the FFBs' weight and the palm trees' age (Ng et al, 2013).

According to Ming and Chandramohan (2002), other competitive in oil production field have improved their cost competitiveness in term of planting material and processing technologies. Thus, in order to expand the oil palm industry in Malaysia, some improvements should be done on the productivity, mechanization and so on. Although many operations have been mechanized and automatized, there are still consists of limitations due to the slow in practicing and adopting the new machines by labours.

2.4.2 Motorized Cutter

The motorized cutters popularly known as Cantas /Ckat in Figure 2.8 are developed by MPOB. These motorized cutters are designed and invented by Haji Razak Jelani and other designers. The cutter that attached to the Ckat is chisel while the cutter for Cantas is sickle. According to Jelani et al (2008), Cantas advanced II is a hand held cutter that can be used to harvest the FFB at height that less than 4.5m. The main components consist of cutting head, telescopic pole and engine. The cutting head included the C sickle, gear set, connecting rod, head casing and cover.

For the telescopic pole, it consists of telescopic shaft, bearing, basic pole and extension pole. Besides, it is powered by 1.3hp petrol engine with two strokes and produces 3000rpm cutting speed. The sickle is used in Cantas due to the unique design that could get access to the fronds and FFB easily and effectively (Jelani et al., 2003).

On the other hand, the Ckat advanced II is another handheld cutter that used to harvest the FFB within 1.2 meters to 2.4 meters. The components of Ckat are similar to the Cantas. It used the rapid acceleration gear with optimized transmission in the harvesting operation. The comparison on the maximum length and total weight between Cantas and Ckat are also summarized in Table 2.1.

Table 2.1 Specifications of Cantas and Ckat

	CANTAS	**CKAT**
Maximum length	3.6 m (telescopic)	2.4 m (telescopic)
Total weight	7.5 kg	6 kg

The vibration method is used in the operation of Cantas and Ckat. As the cutters need to be performed in vertical direction, the vibration action is transferred continually and vertically to the FFB during harvesting process. It is produced due to the effect of moment developed by the cutting force and the distance from the sickle holder. This motorized cutter reduces number of the labors that involved in harvesting process and increases the productivity of oil palm. In the trails that carried out by Jelani et al, it shown that the productivity by using Cantas was reached 560 to

750 bunches per day. This means that the labor requirement is reduce almost 50% in harvesting operation.

Figure 2.8 Cantas and Ckat

(Source: Fancy Power Sdn Bhd, 2016)

However, there are difficulty in harvesting of FFB and might influenced the efficiency of harvesting operation. This is because the fronds and brunches are made by fibre bundles. Labors might need to use some energy during harvesting of oil palm (Jelani, 1997). Besides, the vibration method in the mechanisms is also the issues that lead to ergonomic risks to labors. The sickle or chisel is attached to the aluminum alloy telescopic pole and it is vibrating to perform the cutting operation. According to Salleh et al (2013), the vibration that transmitted to labors hands and arms in the regularly or frequently exposure during harvesting of oil palm FFB can lead to the risk of hand arm vibration syndrome (HAVS).

2.5 OTHER CUTTING / HARVESTING TOOLS

In the designing of an oil palm harvester, few factors are needed to be considered. It consists of ergonomic problem, light weight, ease to handling, technique in harvesting, maximum height of harvesting as well as its safety. Therefore, other tools are studied in order to help in design concept generation.

2.5.1 Date Palm Machine

In the harvesting of date palm, it requires a man to climb up the tree and work at a considerable height above the ground. This can be considered as dangerous operation that compound by severe labor storage. In order to reach and elevate to the date palm fruits, an electro hydraulic controlled basket as shown in Figure 2.9 is mounted on a four wheel drive. The basket is driven by a diesel engine which can be used to elevate a man to the height of tree. The tests have shown that it is effective in harvesting and it significantly better than transitional method. However, the positioning of the machine to the tree is slow and it could not be travel over the ground with soft condition (Al Suhaibani et al, 1992).

Figure 2.9 Date palm machine

(Source: Southern Arava R&D, n.d.)

2.5.2 Tree Climbing Robot

According to Shokripour, Ismail and Karimi (2010), the tree climbing robot as in Figure 2.10 is designed which controlled by four wheels. It can be used to carry the maximum weight of 7kg with keeping its balance. It used alternative current (AC) to drive the cutting machine which converts from direct current (DC) by using inverter device. The power that required operating the robot is generated by DC micro gear motor. A gearbox is also used to control the speed of cutting system for accurate and smooth cutting. A test is carried out on the balancing of the robot. However, the limitations of the climbing robot are due to the irregularities of the surface of oil palm tree trunk. This will cause the robot to stuck and stop when climbing. The rectangular blades cutting machine with reciprocating motion is then designed to attach to the tree climbing robot. The centre of the oil palm leaves which is made by hard wood cause the intense vibration to be generated during the cutting process (Shokripour et al, 2012).

Figure 2.10 Tree climbing robot with cutting machine

(Source: Shokripour et al, 2012)

2.5.3 Portable Trimmer

It is a portable device that used to cut the weeds or grass by rotating the rotary cutter. The portable trimmer consists of a cylindrical brake drum portion that connected to a cutter blade retainer, a support shaft, an anti-rotation device and brake shoes. The anti-rotating device is used to fix the position of cutter during replacement or installation of cutter while the braking device is used to prevent the rotary cutter from rotating. The portable trimmer is driven by two strokes cycle air cooled compact internal combustion engine so that it will be rotate at low speed when the trimmer is not cutting grass. It is light in weight as possible to reduce the work loads of labours during trimming the weeds or grass (Nagashima, 2000).

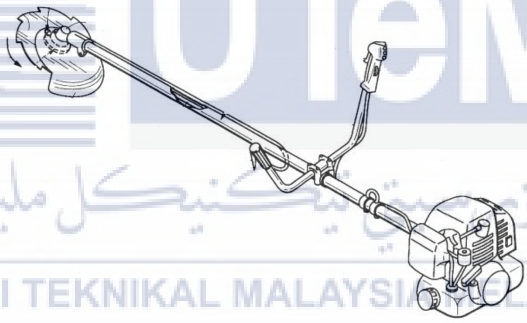


Figure 2.11 Portable trimmer

(Source: Nagashima, 2000)

2.5.4 Circular Saw Blade

According to Haughton and Haughton (2005), a circular saw blade is made up by a circular disk with cutting tooth attached to the periphery of the disk. Each of the teeth that attached to the disk is spaced apart and it extends outward and upward from the circular blade portion. The circular disk is made by steel which has high strength, good manufacturability and low in cost. For the tooth, it is made by carbide which has properties that high in highness, high abrasion resistance and good toughness. Both of the disk and tooth are joined together by soldering and brazing process. These blades are used to cut materials such as woods as it can be rotate in high speeds in excess of 160 mph at circumference.

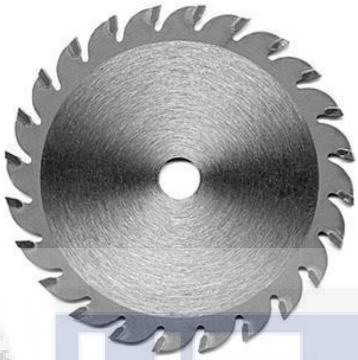


Figure 2.12 Circular saw blade

(Source: Industrial carbide, 2016)

2.6 PRODUCT DEVELOPMENT PROCESS

Product development process that shown in Figure 2.13 is a general outline that used in getting a product idea from concept until the designing of a new product to market. It consists of the planning, concept development, system level design, detail design, testing and refinement as well as the product ramp-up. The 'gate' between two processes symbolizes that the project must be passed through the stage successfully before it moves to the next stages. This process is simple and easily to be understand by engineers and managers of company. However, the level of the design work will be decreased and the manufacturing work will be increased if these stages are used in the flow of the project. Therefore, many companies modify this process based on circumstances of company (Dieter and Schmidt, 2013).

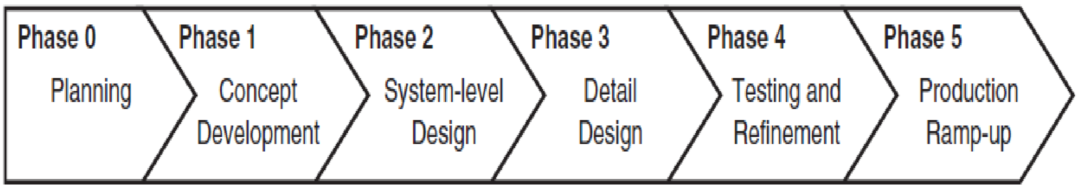


Figure 2.13 Product development process in stage gate format

(Source: Dieter and Schmidt, 2013)

2.6.1 Quality Function Development (QFD)

Temponi, Yen and Tiao (1999) states that QFD is a planning and team problem solving tool that has been adopted by a wide variety of companies as the tool of choice for focusing a design team's attention on satisfying customer needs through the product development process. It comprises several matrices to clearly establish the relationship between function of company and satisfactions of customer. These matrices are based on the matrix related to 'what-how' which known as HOQ. It is a process that translates the customer needs into the process step specifications. This also shows relation of the data produced in one stage of the process to the decision made in next process stage.

2.6.1.1 House of Quality (HOQ)

HOQ can be considered as matrices of an iterative process that known as QFD. The foundation belief that a new product should be designed to reflect customers' requirement and desires which usually used natural language. The HOQ as shown in Figure 2.14 is the most recognized and widely used matrix in the quality function development process as it takes the information that developed from design team and then translates it into a format which is more useful in generation of product. According to marketing research and benchmarking data, it converts customer requirements into engineering targets that the new product design needed to be met. The general HOQ is commonly made up of six major components. It includes the customer requirements, a planning matrix, an interrelationship matrix, a technical correlation matrix, and a technical priorities or benchmarks and targets section (Park and Kim, 1998).

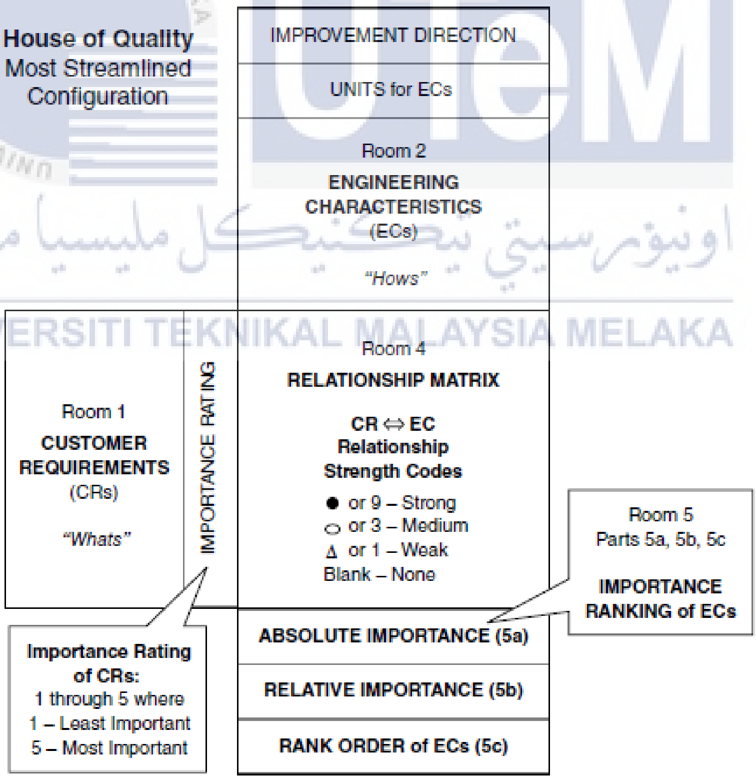


Figure 2.14 House of quality (HOQ)

(Source: Dieter and Schmidt, 2013)

2.6.2 Product Design Specification (PDS)

Product design specification (PDS) is a basic control and reference document created during the problem definition activity. It details the requirements that must be met in order for the product or process to be successful. It is a basic control and reference document for the design and manufacture of the product. Besides, it also contains all the facts related to the outcome of the product development. PDS is used to finalizes the process of identification of customer requirements and transfer them into the technical framework for the establishment of design concept. The content of PDS can be categorized into product identifications, market identifications, physical descriptions, manufacturing specifications and so on (Dieter and Schmidt, 2013).

2.6.3 Morphological Chart

According to Richardson (2010), a morphological chart is an ideation tool that represents a large qualitative design space. It uses as function representation of the design problem by using the function list. It can also consider as a table that generally developed as an analysis tool for design concept. All of the concepts are organized to build the suitable arrangements and achieve the overall function of the product. The design characteristics which are independent are listed and different engineering solutions are determined for each solution (Tayal, 2013).

2.6.4 Pugh Concept Selection

Pugh Matrix (PM), known as Pugh Concept Selections is a type of matrix diagram that allows the comparison of number of design to meet a set of criteria (Pugh, 2009). It is a quantitative technique that usually used to rank the multi-dimensional options of an option set as well as rank investment options, product options or other set of multidimensional entities as shown in Figure 2.15. Besides, it provides a simple approach to the multiple factors into account when reaching a decision.

				Design Concepts					
		Pugh Concept Selection Matrix	Wieght	Electric 4-slot	Toasting Fork & Fire	Electric Conveyor	Gas Grill		
Selection Criteria	Good Toast Quality	Even Toasting		S	- -	S	-		
		Good Taste		S	+ +	S	S		
		Repeatable		S	- -	+	-		
		Quick		S	+	S	S		
	Capacity	Large Range of Bread Products		S	+	S	+		
		Multiple Slices/Units		S	- -	+	+		
	Long Life	Reliable		S	+	-	S		
		Durable		S	+	S	S		
		Low Maintenance		S	- -	-	S		
	Physical Attributes	Affordable		S	+	-	+		
		Attractive		S	+	-	-		
		Safe		S	- -	-	- -		
		Good Size		S	- -	-	-		
	Easy to Use	Easy to use Controls		S	-	S	+		
		Easy to Load		S	-	+	-		
		East to RemoveToast		S	- -	+	-		
		TOTAL +		0	8	4	4		
		TOTAL -		0	18	6	-8		
		TOTAL SCORE		0	-8	-2	-4		
		WEIGHTED SCORE							

Figure 2.15 Pugh Concept Selection

(Source: Pugh, 2009)

2.6.5 CATIA

Computer Aided Three Dimensional Interactive Application, well known as CATIA is created, developed and owned by the Dassault System. It mostly used in designing and manufacturing industrial sectors such as construction, aerospace, electronics, machinery and so on. Besides, CATIA is also common in engineering field as the design leading software for 3D design. This is because it allows the users to simulate the industrial design from initial concept to product design, analysis, assembly as well as maintenance.

2.7 LEAD SCREW SYSTEM

Based on Vahid, Eslaminasab and Golnaraghi (2009), lead screw mechanism in Figure 2.16 is usually used to convert the rotational motion to linear motion. It can also be categorised into type of gear system as it employed and provided an economical solution in shifting of motion of rotary to translational. When a load is applied on the lead screw, the load will be distributed among the threads of the screw and nut which can range from highly non uniform to nearly uniform (Murphy and Blanchet, 2008). The lead screw system is widely used in the simple transfer application that requiring of the speed, accuracy, precision and rigidity.

Figure 2.16 Lead screw system

For the mechanical analysis of the lead screw system, it is usually limited to the factor that affecting its static performance. It included the efficiency, driving torque as well as the load capacity. However, the critical shaft speed and the interaction of the contacting lead screw and nut threads is most importance analysis for the lead screw system and it can be easily calculated as shown below by considering the end support factor and screw diameter.

$$\text{Critical speed, } C_s = \frac{(4.76x10^6)dC}{l^2}$$

Where d = diameter of screw

C = end support factor

l = length between support

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter describes the procedures and methods that used in designing an oil palm harvester. The flow chart that used in developing the oil palm harvester is shown in Figure 3.1. It is done to show the overall processes and as a guideline in order to achieve objectives of the project. It starts with the definition of problem and background research that related to oil palm harvester. After collected some information from literature review, the project is done with designing processes which includes the specifications and needs identification, concept generation, concept evaluation, embodiment design, analysis and discussion as well as detail design of the oil palm harvester. Lastly, this project is also completed with the documentation and presentation at the final stage.

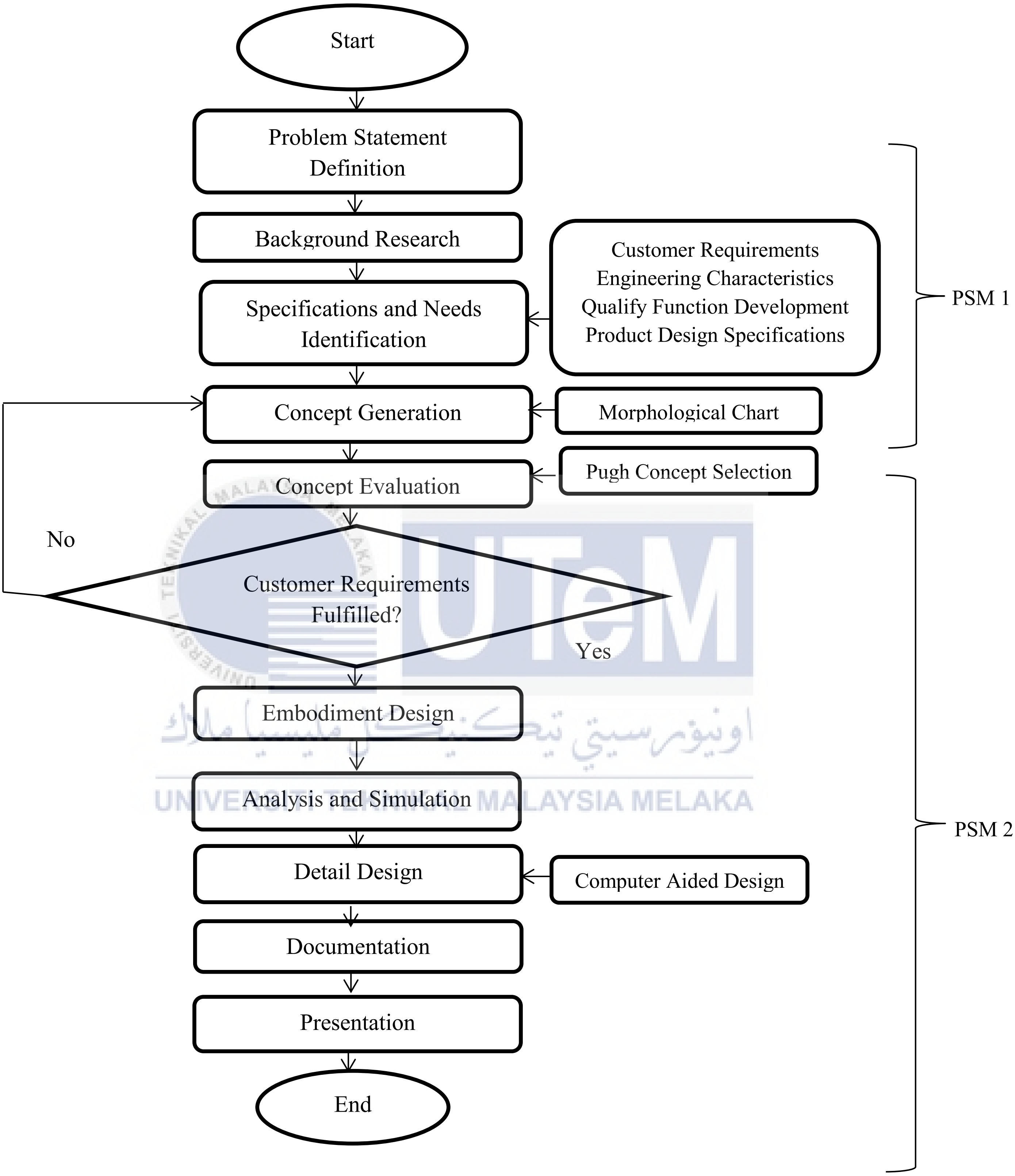


Figure 3.1 Project flow chart

3.2 METHODS

There are several methods can be used to obtain information and ideas for designing an oil palm harvester in this project. The main method that used to gather information and knowledge of oil palm harvester is internet articles.

3.2.1 Internet Articles

It is used to determine and identify the physical and engineering characteristics of the oil palm in term of the trees, FFB as well as oil palm fruits. It is also used to investigate the specifications and characteristics of existing oil palm harvester from internet articles, journals as well as literature review. The relevant information is defined and analyzed.

3.3 SPECIFICATIONS AND NEEDS IDENTIFICATION

The problems and limitations on the existing oil palm motorised cutter are identified as it can be used as requirement and improvement in new design of oil palm harvester. The customer requirements and engineering characteristics are listed as well as the HOQ is generated to show the specifications and needs on the oil palm harvester. The PDS are also identified in this stage in order to complete the designing process.

3.3.1 Customer Requirements

The requirements of customer on the oil palm harvester are determined by identifying what the needs are the harvester must meet. The needs of customers are important to the development of product design specifications for new design of oil palm harvester. Besides gathering the information from brainstorming, the research on technical literature is also used in this process. The design problems or limitations in the existing motorized cutter that determined from literature review in subtitle 2.4.1 and 2.4.2 are turned and changed into the requirements that should meet in designing an oil palm harvester.

3.3.2 Engineering Characteristics

The engineering characteristics on the oil palm harvester which related to the product performance measures and features are determined by means to satisfy the customer requirements. It is a set of physical properties that need to be determined to describe the behavior of oil palm harvester. The measurement and characteristics of the existing motorized cutter that shown in the literature review with subtitle 2.4.2 are used as references in generating the engineering parameters of new design of oil palm harvester in this project.

3.3.3 Quality Function Development (QFD)

The QFD process is done by developing a HOQ. The customer requirements and engineering characteristics of the oil palm harvester that determined from pervious stage are listed in the main rooms of HOQ. Besides, the relationship matrix is done based on the relationship between the requirements and characteristics of harvester. The end results of HOQ are then shown at bottom of the house as rank order to guide the selection and evaluation of the concept design of oil palm harvester.

3.3.4 Product Design Specification (PDS)

PDS is a basic control and reference document for problem definition process. The critical specifications and statements of oil palm harvester are listed in PDS according to the customer requirements and reviews from existing motorized cutter and other harvesters. It is generated by finalized and grouped the requirements and characteristics of oil palm harvester that developed in the HOQ.

3.4 CONCEPT GENERATION

Concept generation is early stage of designing an oil palm harvester according to the specifications and requirements of customer. It is also a process that creates many feasible alternatives to a given PDS. It provides an explanations or descriptions of the oil palm harvester in term of a set of integrated products and ideas. The better understanding of the problem statement is very important in generating the concept design of harvester. The “why” technique is also used in this process in order to get to the root of the problems and the better solutions for the problem found.

3.4.1 Morphological Chart

Morphological chart is chosen in generating ideas of conceptual designs. It is an ideation tool that represented a large qualitative design space. It is used to explore and synthesis all the relationship of components in the oil palm harvester in order to fulfil the same requirement functionality. All of the concepts are organized to build a suitable arrangement and to achieve overall function of the oil palm harvester. Each of the concepts in the chart is different from each other in terms of physical, mechanism as well as geometric.

3.4.2 Conceptual Design

Different designs are drawn and presented according to the different combinations of components or parts that listed in morphological chart. Those designs are drawn based on the relationship in multidimensional problems so that the functionality required by customers is met. Each of the concept design is explained in term of its characteristics, function, mechanisms and so on.

3.5 CONCEPT EVALUATION

Concept selection is a process with the identification of alternatives and outcomes of the alternatives as well as the subjection of the related information to a rational process in decision making. It involves both of the comparison and decision making process on the conceptual designs that drawn. Those designs are evaluated based on their characteristics and specifications. A best design with higher ranking is selected to proceed to next stage as it has the highest potential for becoming a quality harvester.

3.5.1 Pugh Concept Selection

Basic decision matrix which known as Pugh concept selection is used in selecting the best design of oil palm harvester from few conceptual designs. It is a matrix diagram that allows the comparison of different designs and identification of the most promising design concept among the alternatives. It compares each of the generated concepts with the chosen datum in term of the specific criteria and requirements. In comparison, the better concept is evaluated with +, worse concept with – and same concept with S. The sum of the + and – for each concept design is determined. At the end of evaluation process, a higher rating concept is selected and established to next stage.

3.6 EMBODIMENT DESIGN

This process is important as it is used to identify the dimension of each parts or components in oil palm harvester. Besides design an aesthetic harvester, it is also used to design a harvester with user friendly and environmentally benign. This embodiment design process includes the product architecture, configuration design and parametric design of the selected oil palm harvester. The materials of components used in designing the oil palm harvester are also presented. The determination of standard components and designing of special purpose parts are also shown in this stage. In addition, the parameters and physical properties of the oil palm harvester are also determined in term of the dimension, tolerances and so on.

3.7 ANALYSIS AND SIMULATION

The oil palm harvester is analyzed by using related theoretical equations or mathematical models. The rotational speed of cutter is done with the assumptions of maximum power used and maximum force applied in order to determine whether the product is designed based on requirements of customers. The speed of threaded rod is also determined with the assumption of maximum time and length as well as the lead screws concept. Besides, the deflection on telescopic pole is also calculated by applying the maximum force. All of the assumptions made and theoretical aspects that used in analysis are also presented and explained. Furthermore, the CATIA is also used in the analysis and simulation on the structure of oil palm harvester which include the cutter, motor housing and telescopic pole. The results that get from CATIA are presented and discussed in this stage.

3.8 DETAIL DESIGN

Detail design is the phase where the design is refined and plans, the specifications and estimates are created. The concept alternatives, preliminary physical architectures, design specifications, and technical requirements of the selected oil palm harvester are transformed into the final, cross-disciplinary design definitions. Besides, the materials used of the oil palm harvester are also determined and dimensions are identified. All of the subassembly and main assembly drawing of harvester are also drawn and presented in form of engineering drawing. The detail drawing of oil palm harvester is done with the revise of PDS as well as the product structure of subassembly drawing.

3.8.1 Computer Aided Design (CAD)

CAD is a computer application system that used in creation, modification, analysis and optimization of design. The detail designs of the selected oil palm harvester are drawn in CAD software, which known as CATIA. All of the components and parts of the harvester are drawn with detail parameters and selected materials. Besides, the complete assembly drawing of selected oil palm harvester is also done by combining all of the components. In addition, the bill of material of harvester is also determined as well as its exploded view.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter points out all the results that determined and identified from the product development process in order to design an oil palm harvester with high operational efficiency and better mechanism. All of the results that explain and discuss are based on different stages that shown in the flow chart.

4.2 SPECIFICATIONS AND NEEDS IDENTIFICATION

4.2.1 Customer Requirements

The customer requirements of oil palm harvester are determined. Few specifications such as the performance, features, cost, reliability, ease to use, safety and so on are considered. It is based on the limitations and problems of existing oil palm motorized cutter that faced by labors as described in subtitle 2.4.1 and 2.4.2. Those limitation and problems should be solved and the customer requirement should be met in order to design a better oil palm harvester. Therefore, few customer requirements are determined as shown below.

i. Light in weight
ii. Ease of handling
iii. Low in cost
iv. Efficiency in operation
v. Low maintenance
vi. Reduction in vibration
vii. Ergonomic design
viii. Safety design

4.2.2 Engineering Characteristics

In order to design a harvester with suitable parameters, the engineering characteristics of oil palm harvester are determined based on the measurement and physical properties of the existing motorized cutter that explained in literature review with subtitle 2.4.2. These engineering characteristics are related to the features that have been identified as the means to satisfy the customer requirement in subtitle 4.2.1. Few engineering characteristics are identified as shown below.

i. Maximum weight
ii. Maximum length
iii. Speed of cutter
iv. Strength of cutter
v. Material used
vi. Cost

4.2.3 Quality Function Development (QFD)

The HOQ is chosen to perform the QFD of the oil palm harvester in this project. By interpreting the relationship between the customer requirements and engineering characteristics of oil palm harvester in subtitle 4.2.1 and 4.2.2, the result of HOQ is determined and shown in the Figure 4.1.

The end results of HOQ are shown at bottom of the house as rank order. The order can be used as guide in the selecting and evaluating for concept design of oil palm harvester. The HOQ shows the most important engineering characteristics in designing an oil palm harvester are the speed and strength of cutter as both of it got the highest ranking in the rank order. The cutter is essential part among the components of oil palm harvester as it carries out the operation of cutting and harvesting of FFB from the trees. However, the least important characteristics are length and cost of the oil palm harvester.

		Engineering Characteristics (Ecs)					
Improvement Direction		↓		↑	↑		↓
Units (ECs)		kg	m	rpm	Pa	n/a	RM
Customer Requirements (CRs)	Importance Weight Factor	Maximum weight	Maximum length	Speed of cutter	Strength of cutter	Material used	Cost
Light in weight	5	9				3	1
Ease of handling	5	1					
Low in cost	4					1	9
Efficiency in operation	5		3	9	9		
Low maintenance	3			1		3	
Reduction in vibration	4			3	3		
Ergonomic design	5	1	1				
Safety design	5		3	1	1	3	
Raw Score (301)		55	35	65	62	43	41
Relative Weight %		18.27	11.63	21.59	20.6	14.29	13.62
Rank Order		3	6	1	2	4	5

Improvement direction
↑ - maximize
↓ - minimize

Importance weight factor
1 - least important
5 - most important

Relationship matrix
1 - weak relation
3 - medium relation
9 - strong relation

Figure 4.1 HOQ of oil palm harvester

4.2.4 Product Design Specification (PDS)

PDS is a documentation process in the problem definition activity. The PDS of the oil palm harvester are listed in Table 4.1 as it gathered all the information and criteria based on the HOQ. The requirements must be met in order to design an oil palm harvester with high efficiency and better mechanism. An oil palm harvester is designed in this project to cut and harvest the oil palm FFB from the trees with maximum height of 4m.

Table 4.1 PDS of oil palm harvester

CRITERIA	SPECIFICATIONS
Performance	• Short harvesting time. • Fast cutting speed with cutter rotational speed of 1400rpm. • Short extension time for 1m pole with 200 seconds.
Functionality	• Powered by 1kW petrol engine. • Rotational movement of cutter and extension of telescopic poles are generated by motors.
Height	• Maximum extension length is 3.7m while minimum retraction length is 2.7m • Reach oil palm tree with maximum 4 meters.
Weight	• Light and strong materials are used in each component. • Weight is approximated to be less than 6kg.
Cost	• Affordable and standard marketing price. • Low material cost, manufacturing cost and operation cost.
Strength	• High strength materials such as aluminium are used. • Harvester with robustness, reliability and compactness. • Resistant to heat, water and wind.
Safety	• Cutter is fixed in position during replacement or installation of new cutter. • Sharp cutter is covered by outer safety guard.
Ergonomics	• User friendly as it is easy to start up by on/off button. • Length of telescopic pole can change automatically. • Easy in handling and transportation with the short adjustable pole.

4.3 CONCEPT GENERATION

In order to design an oil palm harvester with higher operational efficiency, the Cantas that developed by MPOB is chosen as a datum. It is invented and designed by Haji Razak Jelani and his designers. The Cantas in Figure 4.2 with the weight of 6.5kg is a motorized cutter that designed with a sickle. It can be used to harvest the oil palm FFB from the tree that less than 4m height. The telescopic pole with length 1.6m to 2.4m is installed with vibrator and it is powered by 1.3hp petrol engine with two strokes. The petrol engine is used to generate the vibration mechanism for creating the great speed in cutting process of the Cantas (Kusuma, G. and Vidhan, S.T, 2015).

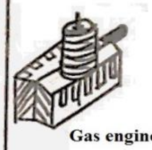
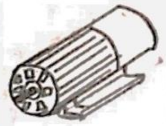
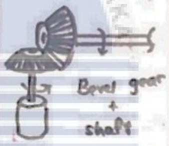
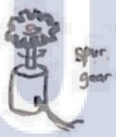
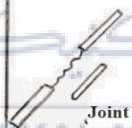
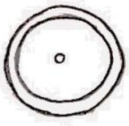
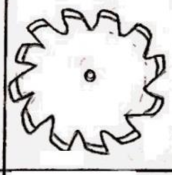
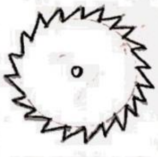
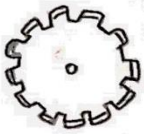
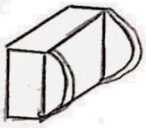
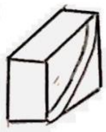
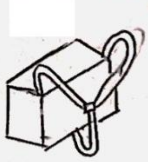
Figure 4.2 Datum, Cantas

(Source: Kusuma, G. and Vidhan, S.T, 2015)

4.3.1 Morphological Chart

The morphological chart is chosen to generate ideas in designing the conceptual design of oil palm harvester. Different characteristics and options such as power source, location of motor and the connection of motor to cutter are focused as the main part of the harvester. Besides, the parts or components like pole, handle, cutter, as well as security belt are also determined. Different conceptual designs of oil palm harvester are generated and drawn by combining different characteristics and options that investigated in morphological chart that shown in Table 4.2.

Table 4.2 Morphological chart of oil palm harvester

CHARACTERISTICS	1	2	3	4	5
POWER / ENERGY SOURCE	 Fuel engine	 Solar engine	 Rechargable engine	 Gas engine	 Electric engine
LOCATION OF MOTOR	One motor (Near to engine)	One moter (Near to cutter)	2 motors (One near to engine and one near to cutter)	2 motors (Both near to cutter)	2 motors (Both near to engine)
CONNECTION OF MOTOR TO CUTTER	 Bevel gear + shaft	 Spur gear	 Cables	—	—
POLES	 Telescopic	 Joint / assembly	 Foldable	 Clamp lock	 Twist lock
HANDLE	 2 handles		Without handle	 1 handle	—
CUTTER / BLADE					 chain saw
SECURITY BELT					—

4.3.2 Conceptual Design

4.3.2.1 Concept design 1

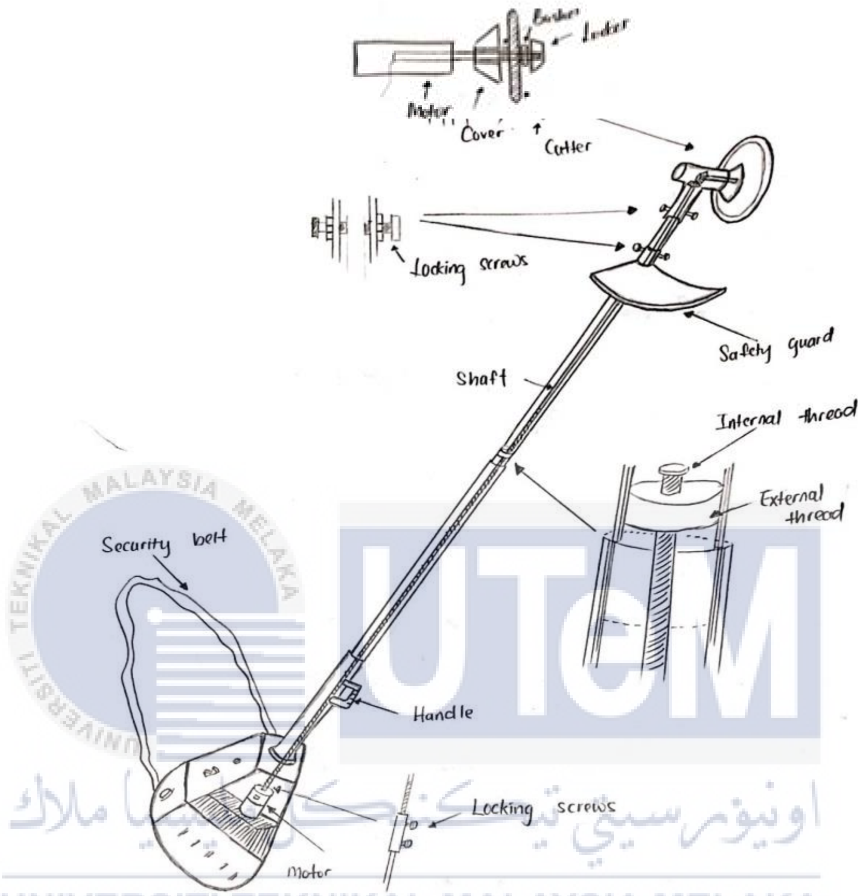


Figure 4.3 Concept design 1

By referring to the morphological chart in Table 4.2, the following characteristics are chosen for concept 1 as shown in Figure 4.3.

Power source	: Option 5	Handle	: Option 2
Location of motor	: Option 3	Cutter /blade	: Option 1
Connection	: Option 3	Security belt	: Option 3
Poles	: Option 1		

Based on the concept 1, the rotational movement of cutter and extension of the telescopic pole are generated by the power from the electric engine. Both of the movements are done by the rotational forces from the motors. Two motors are used in this design as the one is attached near to engine and another is near to the cutter. The telescopic pole is extended and retracted by the rotational movement of the internal thread shaft that guided by the motor near the engine. Besides, the rotational movement that generated by the motor which attached at top of the harvester is used to move the cutter. The normal circular blade is used as cutter in this design because it is simple and light in weight.

4.3.2.2 Concept design 2

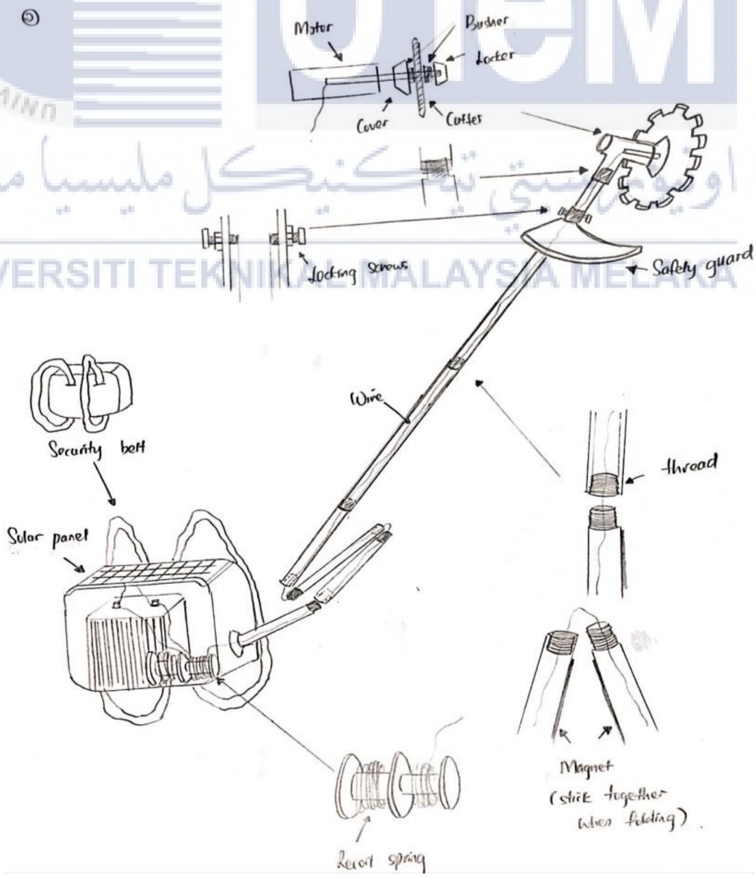


Figure 4.4 Concept design 2

By referring to the morphological chart in Table 4.2, the following characteristics are chosen for concept 2 as shown in Figure 4.4.

Power source	: Option 2	Handle	: Option 4
Location of motor	: Option 2	Cutter /blade	: Option 4
Connection	: Option 3	Security belt	: Option 1
Poles	: Option 3		

In concept 2, the solar engine is used to generate power for the rotational movement of the cutter. The motor which attached near to the cutter is used to generate the rotational force to the cutter. In this concept, the circular blade with right angle flat teeth is used as the cutter. On the other hand, the length of the pole can be increased by connecting the foldable poles. Those poles can be locked to each other with the thread that builds at the end of each pole. The pole can also be kept together in bundle as each pole is built with magnet. In addition, the retractable cord with horizontal position that kept in the engine bag is used in this design to roll up the wire when the pole is adjusted to shorter length. The double shoulder security belt is also attached near to the engine bag for convenience to the labours that carry the harvester during the harvesting process.

4.3.2.3 Concept design 3

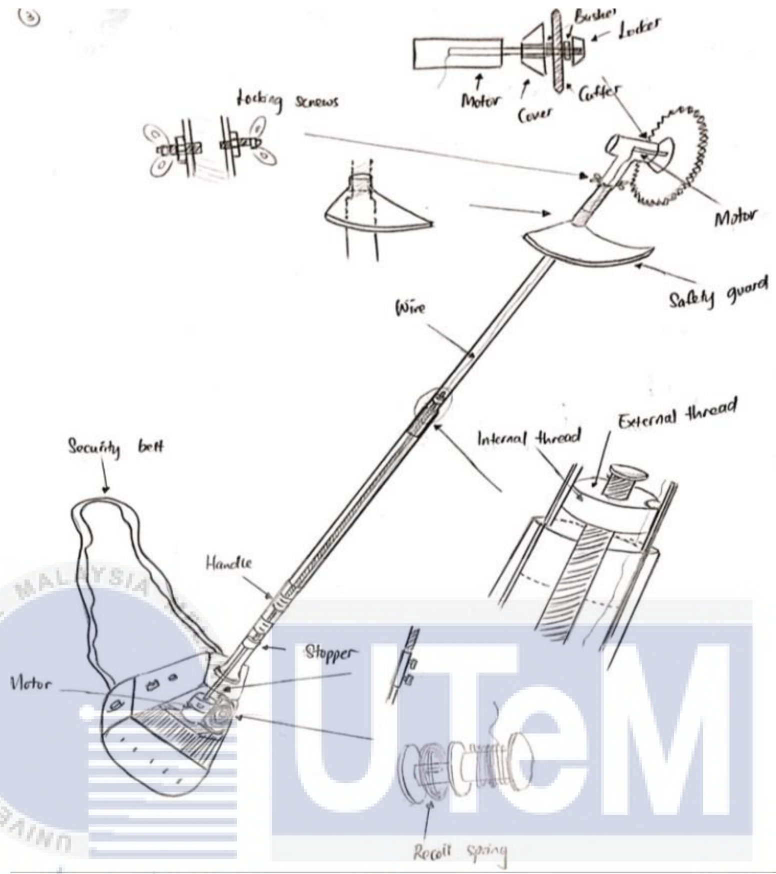


Figure 4.5 Concept design 3

By referring to the morphological chart in Table 4.2, the following characteristics are chosen for concept 3 as shown in Figure 4.5.

Power source	: Option 1	Handle	: Option 1
Location of motor	: Option 3	Cutter /blade	: Option 3
Connection	: Option 3	Security belt	: Option 2
Poles	: Option 1		

Based on concept 3, fuel engine is used to generate power for the rotational movement of cutter and extension of the telescopic pole. Both of the movements are done by the rotational forces from the motors. Two motors are used in this design as one is attached near to engine and another is near to the cutter. For the motor that attached near to the cutter, it is connected to engine with long wire. The wire is controlled and rolled up by a retractable cord when the poles retracted to shorter length. The rotational movement is also generated by the motor to move the inclined teeth circular blade. The telescopic pole is extended and retracted by the rotational movement of the internal thread shaft that guided by the motor near the engine.

4.3.2.4 Concept design 4

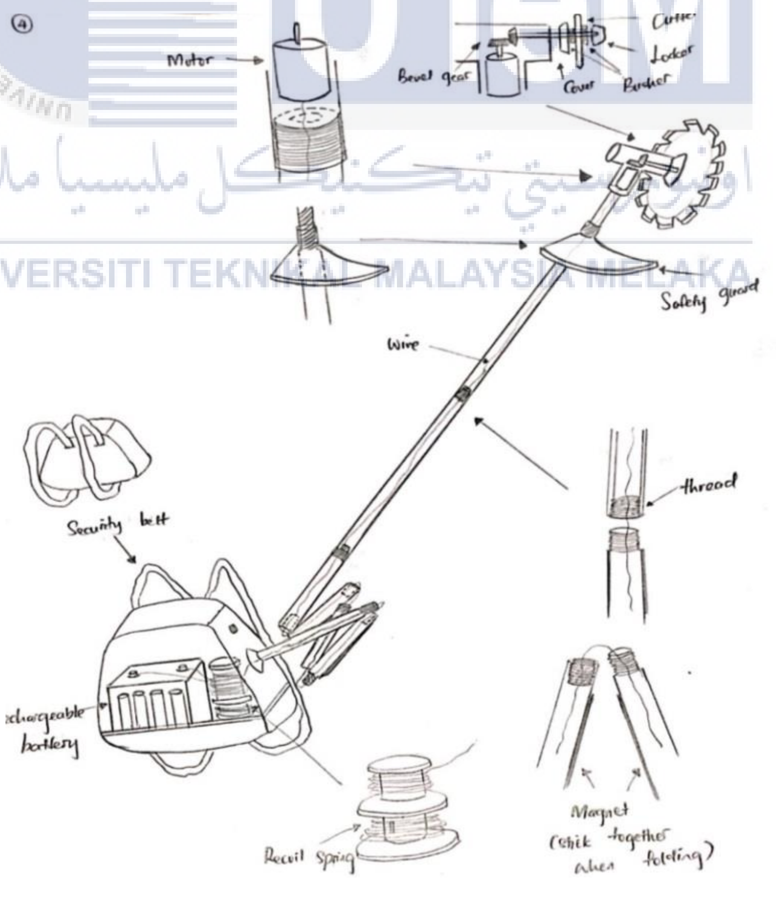


Figure 4.6 Concept design 4

By referring to the morphological chart in Table 4.2, the following characteristics are chosen for concept 4 as shown in Figure 4.6.

Power source	: Option 3	Handle	: Option 3
Location of motor	: Option 2	Cutter /blade	: Option 2
Connection	: Option 1	Security belt	: Option 1
Poles	: Option 3		

In concept 4, the rechargeable battery is used to generate power for the rotational movement of the cutter. The motor which attached near to the cutter is used to generate the rotational force to the shaft and bevel gear. Then, the force and movement from the bevel gear are transferred to the circular blade with inclined flat teeth. On the other hand, the length of the pole can be adjusted by connecting the foldable poles. Those poles can be locked to each other with the thread that builds at the end of each pole. The poles are also attached with magnet so that it can be kept in bundle. The retractable cord is also used in this design to roll up the wire when the pole is adjusted to shorter length. In addition, the double shoulder security belt is also used in this design as it is attached near to the engine bag.

4.3.2.5 Concept design 5

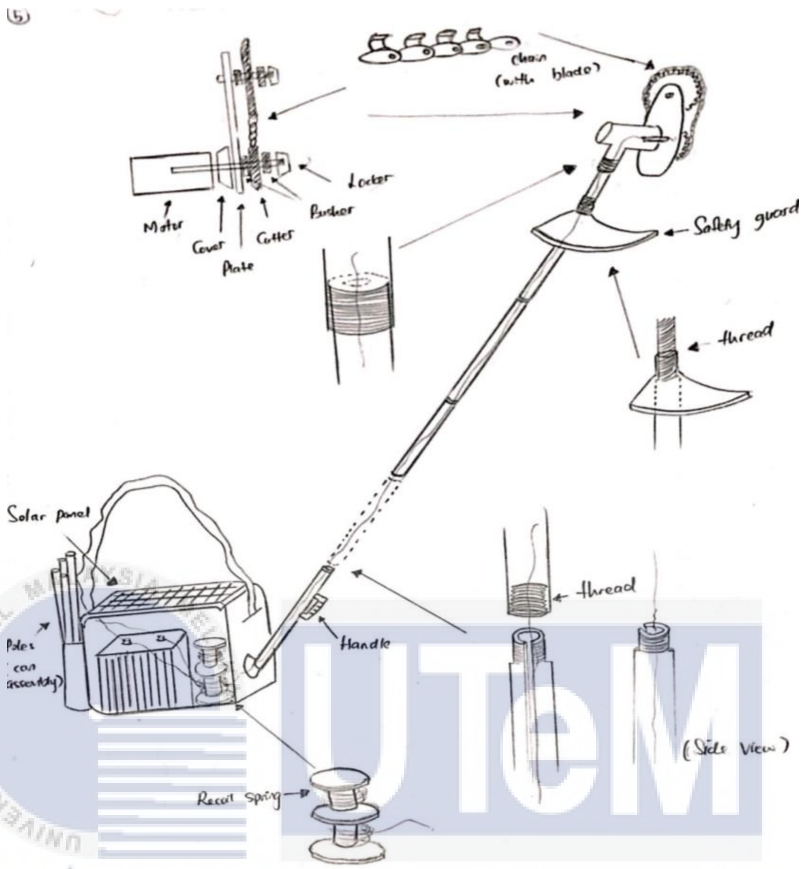


Figure 4.7 Concept design 5

By referring to the morphological chart in Table 4.2, the following characteristics are chosen for concept 5 as shown in Figure 4.7.

Power source	: Option 2	Handle	: Option 2
Location of motor	: Option 2	Cutter /blade	: Option 5
Connection	: Option 2	Security belt	: Option 2
Poles	: Option 2		

According to the concept 5, the rotational movement of cutter is generated by using the power from solar engine. The chain saw concept is chosen to be applied to the cutter in this concept design because it can minimize the power that used to generate the rotational movement of cutter. This means that the motor which attached near to the cutter is used to generate the rotational force to the spur gear and the movement is then transferred to the cutter by using a chain. On the other hand, the length of the pole can also be increased by joining or assembly the separate poles with various lengths. It can be locked to each other with the thread that builds at the end of the poles. Those poles can also be kept in another bag that attached near to the engine housing. The retractable cord is arranged in vertical position in this design in order to roll up the wire when the pole is adjusted to shorter length.

4.4 CONCEPT EVALUATION

4.4.1 Pugh Concept Selection

In this stage, the Pugh matrix (PM) is chosen for the concept evaluation of the oil palm harvester. Among five of the conceptual designs of harvester, one of the best design is chosen based on the comparison with the selected datum in term of the criterion stated in Table 4.3.

Table 4.3 Concept evaluation of oil palm harvester

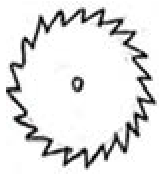
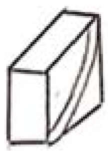
CRITERION	**CONCEPT**					
	1	**2**	**3**	**4**	**5**	**Datum**
Performance	+	0	+	0	0	|
Functionality	-	+	+	+	0	|
Height	+	-	+	-	-	|
Weight	0	-	0	-	+	D
Cost	-	0	-	0	0	A
Strength	+	0	+	0	-	T
Safety	-	+	-	-	-	U
Ergonomics	+	0	+	0	0	M
Addition	4	2	5	1	1	|
Subtraction	3	2	2	3	3	|
Final Score	1	0	3	-2	-2	|

4.4.2 Best Concept

Based on the Pugh concept selection in Table 4.3, the best concept design for the oil palm harvester is concept design 3 as in Figure 4.8. This is because it consequences with the consideration of engineering criteria and customer requirements. The concept design 3 also gets higher final score than other designs with 5 points in addition and only 2 point in subtraction. Therefore, design 3 is chosen for further discussion in this project as it has the highest potential to become a quality product. The criteria and concepts that used to complete the best design of oil palm harvester are also discussed in Table 4.4.

Figure 4.8 Best concept of oil palm harvester

Table 4.4 Criteria and concept in selected harvester

CRITERIA	IDEA / CONCEPT		REASON (S)
Power source	Option 1		Diesel engine is better in efficiency, fuel economy and higher compression ratio than the petrol engine.
Location of motor	Option 3	2 motors (One near to engine and one near to cutter)	Motors are located near to the cutter and engine in order to reduce the energy loss and increase efficiency of rotational movement.
Connection of motor to cutter	Option 3		The cutter is attached to the motor together with the cover, bushes and locker. The rotational movement of motor is directly transferred to the cutter.
Poles	Option 1		The automation mechanism is built in the telescopic pole and it is easy in handling, controlling and operating.
Handle	Option 1		The rubber handles can increase the friction between labor's hand and pole to avoid the slipping during harvesting of oil palm FFB.
Cutter/ blade	Option 3		The circular blade with inclined teeth is used and it is made from carbide steel which is sharp and good in cutting.
Security belt	Option 2		The inclined security belt can evenly distribute the weight of the harvester to the shoulder of labors and reduce the weight that supported by their hands.

In the selected oil palm harvester, the diesel engine is used as power source. This is because it can be used to generate power in better efficiency for the rotational movement of cutter and extension of the telescopic pole. Both of the movements are done by the rotational forces from the motors. The diesel engine is connected to two motors which one is attached near to the cutter and another is near to the telescopic pole. The motor that used to generate movement for cutter is located near to the cutter to reduce the energy loss. The rotational movement is generated by the motor to move the inclined teeth circular blade.

On the other hand, the wire that used to connect the motor with engine is kept inside the long pole. The retractable cord is attached in the engine housing in order to control and roll up the wire when the pole is retracted to shorter length. Furthermore, another motor is attached near to the engine housing and used to control the telescopic pole. The telescopic pole is extended and retracted by the rotational movement of the internal thread shaft that guided by the motor. The threaded nut is installed in the pole and allowed the threaded rod to turn in and out to generate the linear motion. Besides, the components such as safety guard, handles and security belt are also installed in the oil palm harvester in order to increase the safety and bring convenience to the labours.

4.5 EMBODIMENT DESIGN

4.5.1 Product Architecture

The mechanism of the selected oil palm harvester is inspired by the Cantas that developed by MPOB. However, the selected harvester is different from the Cantas as the principle of the rotational movement of motor are used in the harvester. This means that the design for the selected oil palm harvester is changed in term of the extension of poles and the mechanism of cutter. These involve the replacing of the manually extension of harvester pole with an automation controlled telescopic pole, the changing of cutting mechanism of harvester and the replacing of cutter and poles with different designs and high strength materials. The oil palm harvester is sketched and drawn roughly in CATIA as shown in Figure 4.9 before it is completed in detail design with the suitable materials and dimensions.

Figure 4.9 Sketch of selected oil palm harvester in CATIA

4.5.2 Material Selection

In this section, the material selection are presented and discussed. Few components that used to complete the selected oil palm harvester are considered in order to select the most suitable materials as well as produce a high quality harvester. The parts that considered in this section included engine housing, poles, threaded rod and nut, cutter, handle as well as security belt.

4.5.2.1 Engine housing

The engine housing is one of the important components in the oil palm harvester as it is a protection to the mechanism of the harvester. This means that it can be used to protect the motor and engine from outer impacts. The Acrylonitrile Butadiene Styrene (ABS) is chosen as material to design the engine housing because it can customize in any form of shape and size. The size of engine housing is based on the size of petrol engine; motor and retractable cord that arrange inside the housing. The ABS as shown in Figure 4.10 is a hard and strong thermoplastic which has high resistance to corrosive chemical as well as physical impact. In addition, it is good in thermal and electrical resistance as well as high in impact strength. The high melting point ABS has also longer lifespan than other plastic. Therefore, ABS is chosen to design the engine housing of the oil palm harvester.

Figure 4.10 Example of ABS housing

4.5.2.2 Poles

Three circular poles with different dimensions are used for designing the telescopic pole of the oil palm harvester. It consists of main pole, middle pole and end pole. The aluminium is chosen to design the poles with the length of 1m, 1.5m and 1.5m respectively. The telescopic pole that built can be extended and retracted within the distance of 1m by using the rotational movement of threaded rod and nut. The aluminium poles as shown in Figure 4.11 are used because it is corrosion resistant and low maintenance care. Besides, it is resisted the ravages of time, humidity and temperature. The aluminium circular poles are also light in weight and have longer life than the steel. Therefore, aluminium 6063 T5 with the certificate ISO 9001:2008 is chosen as the material for the poles.

Figure 4.11 Example of aluminium poles

4.5.2.3 Threaded rod and nut

The threaded rod and nut that used in the oil palm harvester are designed according to the lead screw concept. The threaded rod is considered as a lead screw with the length of 2.5 m and it is used as shaft in the harvester. However, there is only 1m thread on the rod and will rotate in and out from the 50mm threaded nut. The rod is connected to the motor and allowed the extension and retraction of the telescopic pole when it turned in and out in the middle of threaded nut. The M20 rod with the thread size of 2.5mm as shown in Figure 4.12 is chosen. Besides, the grade B7 stainless steel with DIN 975 is chosen for the material of the rod and nut. For the threaded nut, the 6H class nut is used. The nut is also set and constrained with the rotating direction of the threaded rod, so that the rod can be rotated and travelled back and forth within the nut.

Figure 4.12 Example of threaded rod and nut

4.5.2.4 Cutter

The inclined teeth circular blade is designed and used as a cutter in the oil palm harvester. The cutter is made up by alloy steel with ISO 9001 as shown in Figure 4.13 which suitable for harvesting the oil palm FFB. Besides, the cutting teeth of the cutter are carbide tipped with the bright polished surface. The 170 x 40T blade is used as it consists of 40 teeth with 17cm in diameter and 0.1cm in thickness.

Additionally, the alloy steel blade is suitable in cutting woods, brush and shrubs as it has greater hardenability and greater stress relief at given hardness. The alloy steel not only good in temperature strength, it is also less in distortion and cracking.

Figure 4.13 Example of alloy steel blade

4.5.2.5 Handle

Rubber is chosen as the material to design the handles of the oil palm harvester. It is designed with the finger nubs as shown in Figure 4.14 in order to prevent the slipping and increase the friction between the labours' hand and the pole during harvesting process. The rubber handle with 11cm length can reduce the vibration and impacts from the engine and motors. Furthermore, the ergonomic comfort of the handle can minimize the fatigue of labours' hands, elbows, and wrists for long time harvesting.

Figure 4.14 Example of rubber handle

4.5.2.6 Security belt

The security belt that used in the harvester is similar as the seat belt that used in cars. It is made up by the polyester and woven as in Figure 4.15 which is inexpensive and durable. The security belt that used in harvester is contacting with the body of labours and used to receive and reduce the weight of the oil palm harvester. Besides, it also softens the impact of the vibration that generated by harvester. The belt with the width of 50mm has the tensile strength which is sufficient to support approximately 30kg of mass.

Figure 4.15 Example of polyester belt

4.6 ANALYSIS AND SIMULATION

Few analyses are carried out before the confirmation of components that need to be used in designing the harvester. These analyses are used to ensure those components used can work properly. The rotational speeds for the motor that used in the cutter and telescopic pole are calculated to determine and examine the efficiency of the oil palm harvester. Besides, the strength of cutter, motor housing and the poles that used to build the oil palm harvester are also analysed in this section.

4.6.1 Analysis on Cutter

Cutter is the main component of the oil palm harvester as it is the tool that used to cut the fronds and harvest the oil palm FFB from the tree. The inclined teeth circular blade is designed as in Figure 4.16 to cut the oil palm FFB effectively and easily. There is only one cutter used in designing the harvester which the cutter is started up by motor that attached near to the cutter. The arrangement and size of the cutter are determined in this section to ensure it can work properly in harvesting process. With the consideration of size of oil palm fronds and its FFB, the alloy steel cutter is designed with the diameter of 17cm and thickness of 1cm with 40 teeth. The rotational speed of cutter is analysed as it will affect the cutting efficiency of the oil palm harvester. The cutting speed can be considered as an ideal number that show the revolution in rotational movement of the cutter in one minute. Assume that the power of the engine is 1000 W and the force is 80N.

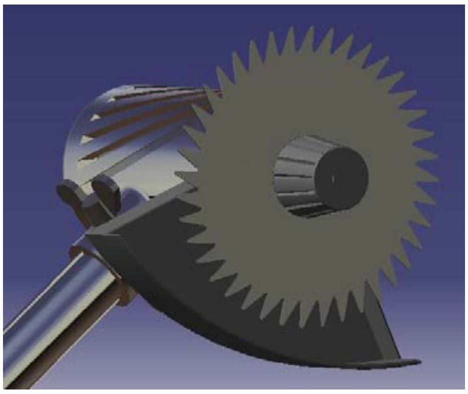


Figure 4.16 Cutter of oil palm harvester

Radius, $r = \frac{17cm}{2}$

$= 8.5cm$

$= 0.085\ m$

Torque, T = Force x radius

$= 80\ N \times 0.085\ m$

$= 6.8\ Nm$

Power, p = Torque x rotational speed

$= T\left(\frac{2\pi n}{60}\right)$

Rotational speed of cutter, $n = \frac{60\,p}{2\pi\,T}$

$= \frac{60\,(1000w)}{2\pi\,(6.8\,Nm)}$

$= 1404.31rpm$

$= 23.41\ rps$

The rotational speed of the cutter is calculated in term of revolution per minute and it got the value of 1404.31 rpm. This means that the cutter is rotate approximate 1404 cycles in one minute. On the other hand, the strength of the cutter is also analyzed in CATIA. The strength of the cutter is important because it is designed specially to improve the cutting efficiency for the harvesting process. Therefore, the strength analysis of cutter is done in the CATIA as in Figure 4.17. The results are getting from CATIA as the 80N force is applied to teeth of the cutter.

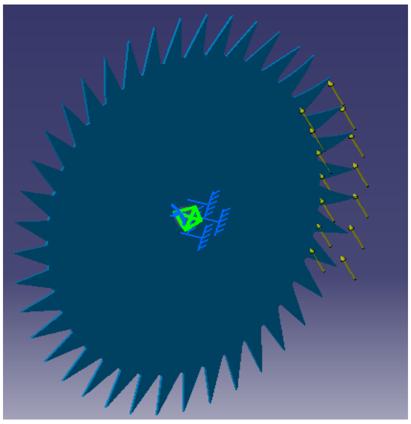


Figure 4.17 Deformation on cutter

The results are divided into two types which are von misses stress and translational displacement. The maximum and minimum values of the von misses stress are 7.55 MPa and 0.755 MPa respectively as shown in Figure 4.18. For the translational displacement, it gets the value of 0.00411mm for maximum and 0.000411mm for minimum as shown in Figure 4.19.

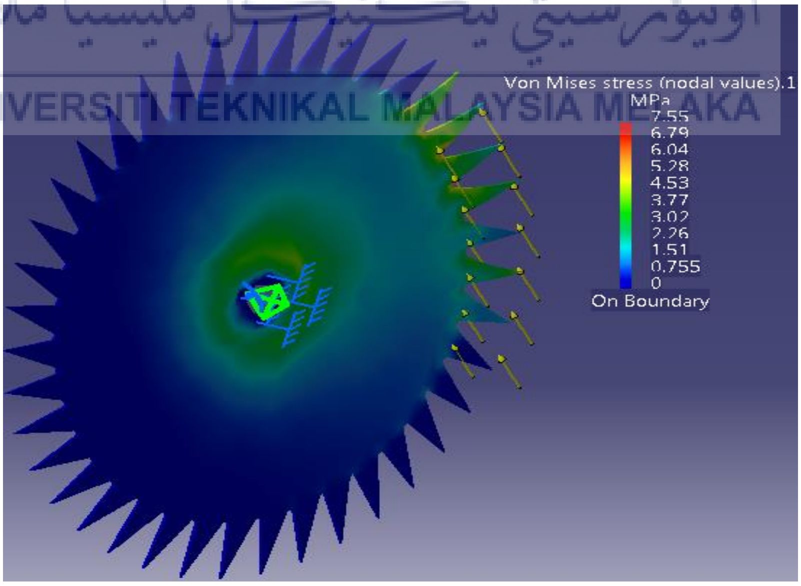


Figure 4.18 Von misses stress of cutter

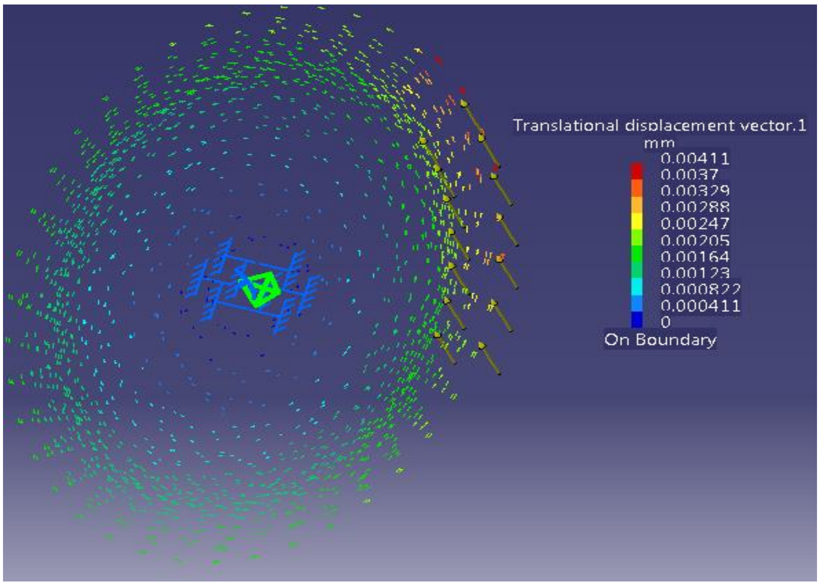


Figure 4.19 Translational displacement of cutter

Besides, the factor of safety for the cutter is also calculated by using the value of the von misses stress that gets from the load analysis. Based on CATIA, the value of mechanical strength of alloy steel is also determined as in the Table 4.5.

Table 4.5 Properties of steel

Properties	**Values**
Young modulus	2×10^5 MPa
Poisson ratio	0.226
Yield strength	250 MPa

$$\text{Safety factor, Sf} = \frac{\text{mechanical strength}}{\text{von mises stress}}$$

$$= \frac{250 \text{ MPa}}{7.55 \text{ MPa}}$$

$$= 33.11$$

In short, the safety factor of the cutter is equal to 33.11. This shows that the cutter can accommodate more than 80N force. It also gets 7.55 MPa in the von misses strength as well as 0.00411mm in the translational displacement.

4.6.2 Analysis on Telescopic Pole

The telescopic pole is designed and combined by using three circular poles (main pole, middle pole and end pole) with different dimension as shown in Figure 4.20. The strength of the poles is depending on the length and material that used in designing the poles. This is because poles with longer length are easy to defect and break. Therefore, the aluminium is chosen to design the poles as it is resistance in corrosion and good in strength. Besides, the deterioration of the poles can be noticed easily as the ductile material is used for the poles.

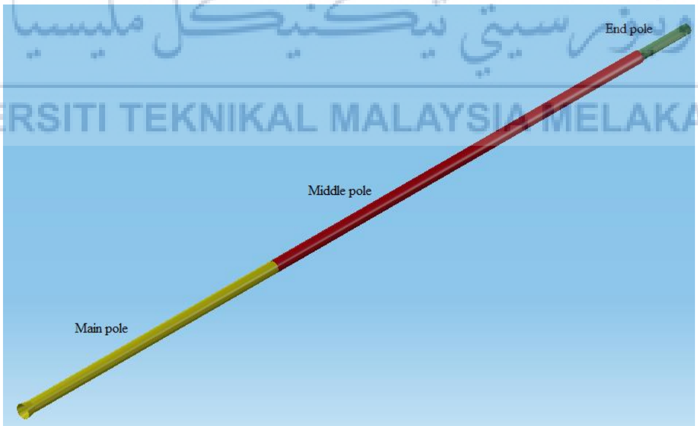
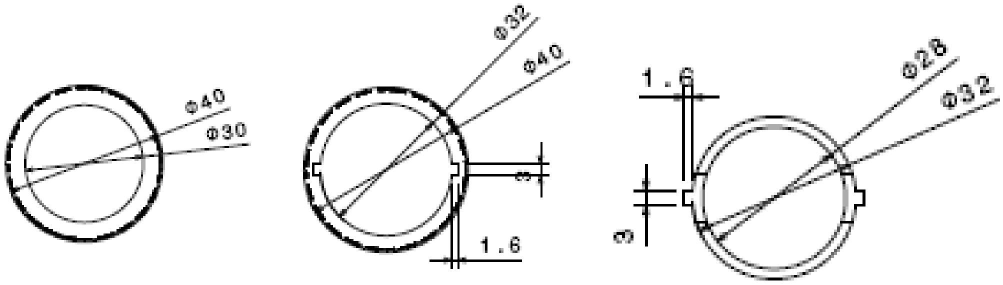


Figure 4.20 Telescopic pole of harvester

The maximum stress and bending moment of the telescopic pole are calculated as well as the amount of the deflection of the pole that might occur during the harvesting process. From the design of harvester, the maximum extension length of the pole is 3.7m while minimum retraction length is 2.7m. Besides, the dimension of each pole is also shown in Figure 4.21 (a), (b) and (c).



(a) (b) (c)

Figure 4.21 (a) Dimension of main pole (b) Dimension of middle pole and (c) Dimension of end pole

The cantilever beam with the load applied at the end as shown in the Figure 4.22 is considered in the telescopic pole and assume that the load applied, P is 50N and Young's Modulus of aluminum is 70 GPa. The section modulus and moment of inertia about the bending axis for each pole with different dimension are calculated.

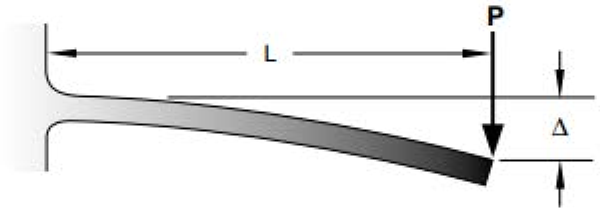


Figure 4.22 Deflection diagram of telescopic pole

Section modulus of main pole, $Z_1 = \frac{\pi(ro^4 - ri^4)}{4ro}$

$= \frac{\pi(0.04^4 - 0.03^4)}{4x0.04}$

$= 3.44 \times 10^{-5}\ m^3$

Moment inertia of main pole, $I_1 = \frac{\pi(ro^4 - ri^4)}{4}$

$= \frac{\pi(0.04^4 - 0.03^4)}{4}$

$= 1.374 \times 10^{-6}\ m^4$

Section modulus of middle pole, $Z_2 = \frac{\pi(ro^4 - ri^4)}{4ro}$

$= \frac{\pi(0.04^4 - 0.032^4)}{4x0.04}$

$= 2.968 \times 10^{-5}\ m^3$

Moment inertia of middle pole, $I_2 = \frac{\pi(ro^4 - ri^4)}{4}$

$= \frac{\pi(0.04^4 - 0.032^4)}{4}$

$= 1.187 \times 10^{-6}\ m^4$

Section modulus of end pole, $Z_3 = \frac{\pi(ro^4 - ri^4)}{4ro}$

$= \frac{\pi(0.032^4 - 0.028^4)}{4x0.032}$

$= 1.065 \times 10^{-5}\ m^3$

Moment inertia of end pole, $I_3 = \frac{\pi(ro^4 - ri^4)}{4}$

$= \frac{\pi(0.032^4 - 0.028^4)}{4}$

$= 0.34 \times 10^{-6}\ m^4$

In order to determine the maximum stress at the outer fiber and maximum deflection of the telescopic pole, the minimum section modulus and moment of inertia as well as the maximum length of pole are considered in the calculation.

Maximum stress, $\sigma = \frac{PL}{Z}$

$= \frac{(50N)(3.7m)}{1.065 \text{ x } 10^{-5} m^3}$

= 17.37 MPa

Maximum deflection, $\Delta = \frac{PL^3}{3EI}$

$= \frac{(50N)(3.7m)^3}{3(70 \text{ GPa})(0.34 \text{ x } 10^{-6} m^4)}$

= 0.035 m

= 35.47 mm

In addition, the maximum bending moment of the telescopic pole is also determined as the load is applied at the end of the pole as shown in Figure 4.23.

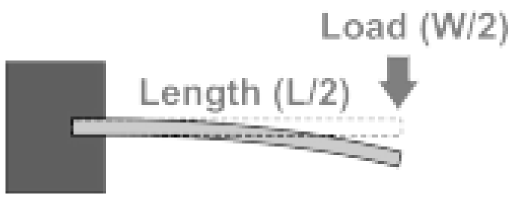


Figure 4.23 Bending moment diagram of telescopic pole

Bending moment, $M = \frac{P}{2} \times \frac{L}{2}$

$$= \frac{PL}{4}$$

$$= \frac{50N \times 3.7m}{4}$$

$$= 46.25 \text{ Nm}$$

Based on the calculation, the maximum stress at the outer fiber and maximum deflection of the telescopic pole get the values of 17.37MPa and 0.035m respectively. Besides, the telescopic pole gets the value of 46.25 Nm for the maximum bending moment. Because of the poles are the main support and backbone for the harvester, its strength is also analysed in CATIA. The force with 50N is applied on each of the pole as in Figure 4.24, Figure 4.25 and Figure 4.26 and the results are determined.

Figure 4.24 Deformation on telescopic pole (main pole)

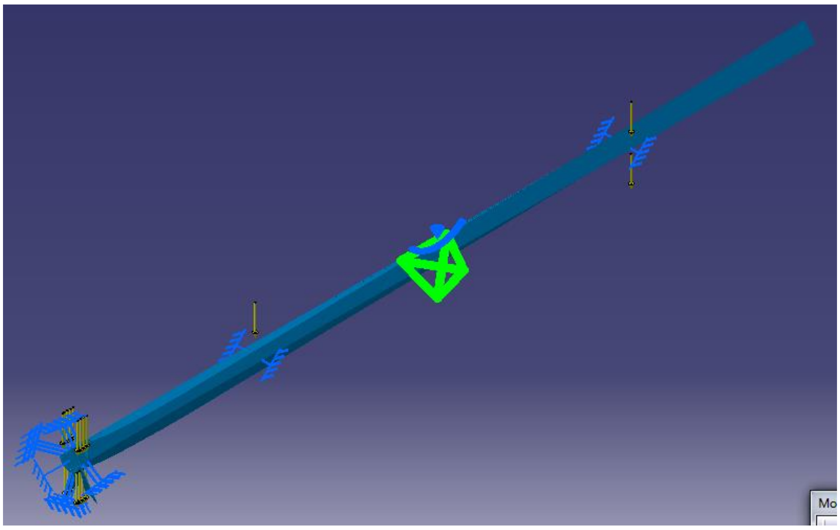


Figure 4.25 Deformation on telescopic pole (middle pole)

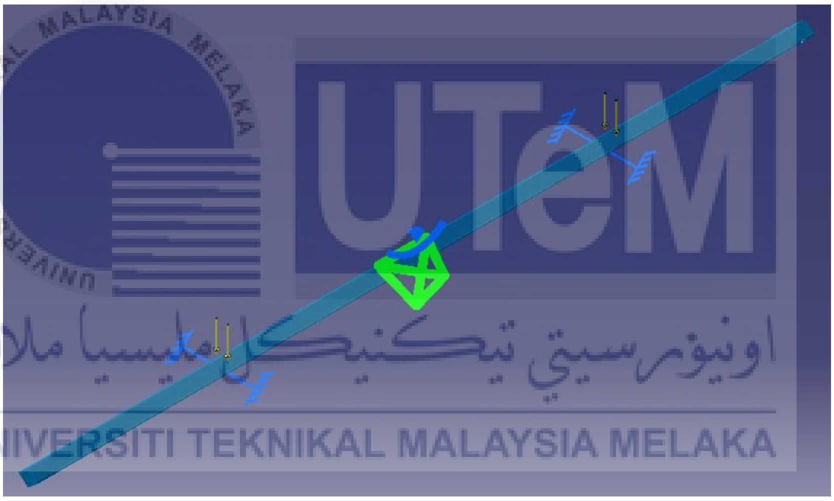


Figure 4.26 Deformation on telescopic pole (end pole)

Two different types of results are determined from CATIA which are von misses stress and translational displacement. The 1m main pole with 40mm outer diameter and 30mm inner diameter is analysed. For the von misses stress, the main pole gets the maximum and minimum values with 8.87 MPa and 0.0386 MPa respectively as shown in Figure 4.27. For the translational displacement, it gets the value of 0.393 mm for maximum and 0.0393mm for minimum as in Figure 4.28.

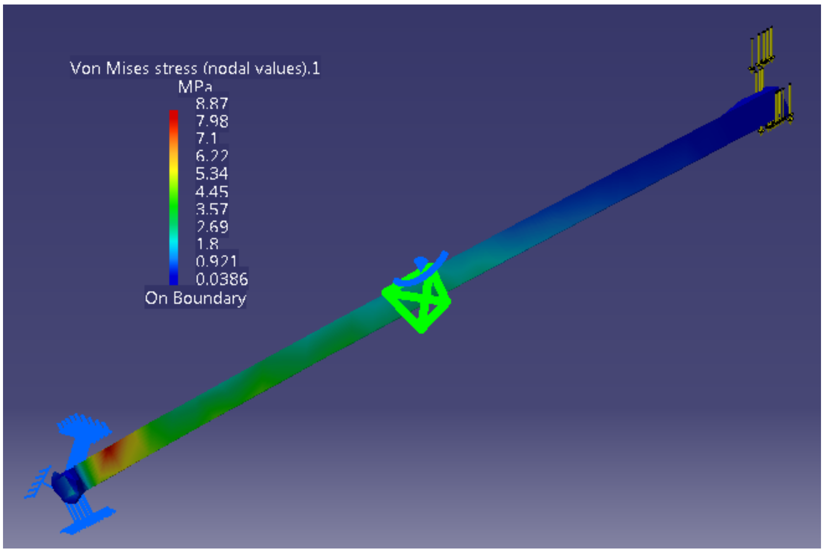


Figure 4.27 Von misses stress of main pole

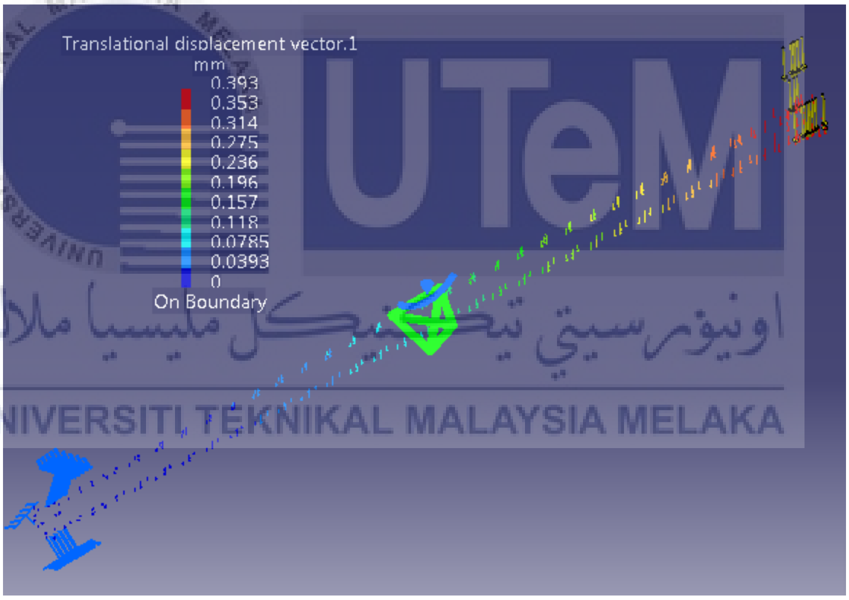


Figure 4.28 Translational displacement of main pole

The 1.5m middle pole with the outer diameter of 40mm and inner diameter of 32mm is also analysed in the load analysis. The middle pole gets the values of maximum 0.32MPa and minimum 0.032 MPa for the von misses stress as in Figure 4.29 while $8.55\text{x}10^{-6}$mm for maximum and $8.55\text{x}10^{-7}$mm for minimum in the analysis on the translational displacement as in Figure 4.30.

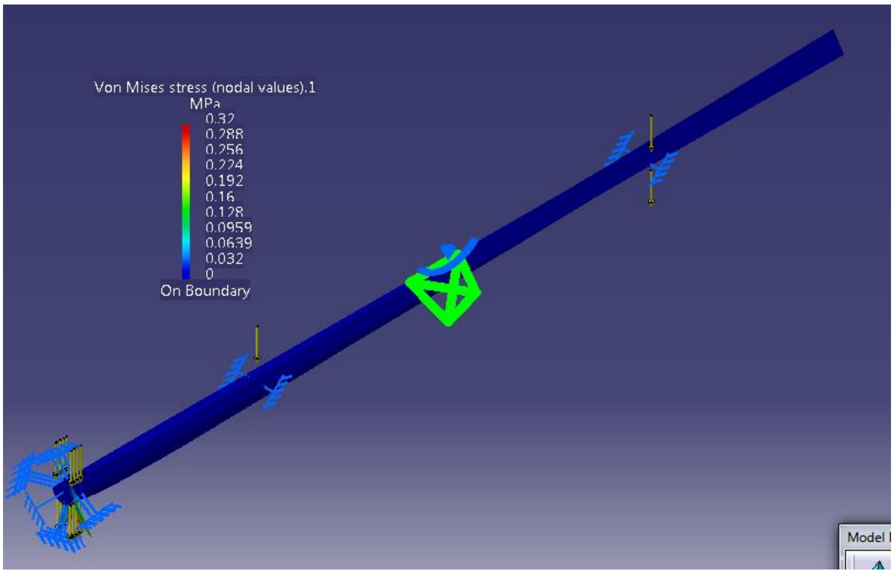


Figure 4.29 Von misses stress of middle pole

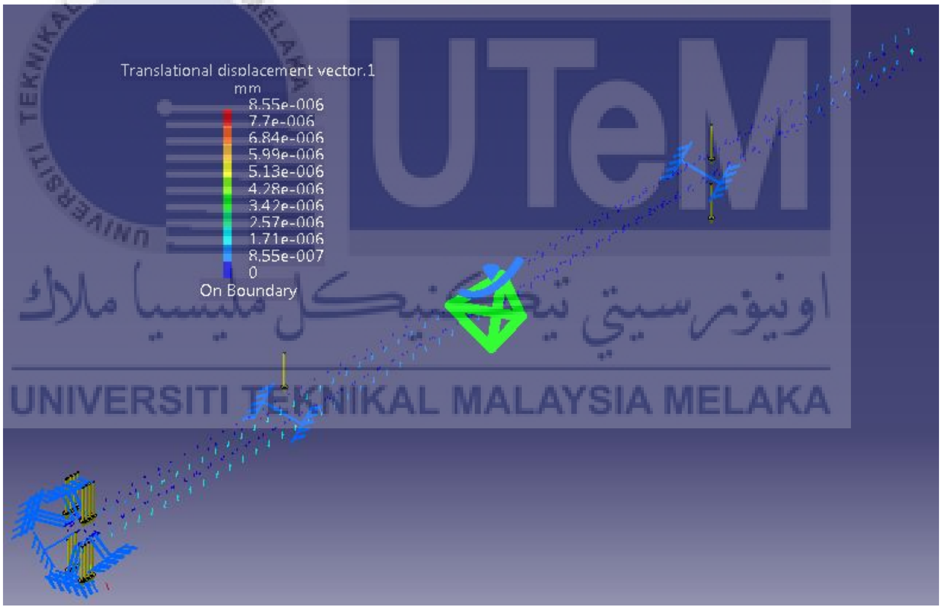


Figure 4.30 Translational displacement of middle pole

In addition, the end pole with 1.5m length, 32mm outer diameter and 28mm inner diameter is analysed. The results of the von misses stress of end pole are determined and get 0.0446 MPa for maximum and 0.0045 MPa for minimum as in Figure 4.31. For the translational displacement, it gets the value of 3.24×10^{-5}mm for maximum and 3.24×10^{-6}mm for minimum as in Figure 4.32.

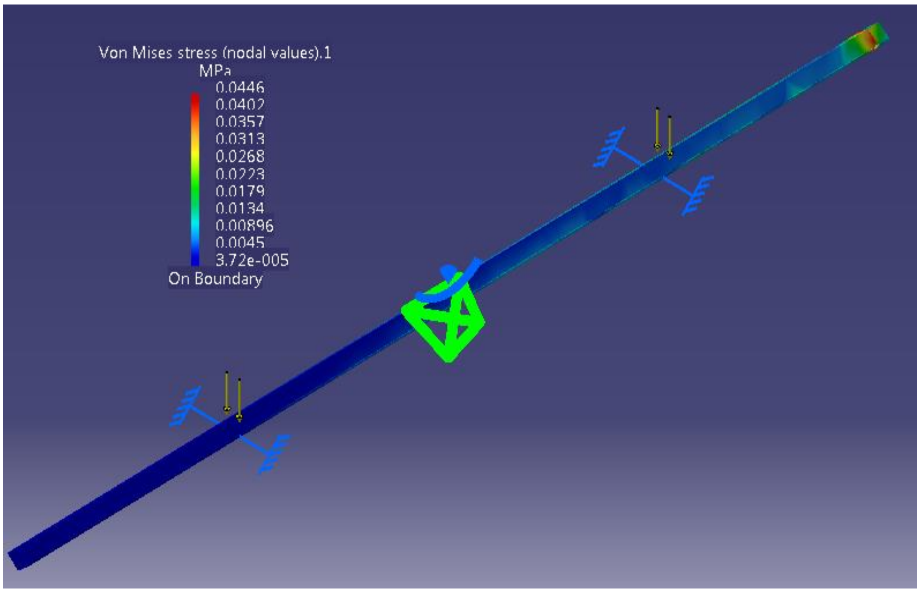


Figure 4.31 Von misses stress of end pole

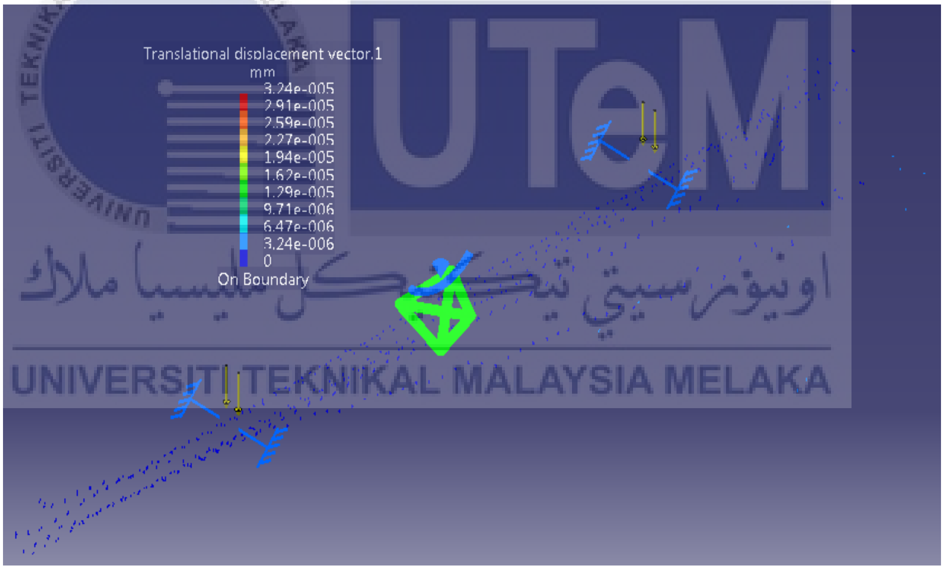


Figure 4.32 Translational displacement of end pole

In short, this means that the poles can withstand the forces that applied on the harvester. This also shown that the deflection may occur at the end of pole due to the lack of stability at the top end of harvester. However, there are only 8.87 MPa for the maximum von misses and 0.393 mm for maximum translational displacement.

4.6.3 Analysis on Threaded Rod and Nut

In the extension and retraction of telescopic pole, it is related to the threaded rod and nut that installed in the middle of the end pole as in Figure 4.33. The calculations of leadscrews as in Figure 4.34 is used in these components as it related to the conversation of energy from motor to the translation of rod into nut. This means that the rotational motion from the motor is converted into linear motion of telescopic pole. There are different types of threads as in Figure 4.35 but the fixed free arrangement of leadscrews is used in this case.

Figure 4.33 Threaded rod and nut in oil palm harvester

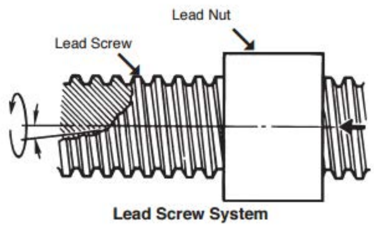


Figure 4.34 Lead screws system

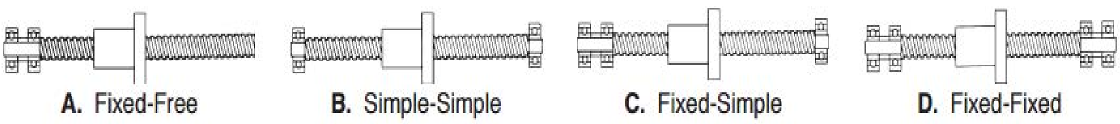


Figure 4.35 Fixed free arrangement of lead screw system

Table 4.6 End support factor of lead screw system

Case A	0.36
Case B	1.00
Case C	1.47
Case D	2.23

The end support factor for different cases of lead screw system is shown in Table 4.6. The 2.5m threaded rod and nut in the harvester is assumed to be in case A as it is fixed one end with connection to the motor and another end is free. Assume the M20 rod with the length of 1m and thread size (lead) of 2.5mm need to complete the full extension or retraction of telescopic pole in 200 seconds, the end support factor, C_s for fixed free system is 0.36 and diameter of rod is 2cm.

Velocity, $v = \frac{length}{time}$

$= \frac{1m}{200s}$

$=0.005m/s$

$= 0.3$ m/min

Critical speed, $C_s = \frac{(4.76x10^6)dC}{l^2}$

$= \frac{(4.76x10^6)0.02m\ x\ 0.36}{(2.5m)^2}$

$= \frac{(4.76x10^6)0.787 \text{ in x } 0.36}{(98.43 \text{ in})^2}$

$= 139$ rpm

Rotational speed of telescopic pole, n = $\frac{velocity}{lead}$

$$= \frac{0.3\ \text{m/min}}{(2.5\text{x}10^{-3})\boldsymbol{m}}$$

$= 120$rpm

$= 2$ rps

The velocity and critical speed for the rotational of telescopic poles in the extension and retraction are analyzed. The result shows that it can generate the velocity of 0.3m/min and critical speed of 139 rpm in the rotational movement. On the other hand, the rotational speed of the telescopic pole in extension and retraction is also calculated in term of revolution per minute and it got the value of 120 rpm. This means that the poles is extended or retracted 2 cycles in one second and its speed is slower than the rotational speed of cutter.

4.6.4 Analysis on Motor Housing

Motor housing in Figure 4.36 is a protection of the motor that attached at the top end of the poles which used to generate the rotational movement for cutter. The material that used to manufacture the motor housing is important as it need to protect the motor from outer impacts. Besides, it also needs to withstand the vibration and rotational forces from the motor. The load analysis on the motor housing that made by aluminium is done in CATIA as in Figure 4.37. The mass of the motor and cutter that assembled at the end of the motor cover are assumed to be 2 kg in maximum. Therefore, 20 N forces are applied in the inner surface of housing and the result is determined.

Figure 4.36 Motor housing of harvester

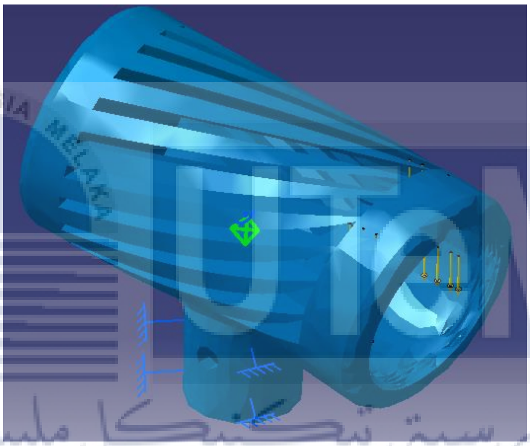


Figure 4.37 Deformation on motor housing

The results of the von misses stress of the motor housing are determined from the load analysis and it get 0.0318MPa for minimum and 0.318 MPa for maximum as shown in Figure 4.38. For the translational displacement, it gets the value of 0.00108mm for maximum and 0.000108mm for minimum as shown in Figure 4.39.

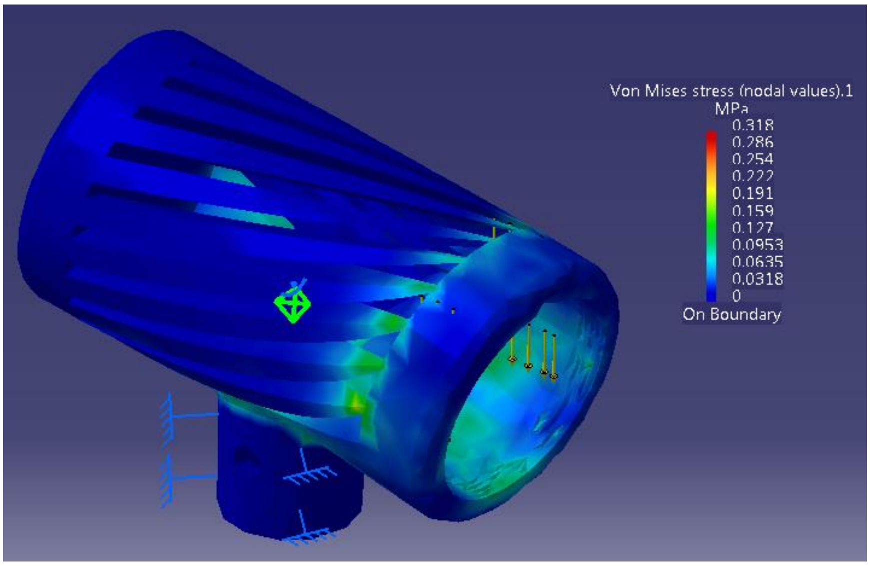


Figure 4.38 Von misses stress of motor housing

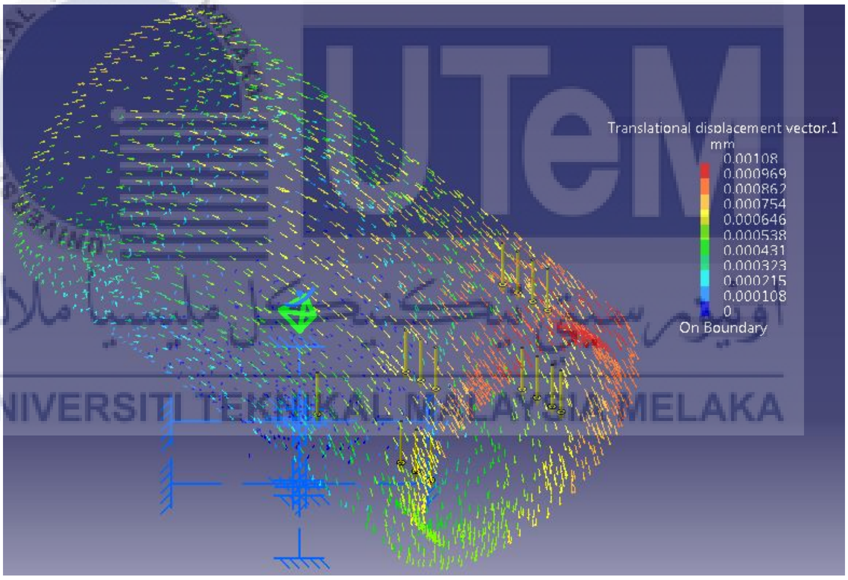


Figure 4.39 Translational displacement of motor housing

Based on the load analysis, the motor housing gets 0.318 MPa for the maximum von misses stress and 0.00108 mm for the maximum translational displacement. Therefore, this means that the housing can withstand the force of 20N that applied in the inner surface of motor housing.

4.7 DETAIL DESIGN

The design of the selected oil palm harvester is drawn and presented using the 3 Dimensional (3D) CAD model with actual size. The detail design of the oil palm harvester is drawn in the CAD software which is CATIA V5R20. The oil palm harvester is divided into 5 subassembly and the main assembly drawing of the harvester is done by combined all of the subassembly drawing and shown in the Figure 4.40 with suitable dimension and materials.

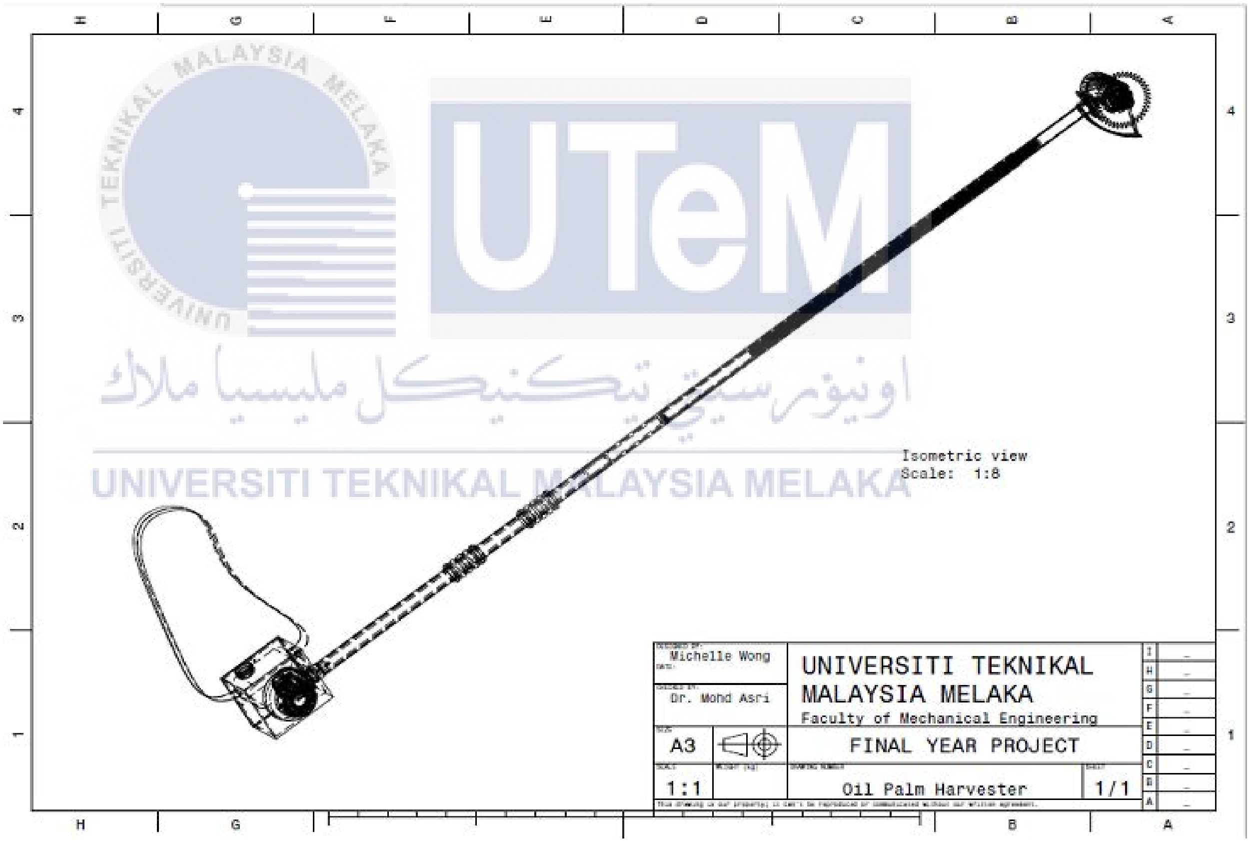


Figure 4.40 Detail design of oil palm harvester

4.7.1 Product Structure

The product structures of the oil palm harvester are presented in Figure 4.41, Figure 4.42, Figure 4.43, Figure 4.44 and Figure 4.45 in order to show the components that included in each subassembly of the oil palm harvester. The design of the harvester is divided into five parts which are cutter motor subassembly, cutter subassembly, poles subassembly, pole motor subassembly and engine subassembly.

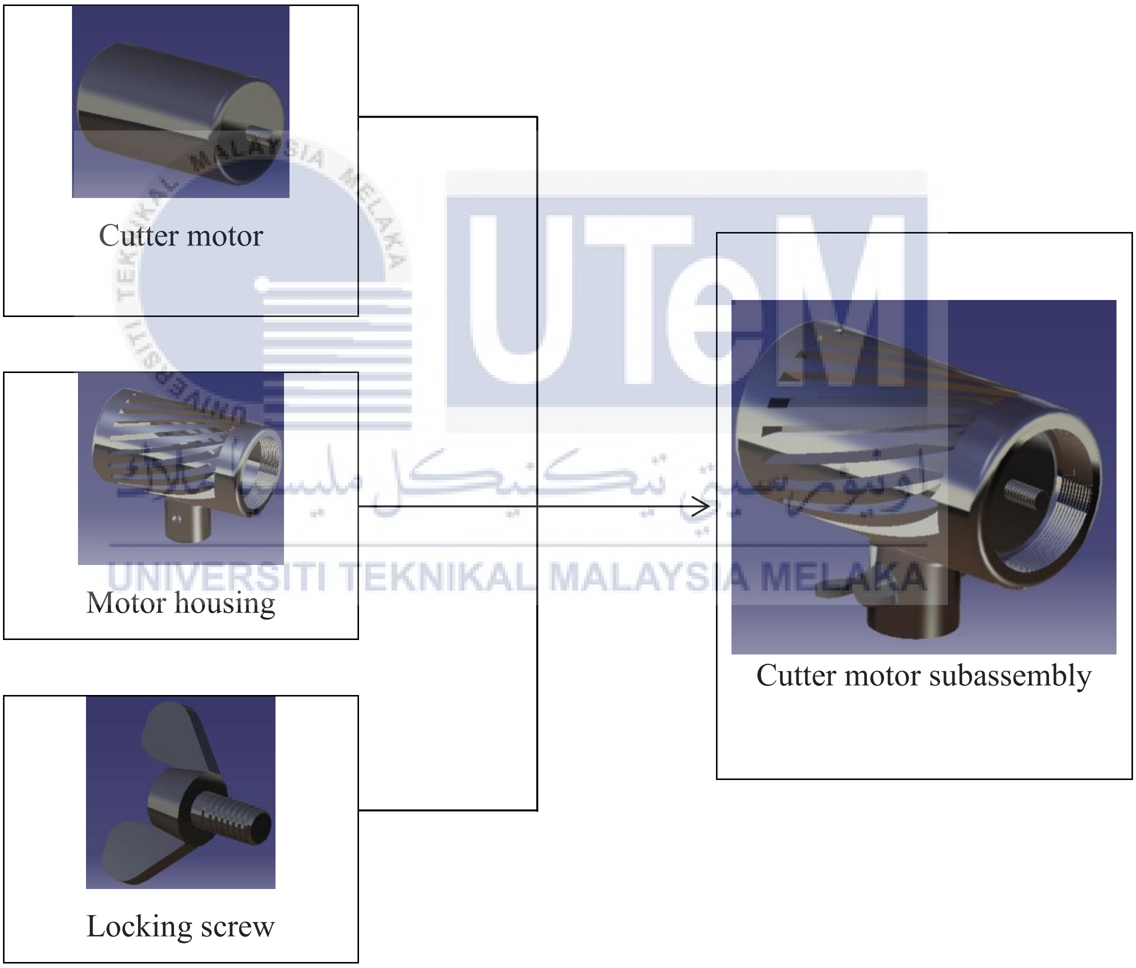


Figure 4.41 Cutter motor subassembly

Figure 4.42 Cutter subassembly

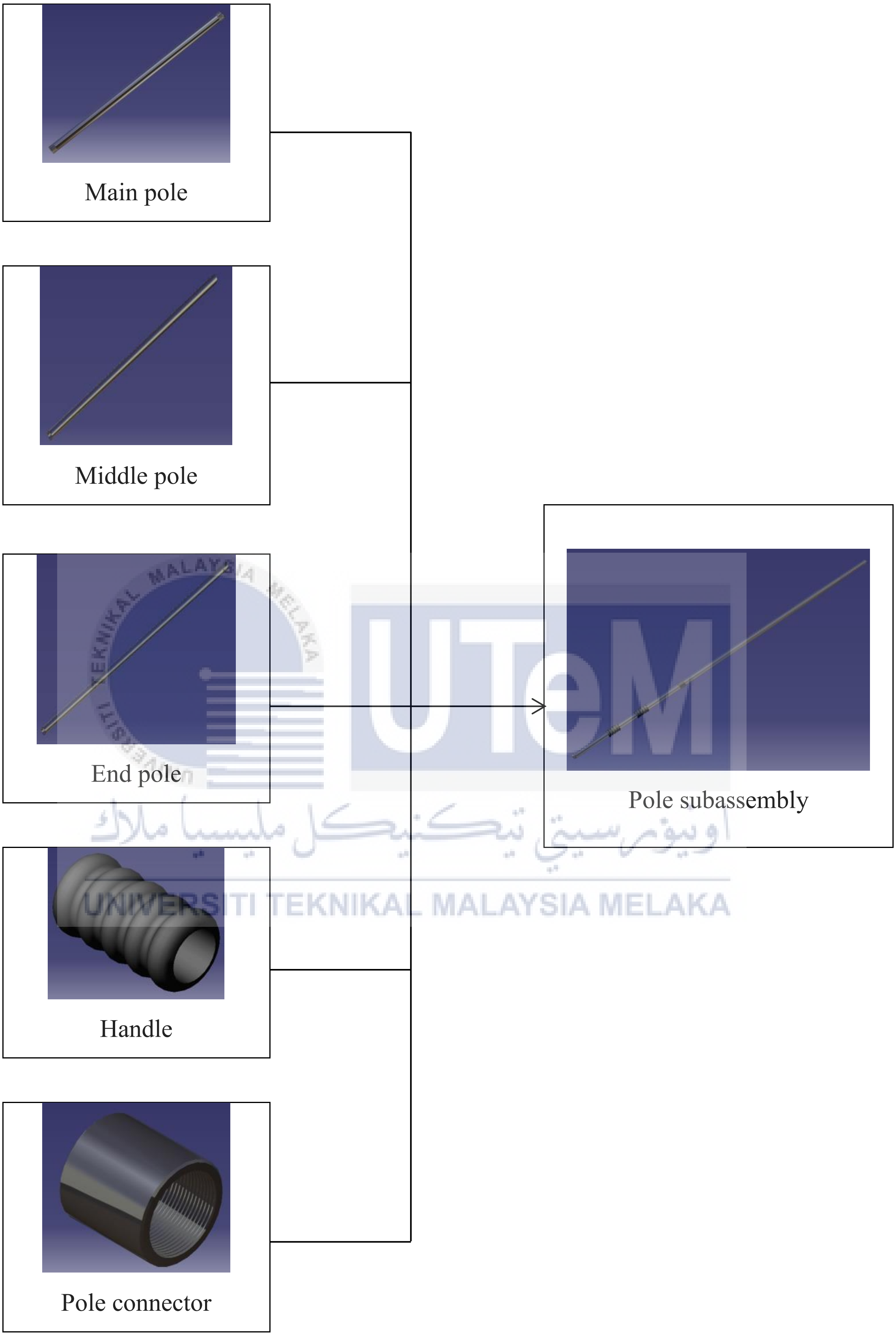


Figure 4.43 Poles subassembly

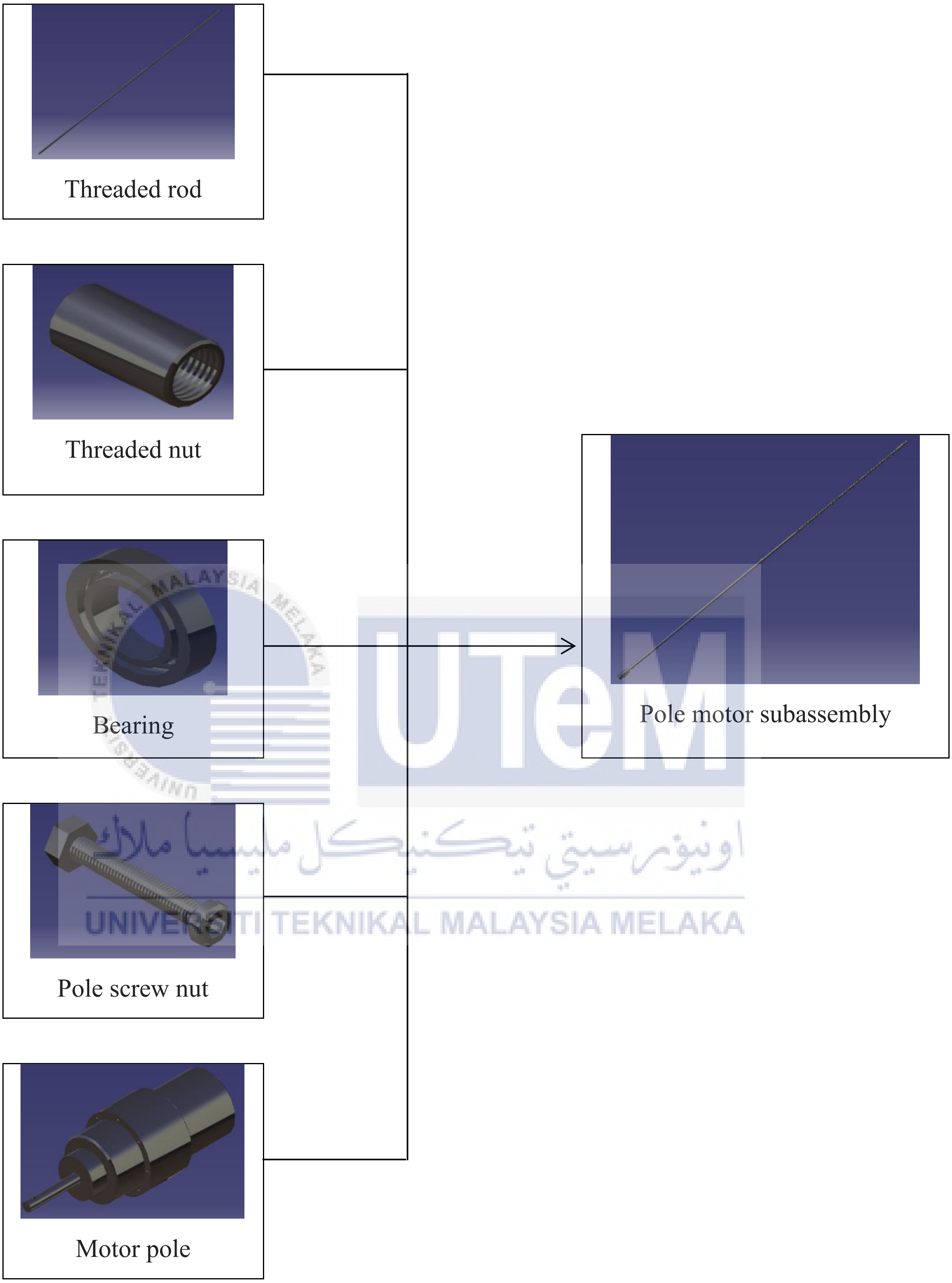


Figure 4.44 Pole motor subassembly

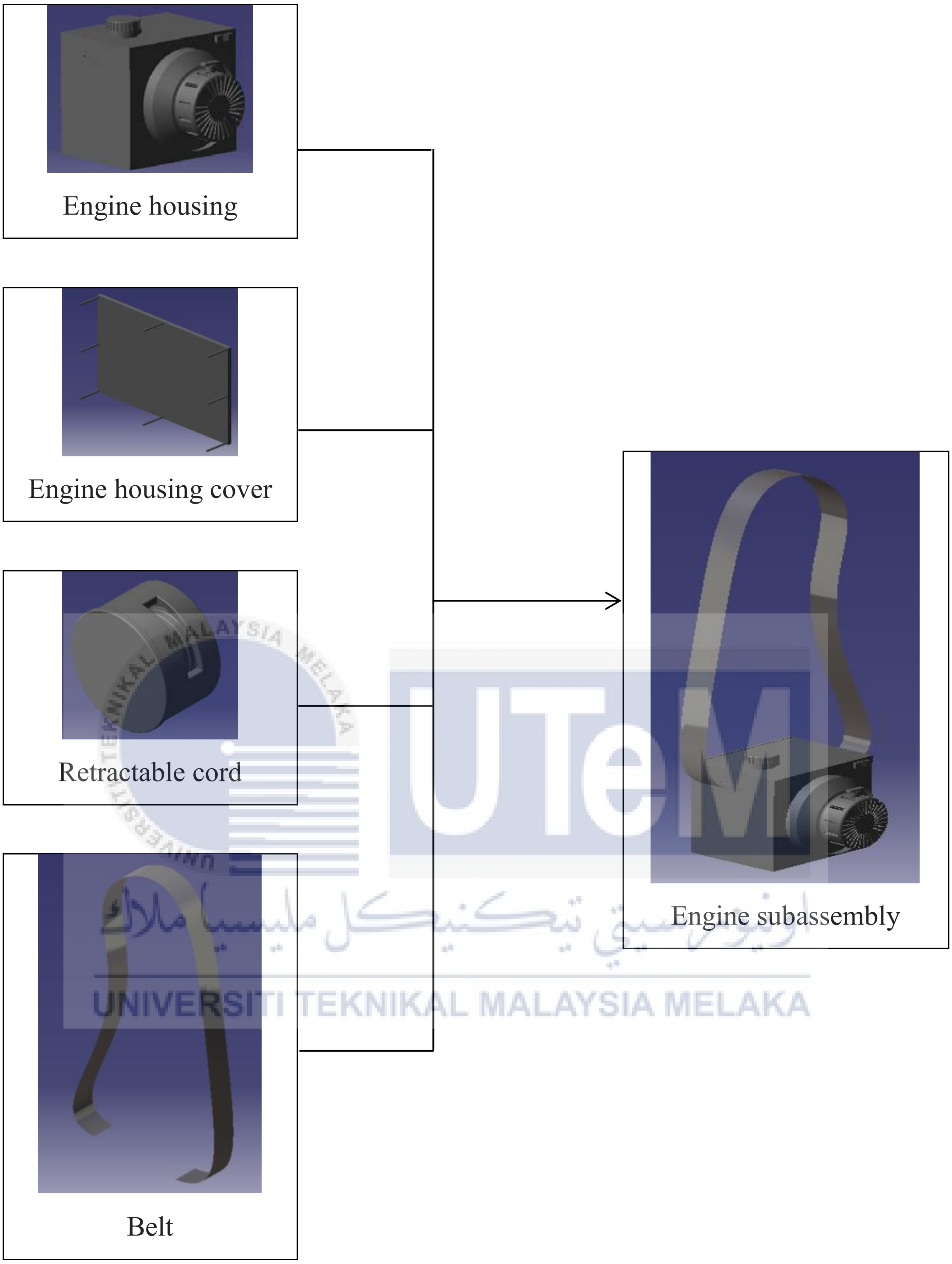


Figure 4.45 Engine subassembly

4.7.2 List of Components in Oil Palm Harvester

The orthographic view of the completed oil palm harvester is drawn and shown in Figure 4.46 to show the top view, front view and side view of the harvester. The exploded view of the harvester is also drawn in Figure 4.47 in order to show the components used and its arrangement in a complete design. Besides, the bill of material (BOM) of the oil palm harvester is also presented in the exploded view in order to list all of the components used and its quantity in designing the oil palm harvester.

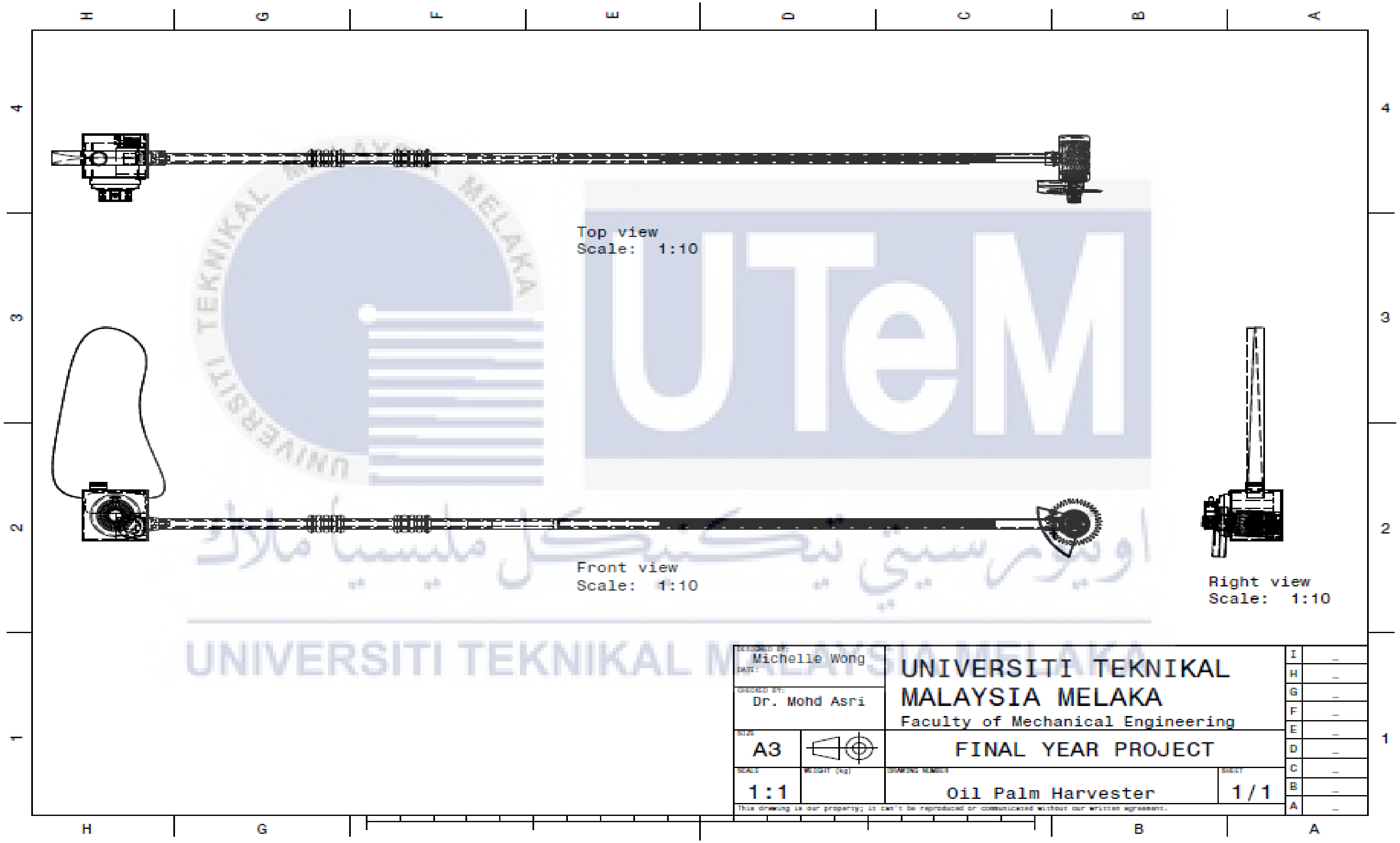


Figure 4.46 Orthographic view of oil palm harvester

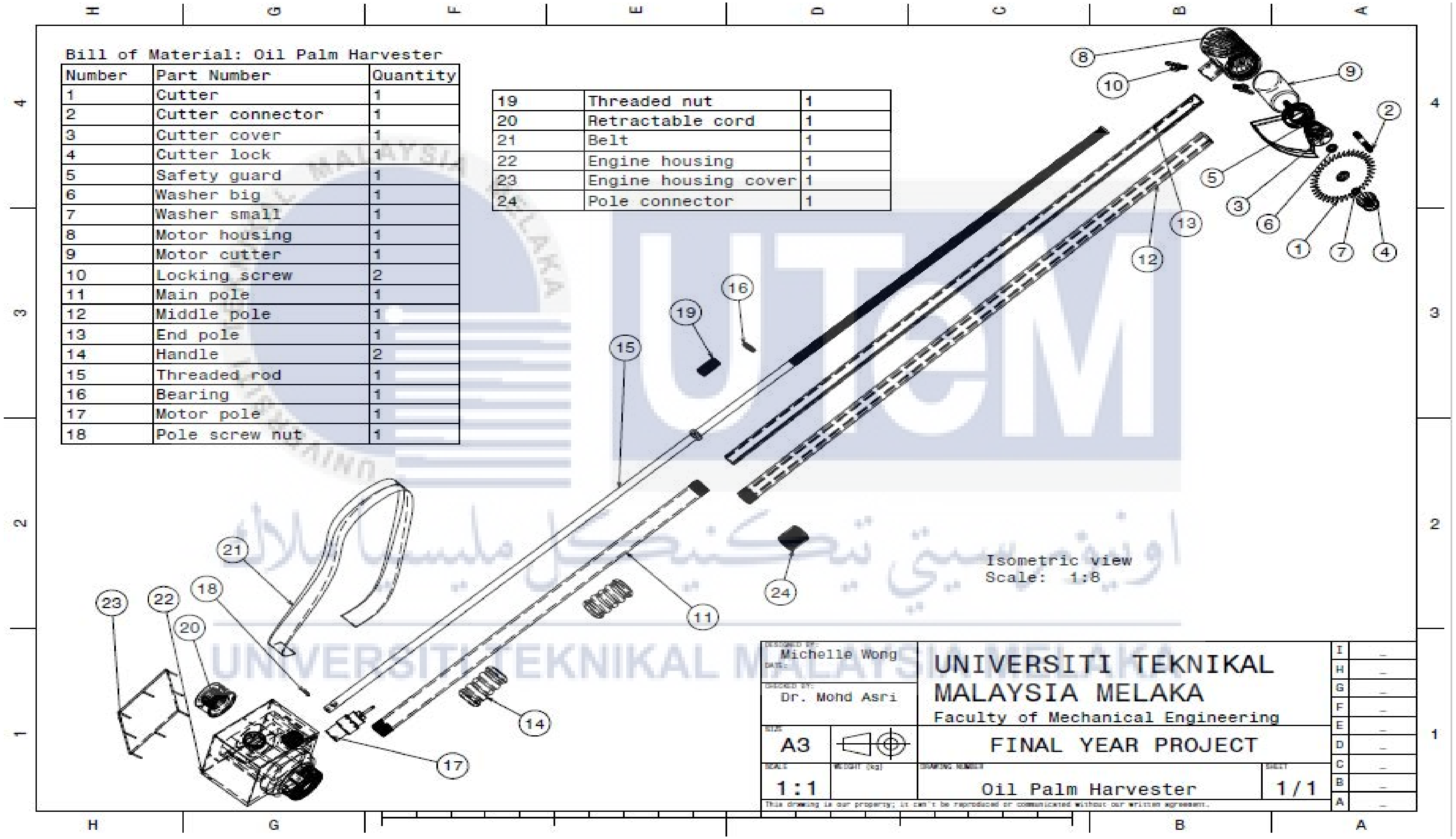


Figure 4.47 Exploded view of oil palm harvester

4.8 MANUFACTURING PROCESS AND COST

The manufacturing process and cost for each component in the oil palm harvester are important in order to evaluate and produce high functioning and low cost design. The material and manufacturing process of each component are determined and listed in Table 4.7 with the components are divided into 2 categories which are custom part and standard part. The custom part is made according to specific design and dimension while the standard part is standard components that purchased from supplier such as bearing, screw and nut.

In addition, the value analysis in costing is used in this section to determine the cost structure of the oil palm harvester and it is summarized in Table 4.8. The total manufacturing cost of a harvester is approximate RM412.80 each and it is estimated in term of material cost, production cost and assembly cost.

Table 4.7 Manufacturing process for each component

NO.	PART/COMPONENT	MATERIAL	MANUFACTURING PROCESS
1	Middle pole	Aluminum	Extrusion, Threading
2	End pole	Aluminum	Extrusion, Drilling
3	Main pole	Aluminum	Extrusion, Threading
4	Motor housing	Aluminum	Extrusion, Drilling, Welding, Threading
5	Threaded rod	Stainless Steel	Extrusion, Threading, Drilling
6	Engine housing	ABS	Injection moulding
7	Cutter	Alloy Steel	Laser Cutting, Grinding, Sharpening
8	Cutter connector	Carbon Steel	Extrusion, Threading
9	Retractable cord	ABS	Injection moulding
10	Engine housing cover	ABS	Injection moulding
11	Handle	Rubber	Injection moulding
12	Safety guard	ABS	Injection moulding
13	Cutter cover	ABS	Injection moulding
14	Belt	Polyester	Calendaring, Slitting
15	Pole connector	Aluminum	Extrusion, Threading
16	Threaded nut	Stainless Steel	Extrusion, Threading
17	Cutter lock	ABS	Injection moulding
18	Motor pole	Standard part	
19	Motor cutter	Standard part	
20	Bearing	Standard part	
21	Locking screw	Standard part	
22	Pole screw nut	Standard part	
23	Washer big	Standard part	
24	Washer small	Standard part	

Table 4.8 Manufacturing cost for each components

NO.	PART/COMPONENT	MANUFACTURING COST		TYPE OF COST, %		
		RM	%	Material	Production	Assembly
1	Motor pole	100.00	24.2	Purchased	Purchased	Purchased
2	Motor cutter	100.00	24.2	Purchased	Purchased	Purchased
3	Middle pole	36.40	8.8	35	55	10
4	End pole	35.00	8.5	35	55	10
5	Main pole	31.60	7.7	40	50	10
6	Motor housing	19.00	4.6	30	60	10
7	Threaded rod	13.00	3.1	35	50	15
8	Engine housing	11.00	2.7	30	60	10
9	Cutter	9.60	2.3	20	70	10
10	Cutter connector	7.60	1.8	35	50	15
11	Retractable cord	7.60	1.8	35	55	10
12	Bearing	6.80	1.6	Purchased	Purchased	Purchased
13	Engine housing cover	5.60	1.4	40	50	10
14	Handle	5.00	1.2	35	60	5
15	Safety guard	4.40	1.1	35	55	10
16	Cutter cover	3.60	<1	40	50	10
17	Belt	3.60	<1	45	50	5
18	Pole connector	2.60	<1	40	50	10
19	Threaded nut	2.40	<1	35	45	20
20	Cutter lock	2.40	<1	35	55	10
21	Locking screw	2.20	<1	Purchased	Purchased	Purchased
22	Pole screw nut	1.60	<1	Purchased	Purchased	Purchased
23	Washer big	1.00	<1	Purchased	Purchased	Purchased
24	Washer small	0.80	<1	Purchased	Purchased	Purchased

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As the oil palm plantation is growing quickly in Malaysia, new technologies should be implemented on harvesting tool in order to catch up with the demand. Therefore, the objectives are determined and done based on the problem statement. An oil palm harvester with the circular cutter and automatically adjustable telescopic pole that operated using rotational mechanism is well proposed. The objectives of this report are successfully achieved as the structure of the cutter and telescopic pole in the oil palm harvester are also determined and analyzed.

Oil palm harvester is a tool that used to harvest the oil palm FFB and cut the fronds from oil palm tree during the harvesting process. The working principle of the oil palm harvester that designed is similar to the Cantas. However, the oil palm harvester that designed is changed in term of the mechanism in the extension of telescopic poles and the operation movement of the cutter. The automatically controlled telescopic pole is designed to replace the manually extension method that used on conventional harvester. This automation mechanism is built in the telescopic pole so it is easy in handling, controlling and operating as it can extent and retract to various lengths easily. Besides, the vibration method that used in the sickle of Cantas is replaced by circular cutter with rotational harvesting mechanism that operated by motor. The inclined teeth circular cutter not only make the harvesting process more effective and easier, it also reduce the tiredness of labours as it is sharper than sickle and easier to reach the oil palm FFB. Labours no longer need to find the suitable position to insert the sickle in the middle of fronds with tight arrangement, they can easily reach and harvest the oil palm FFB from the bottom of the bunches.

Furthermore, the CATIA is used in this project in order to complete the designing section of the oil palm harvester. The selected oil palm harvester which consequences with the consideration of engineering criteria and customer requirements is drawn in this project with assembly drawing and detail drawing as well as analysed with the load analysis on components of the oil palm harvester.

5.2 RECOMMENDATION

The harvesting of the oil palm FFB becomes a vital stage of overall process in oil palm plantation as the rise in the demand of the oil palm product around the world. Therefore, the oil palm harvester that designed is highly recommended to fabricate as it not only can make the harvesting process easy and effective, it also reduce the workloads of labors. In addition, there are still some additional parts that need to be improved and designed in this harvester. The minimum length of the telescopic pole when retraction can be reduced in the future design for more easily in handling and operation. Besides, the wiring and connection between the engine and motors also need to be considered and designed.

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Appendix A

Appendix A1

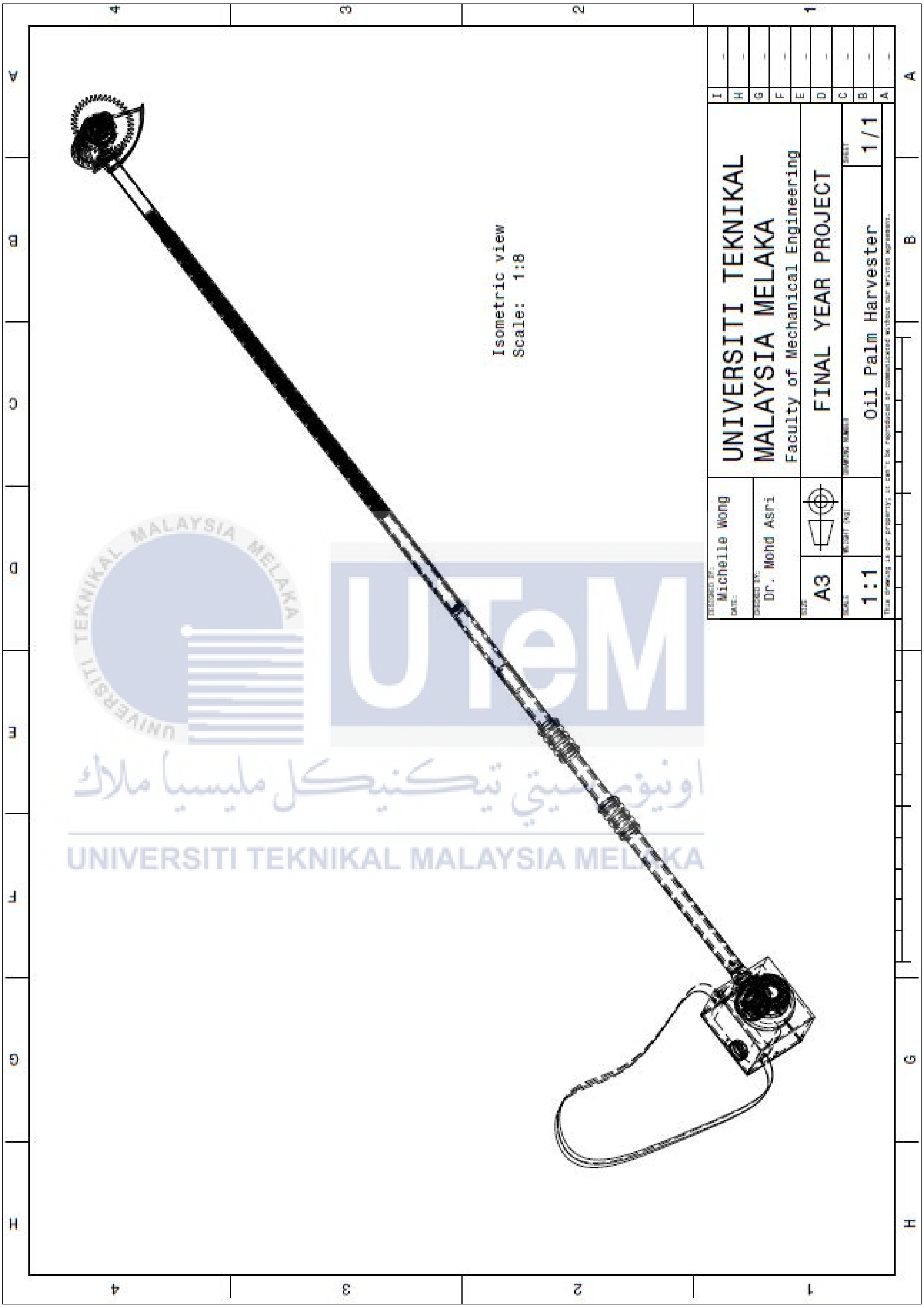
ACTIVITIES/ TASKS	WEEKS													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Objectives and scopes review														
Background study and problem determination														
Internet and library research														
Progress report preparation														
Progress report submission														
Literature review														
Flow chart generation														
Methods and procedures determination														
Preliminary result generation														
Report preparation														
Report submission														
Presentation slide preparation														

Appendix A2

ACTIVITIES/ TASKS	WEEKS 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Morphological chart generation	■	■												
Conceptual design generation		■	■											
Design improvement			■	■	■									
Design evaluation						■								
Progress report preparation			■	■	■	■	■							
Progress report submission							■							
Material selection							■	■						
Analysis and simulation								■	■	■	■			
Part and subassembly generation											■	■		
Detail design and product structure generation											■	■	■	
Manufacturing process and cost determination													■	
Report preparation							■	■	■	■	■	■	■	■
Report submission														■
Presentation slide preparation														■

Appendix B

Appendix B1



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MALAYSIA MELAKA
Faculty of Mechanical Engineering
FINAL YEAR PROJECT
Oil Palm Harvester
Michelle Wong
Dr. Mohd Asri
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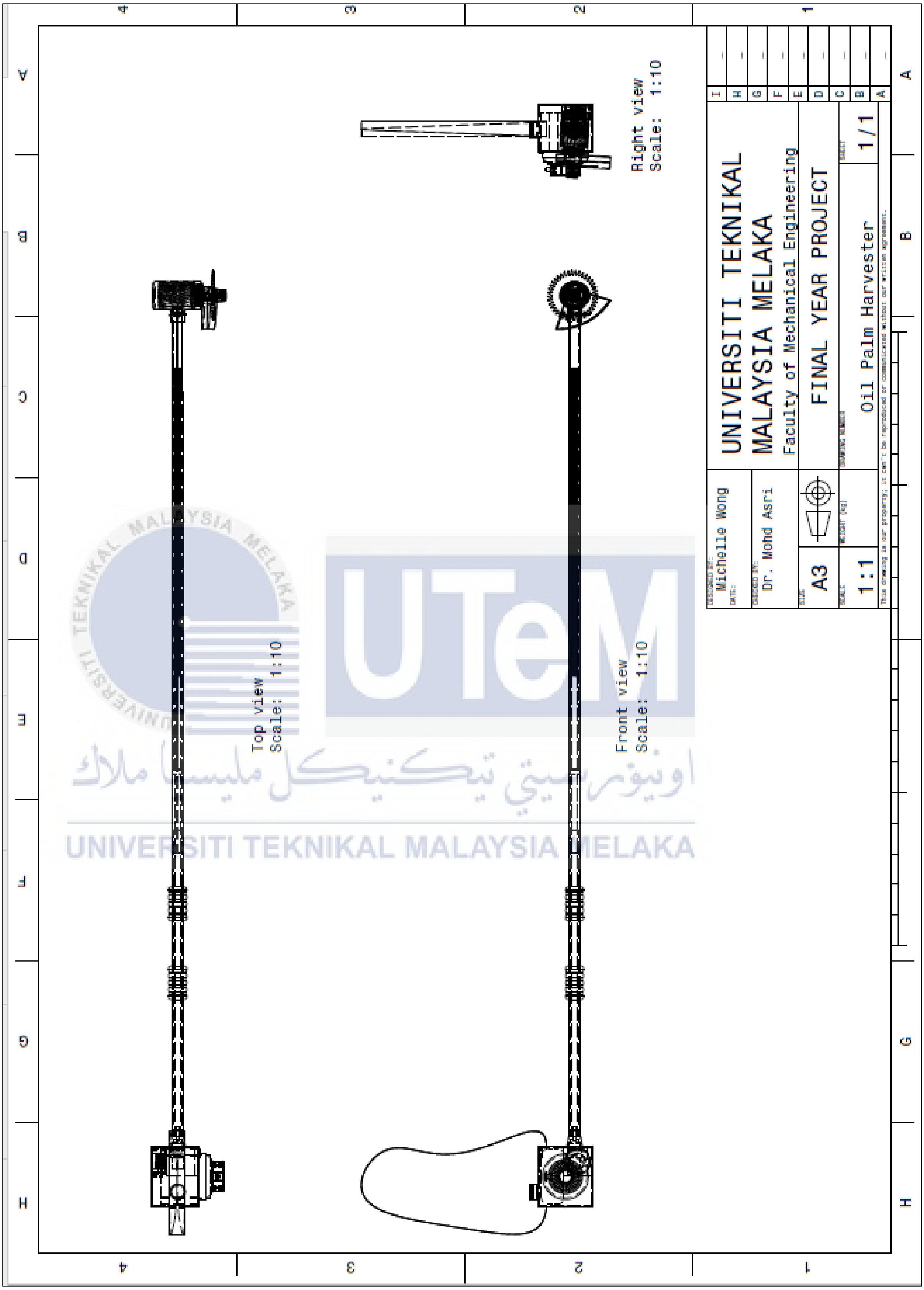
Appendix B2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Top view
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Front view
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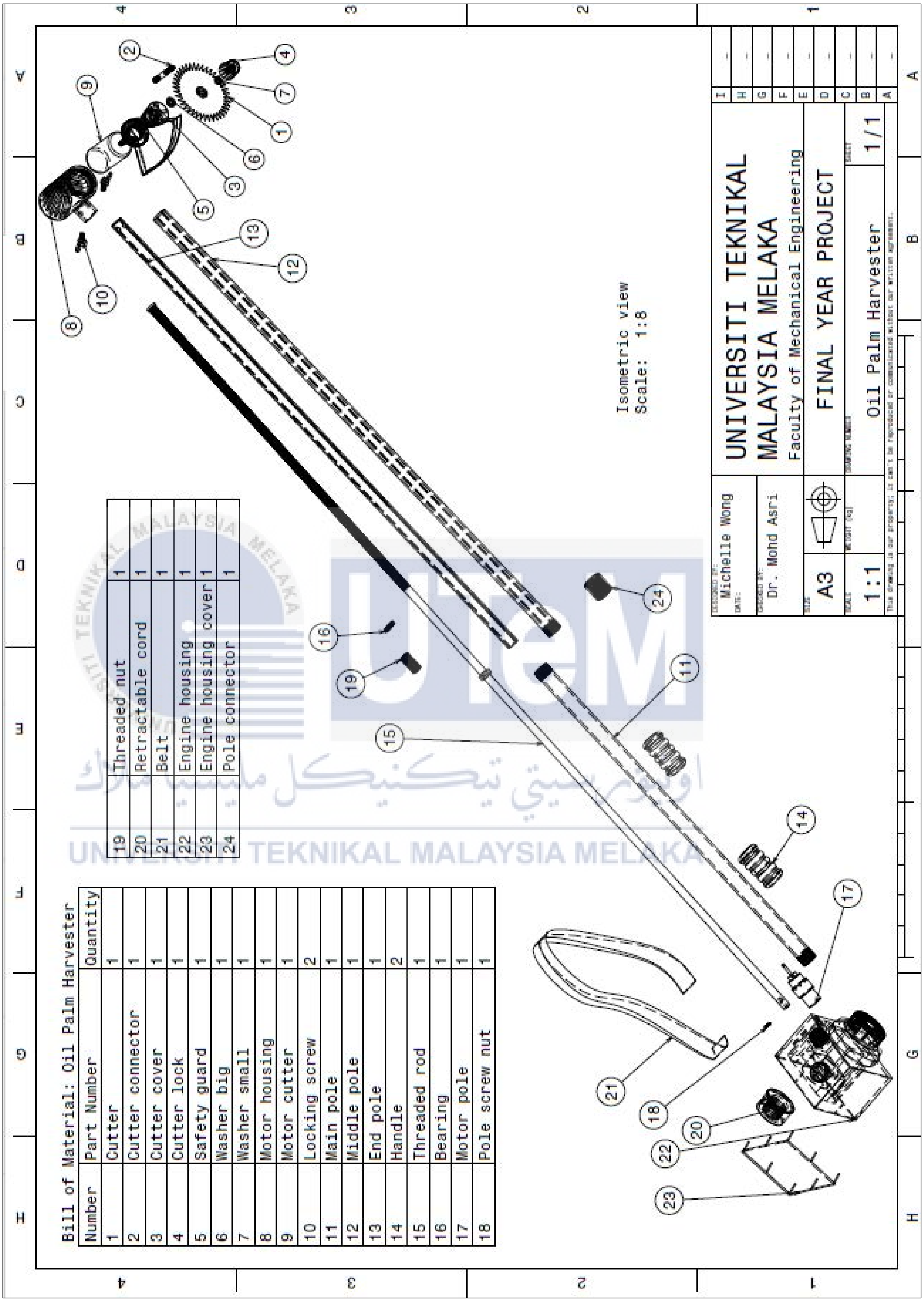
Appendix B3



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3	Cutter cover	1
4	Cutter lock	1
5	Safety guard	1
6	Washer big	1
7	Washer small	1
8	Motor housing	1
9	Motor cutter	1
10	Locking screw	2
11	Main pole	1
12	Middle pole	1
13	End pole	1
14	Handle	2
15	Threaded rod	1
16	Bearing	1
17	Motor pole	1
18	Pole screw nut	1

19	Threaded nut	1
20	Retractable cord	1
21	Belt	1
22	Engine housing	1
23	Engine housing cover	1
24	Pole connector	1

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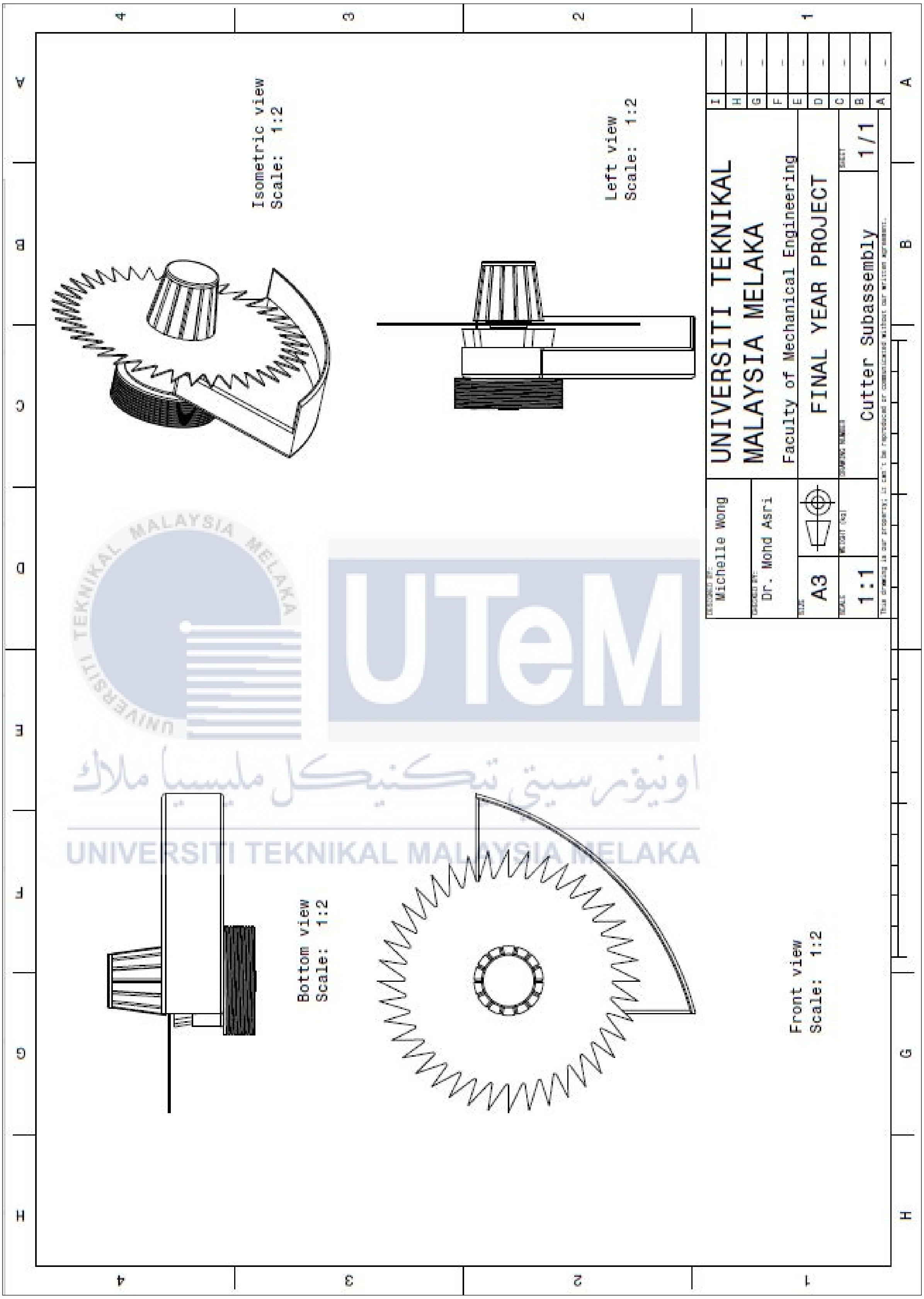
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Bottom view
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Front view
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Cutter Subassembly
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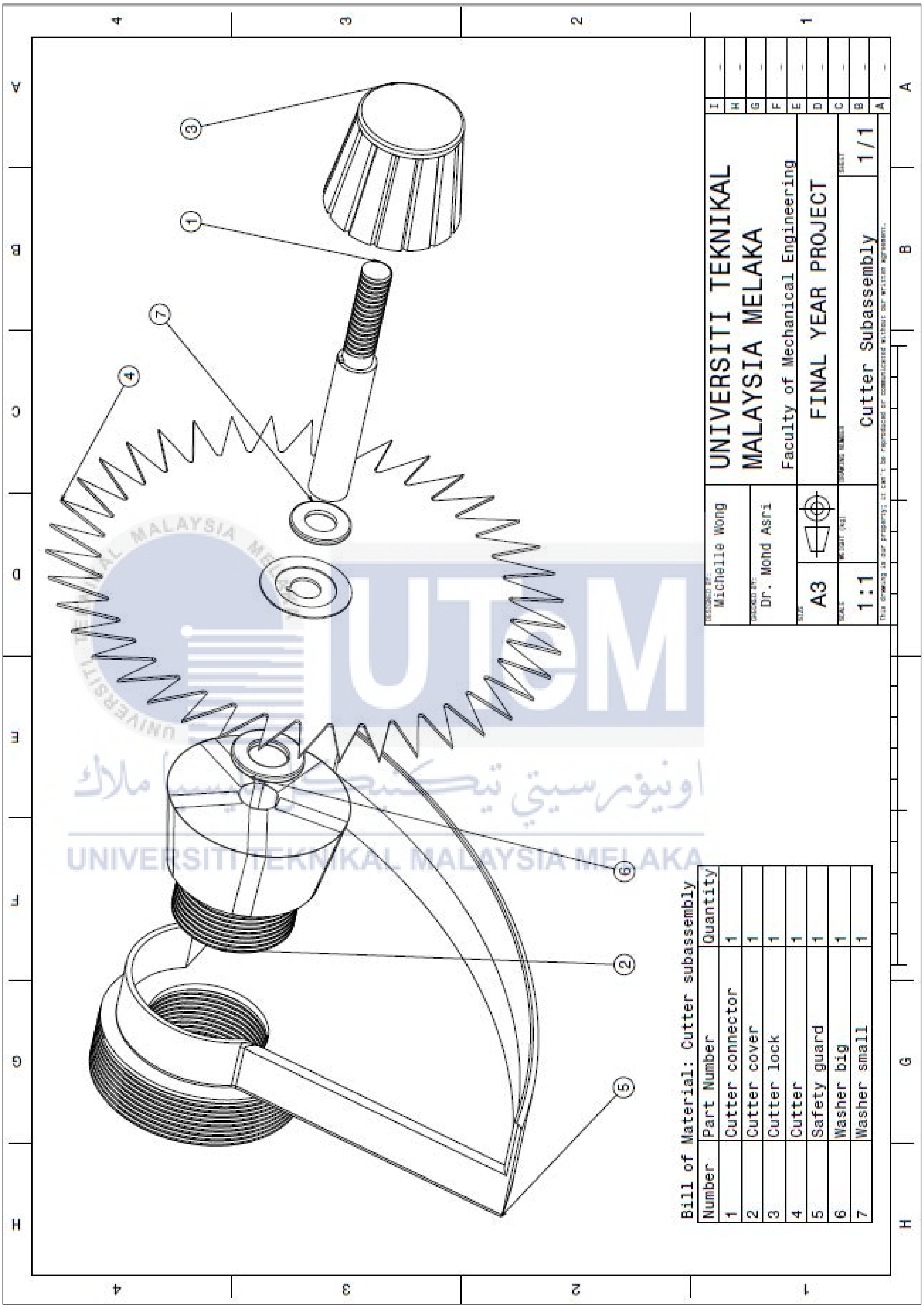
Appendix B5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Cutter Subassembly
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Dr. Mohd Asri
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1 | Cutter connector | 1
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5 | Safety guard | 1
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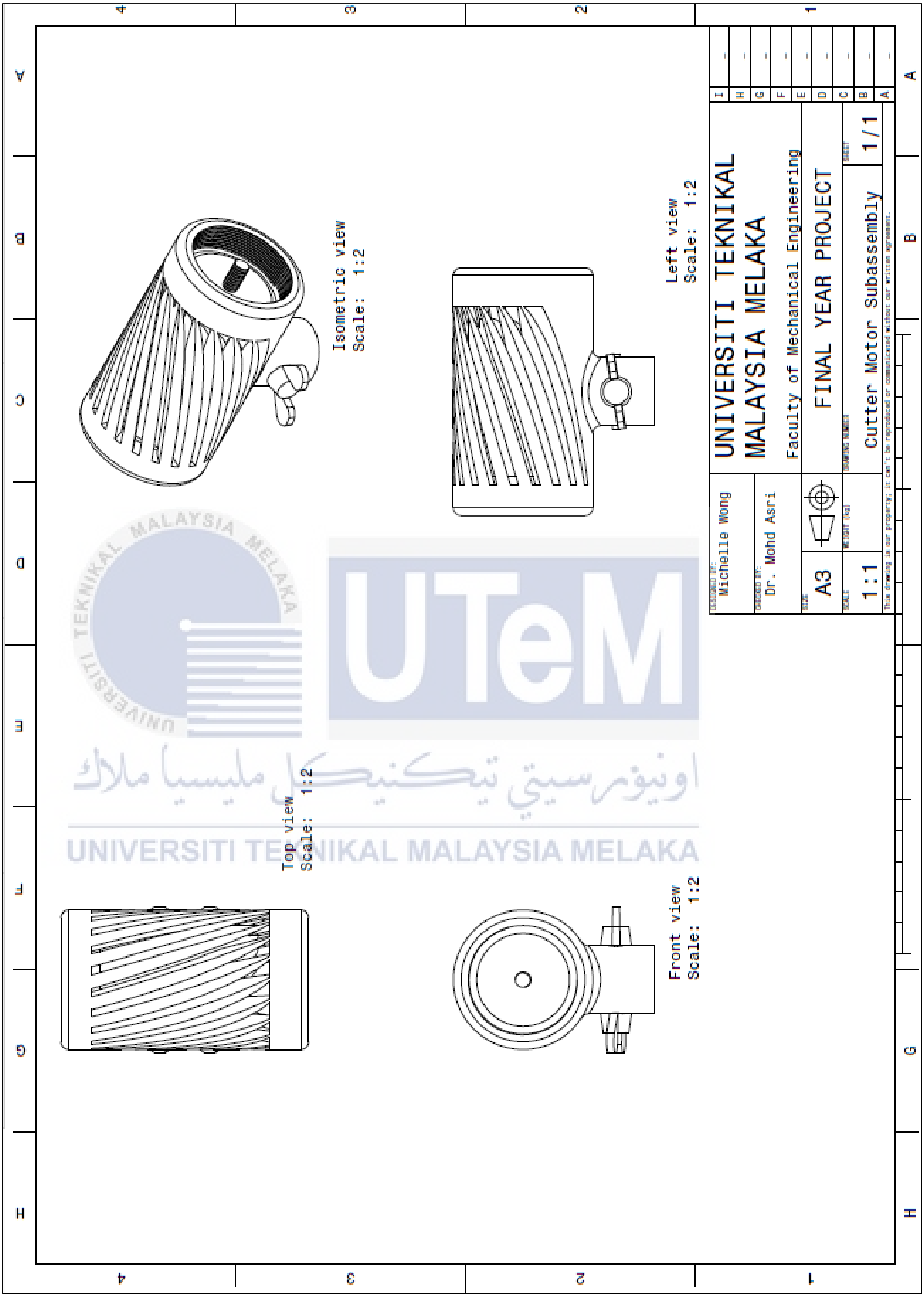
7 | Washer small | 1

Appendix B6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Top view
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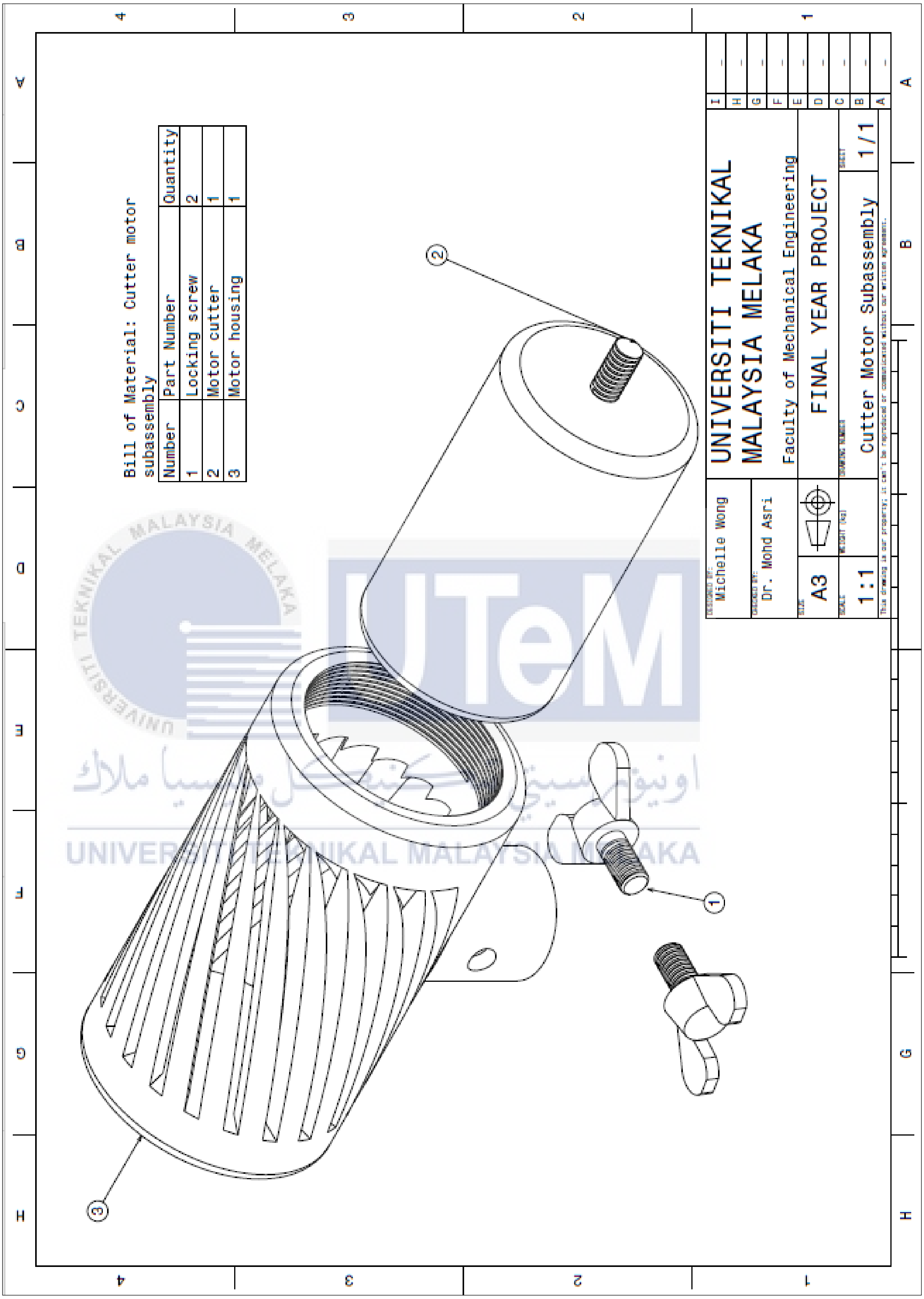
Appendix B7



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3 | Motor housing | 1
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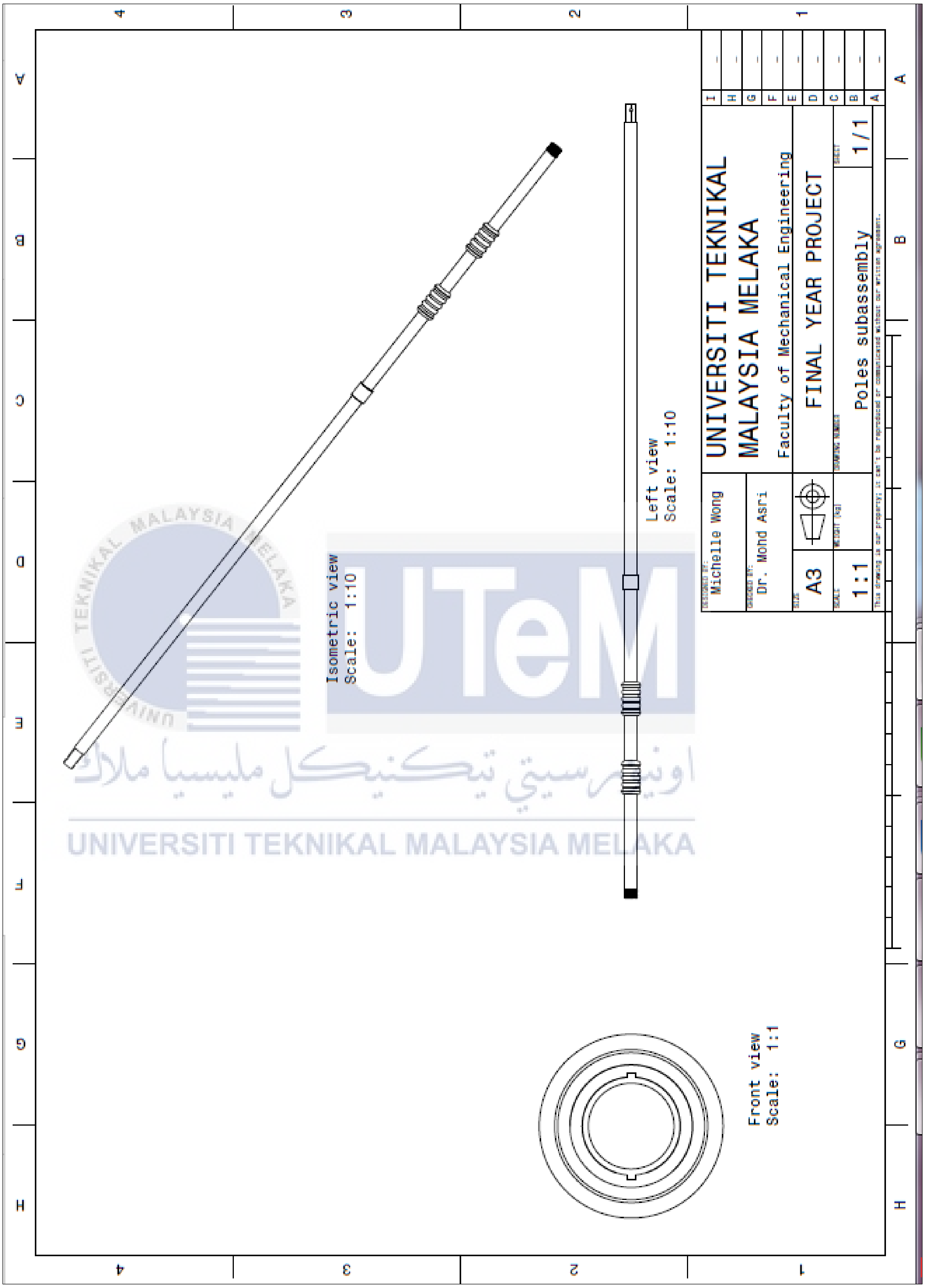
Appendix B8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Poles subassembly
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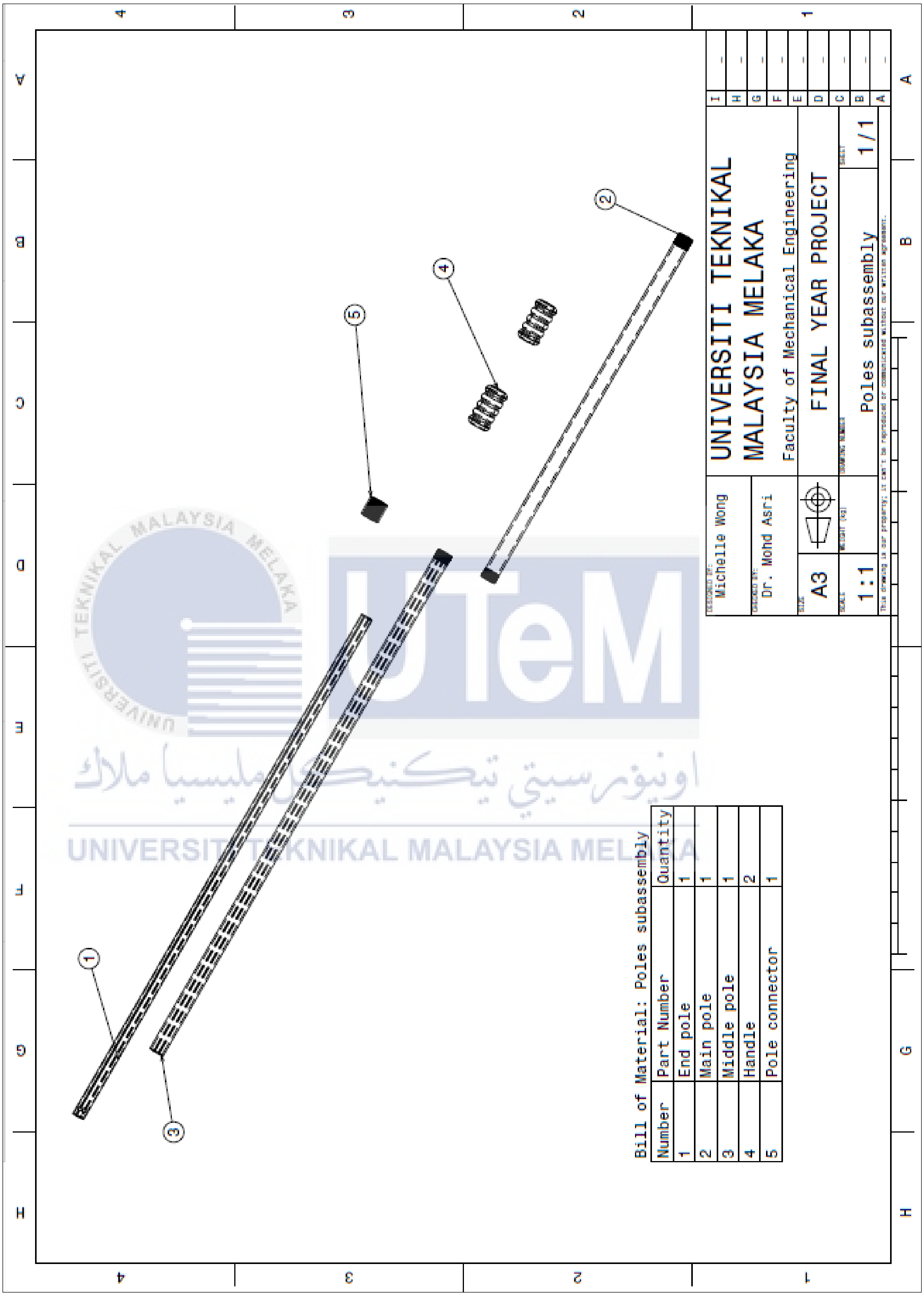
Appendix B9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FINAL YEAR PROJECT
Poles subassembly
Michelle Wong
Dr. Mohd Asri
A3
1:1
1/1
Bill of Material: Poles subassembly
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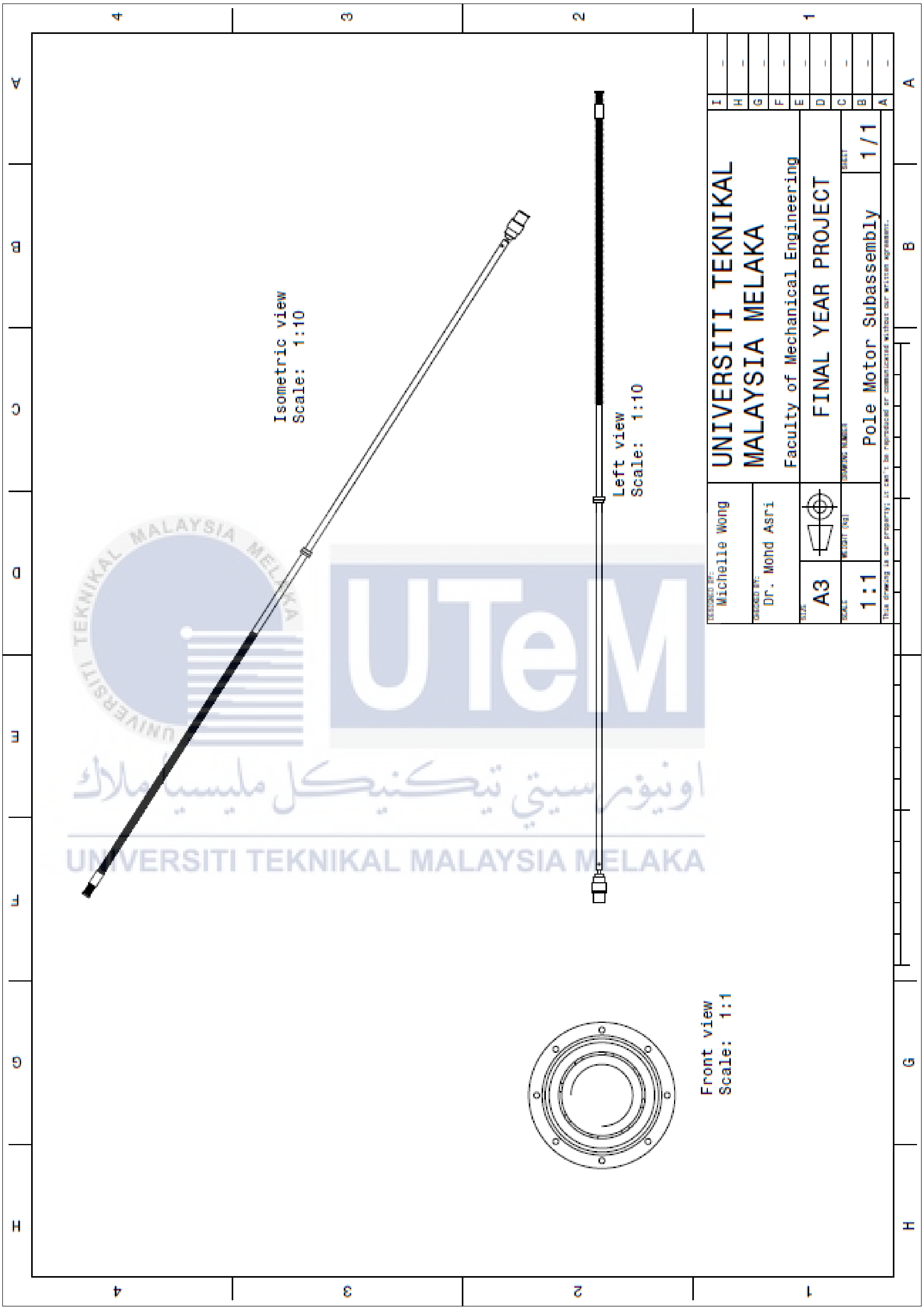
2 | Main pole | 1
3 | Middle pole | 1
4 | Handle | 2
5 | Pole connector | 1

Appendix B10



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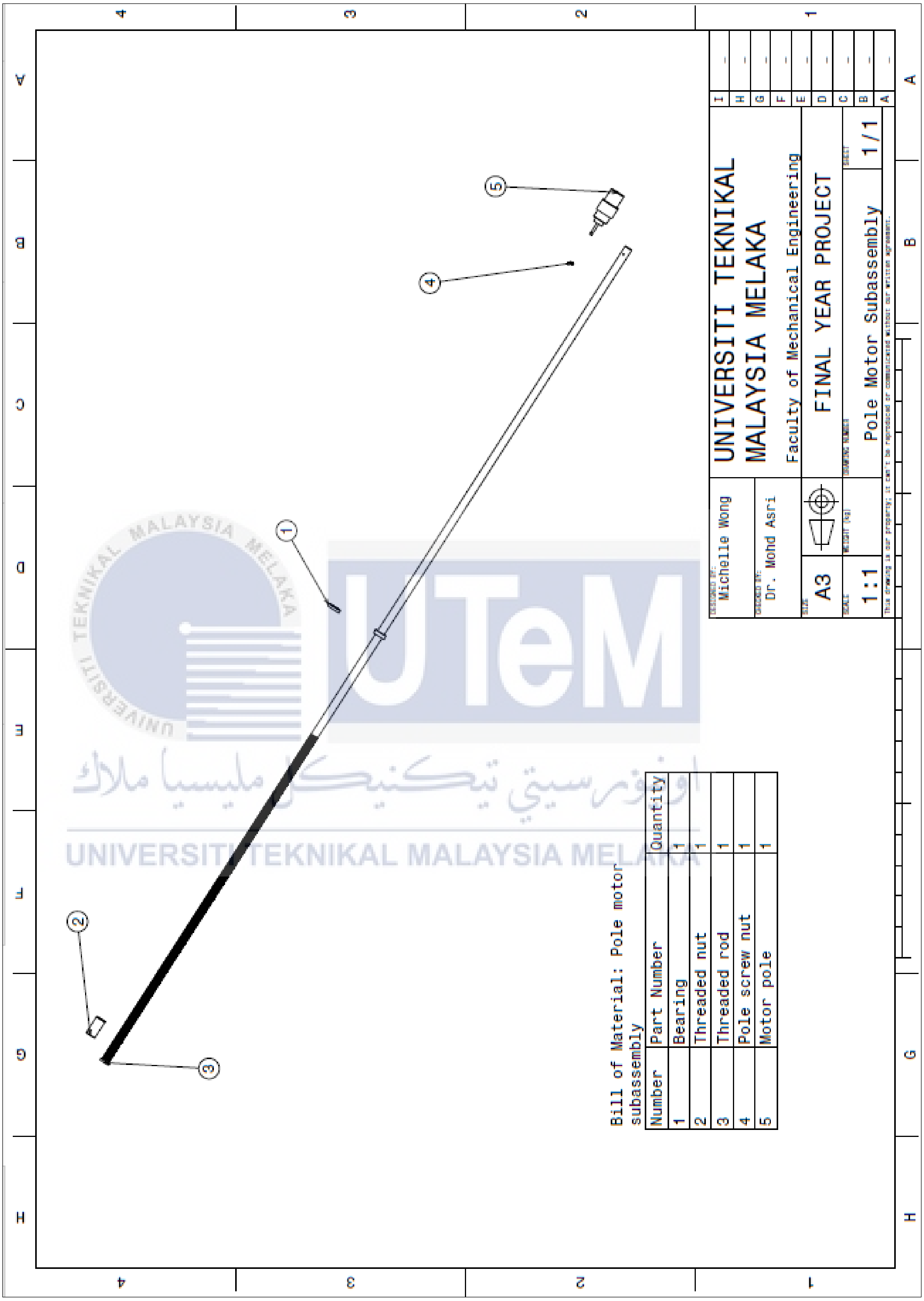

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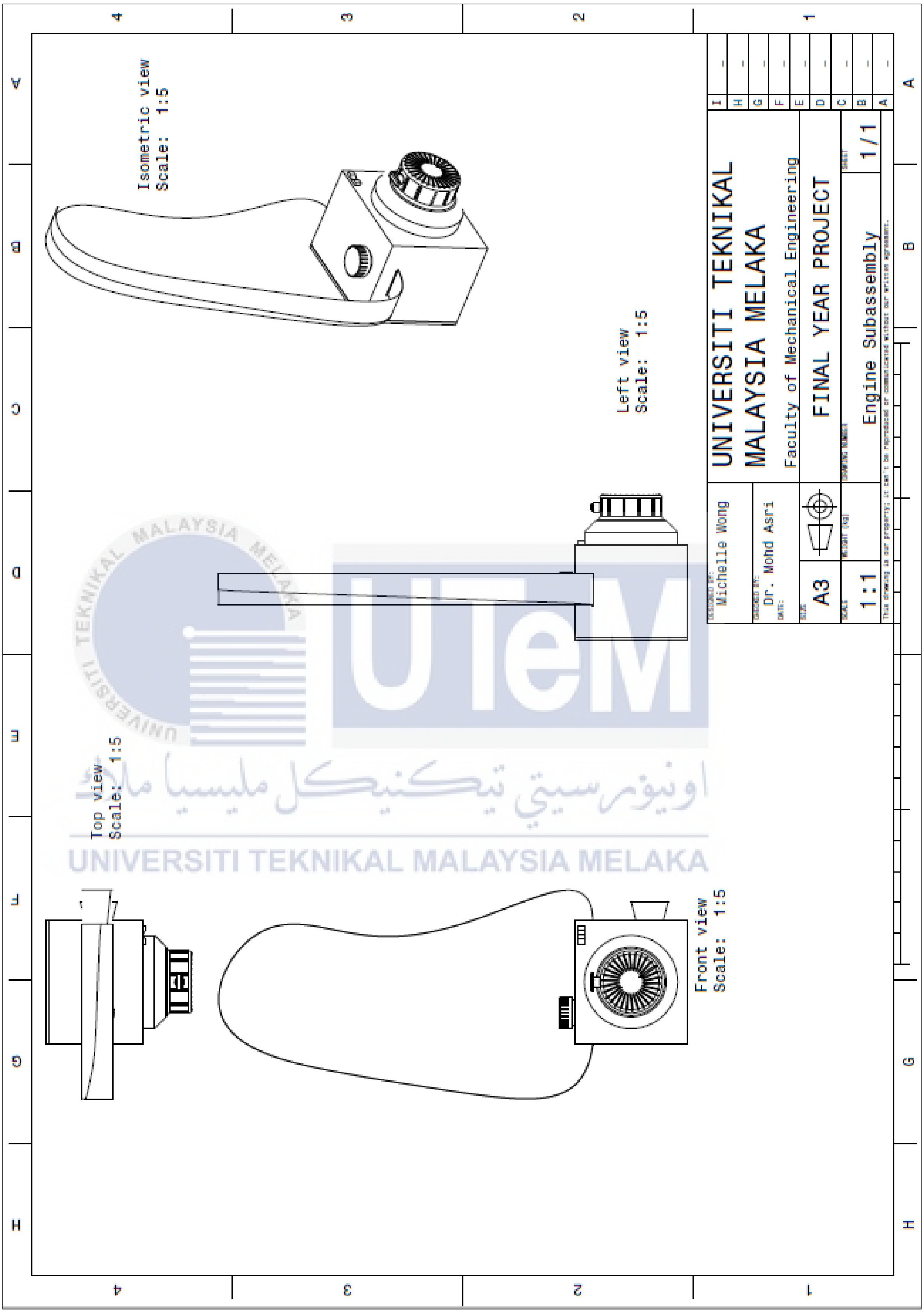

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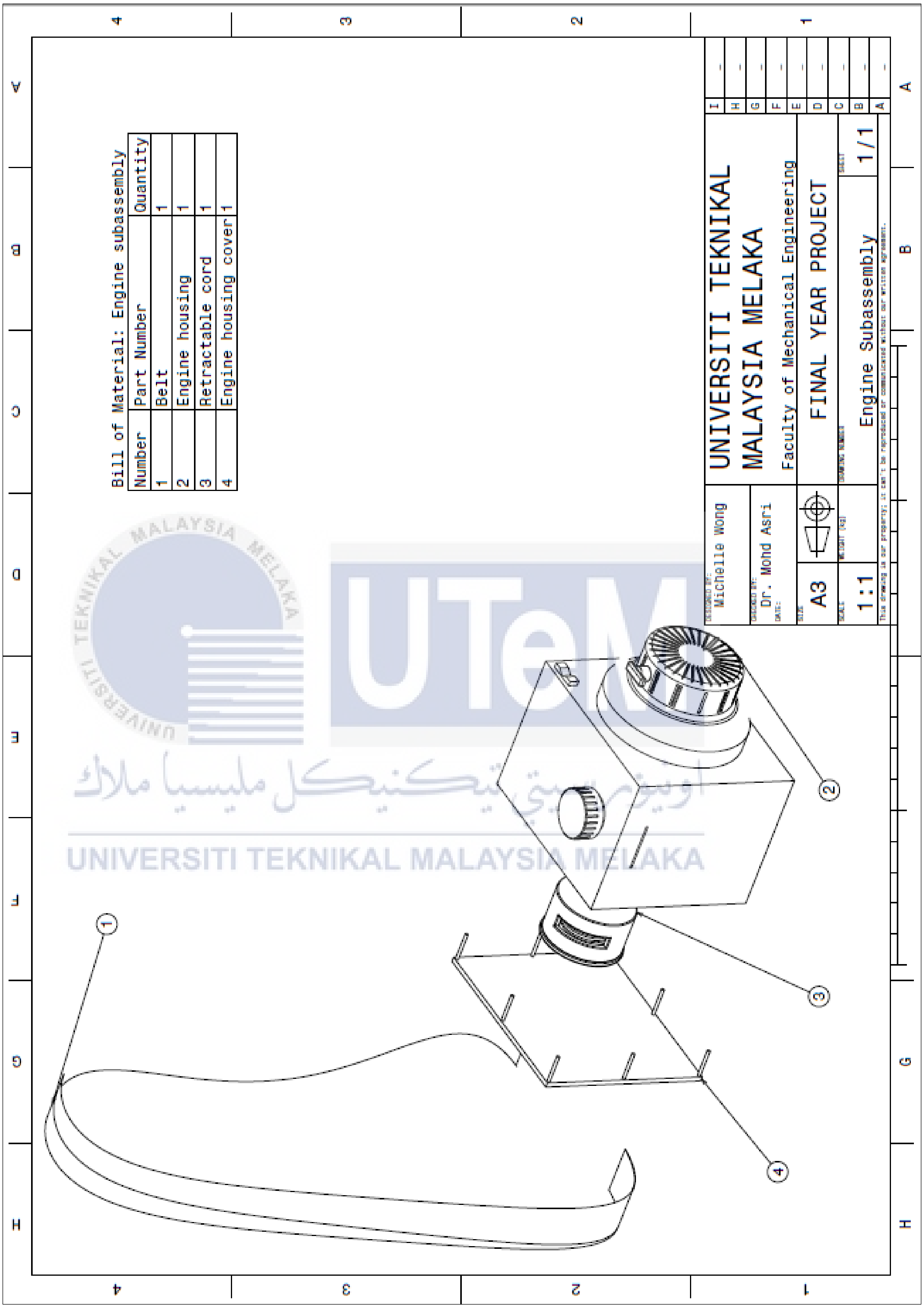
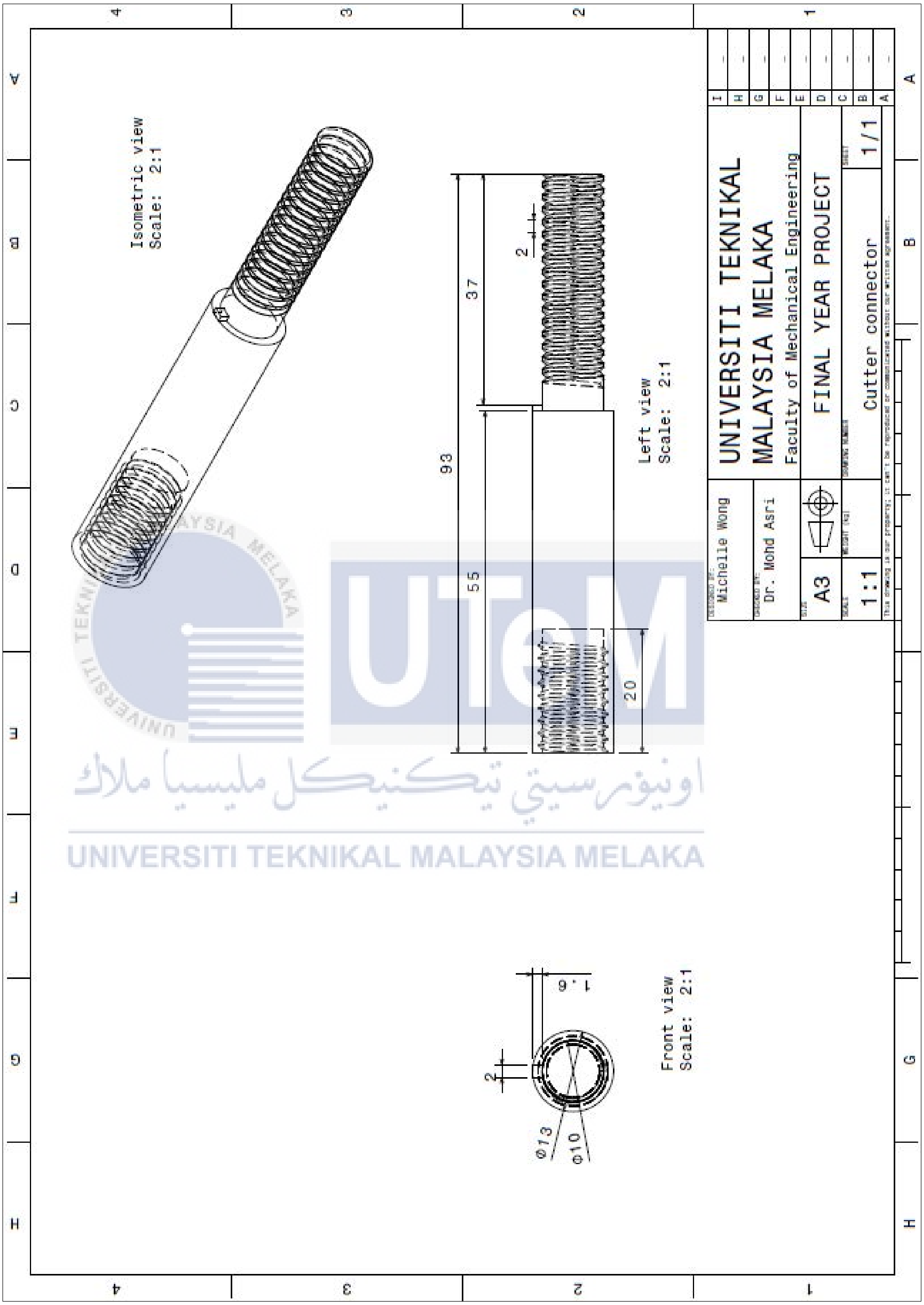
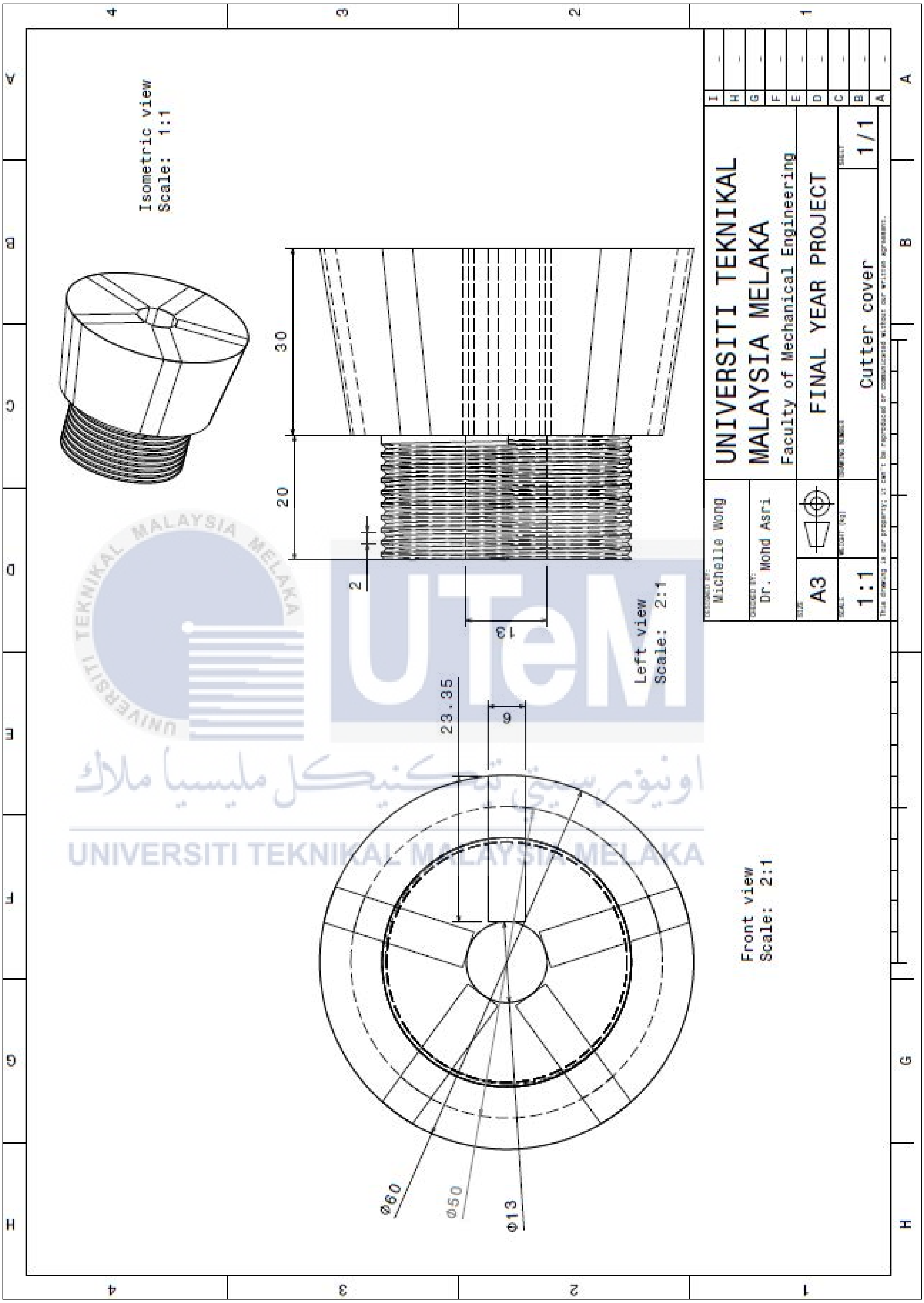


AppendixB14



Appendix B15



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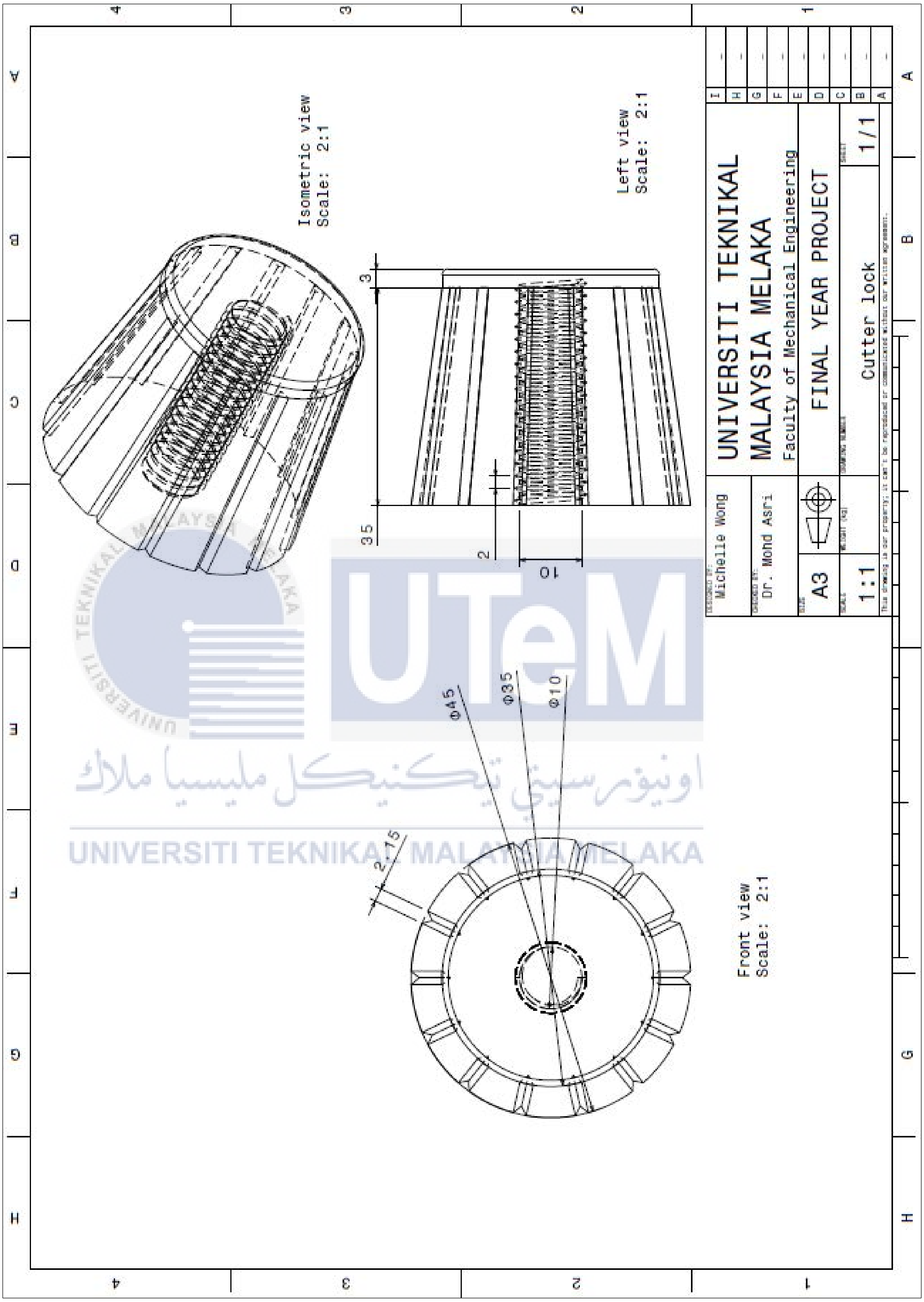
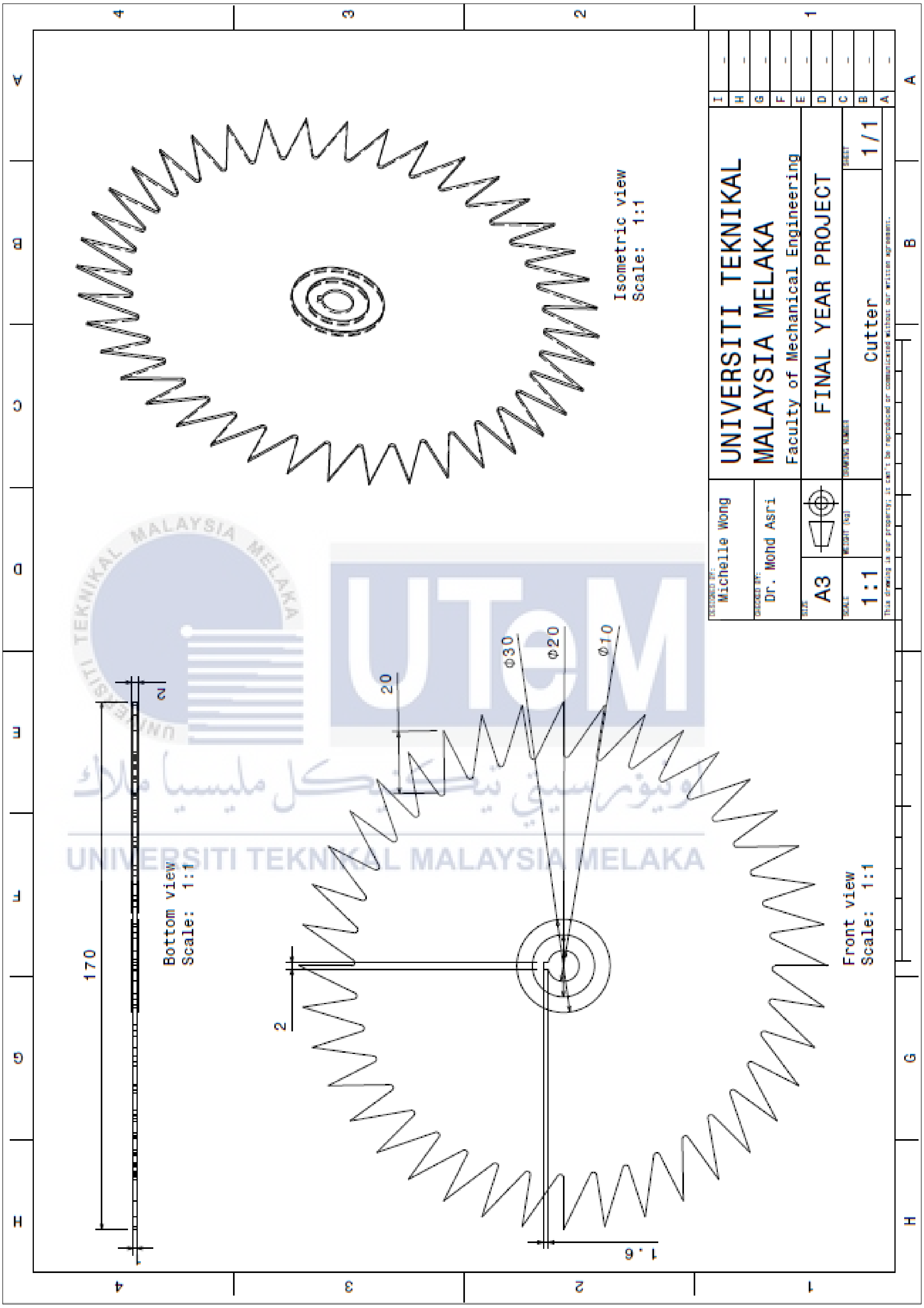
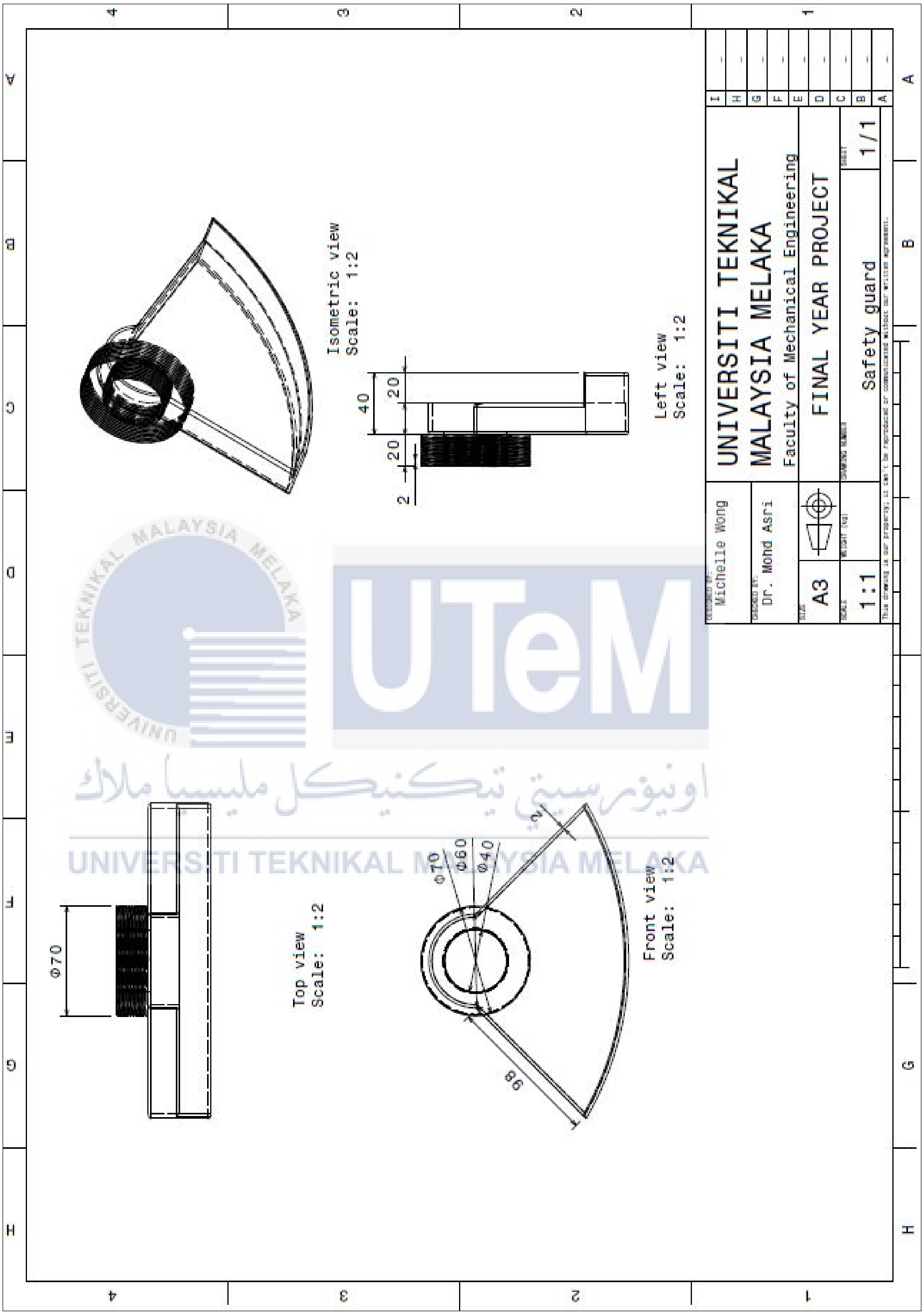


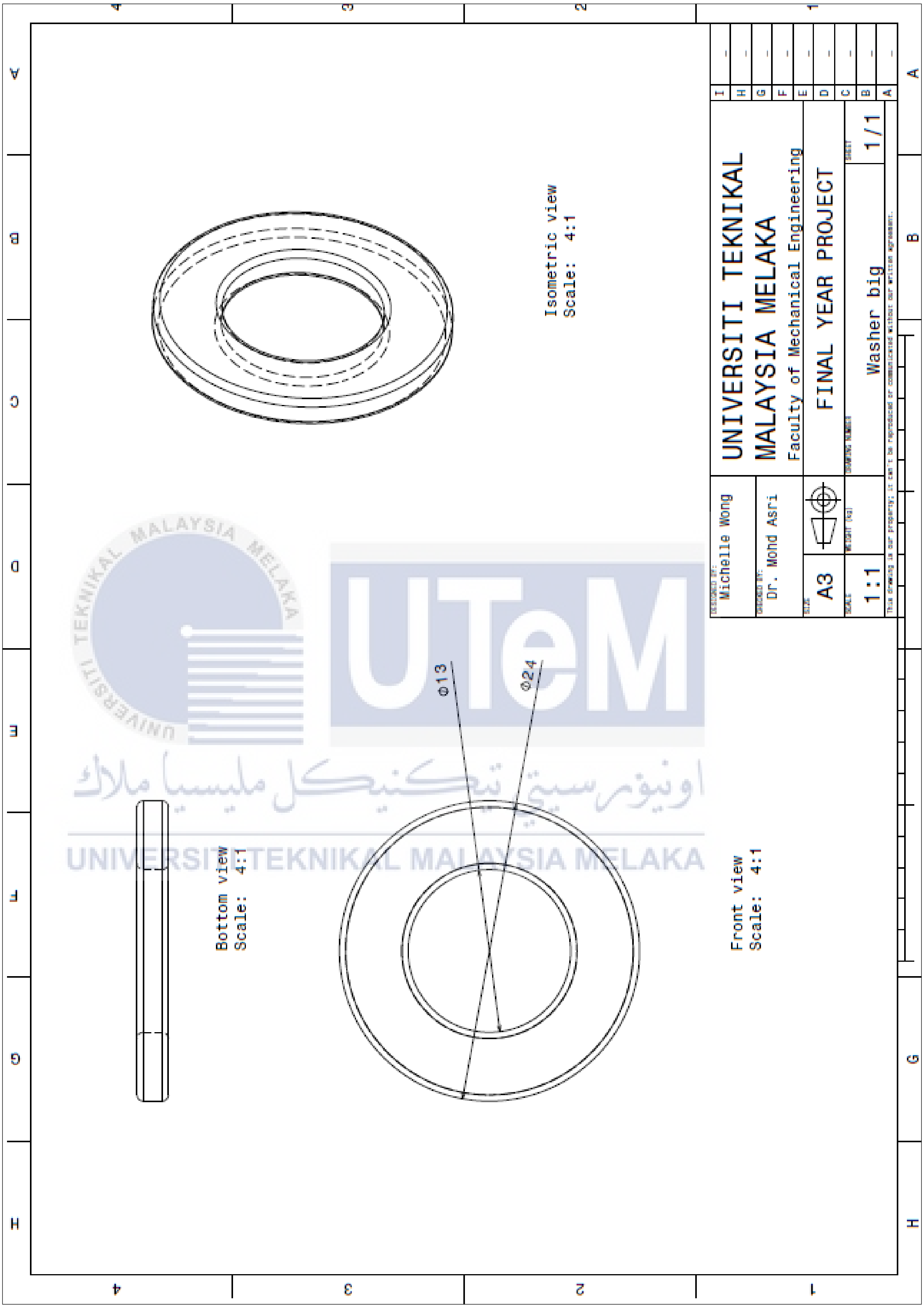
Appendix B17



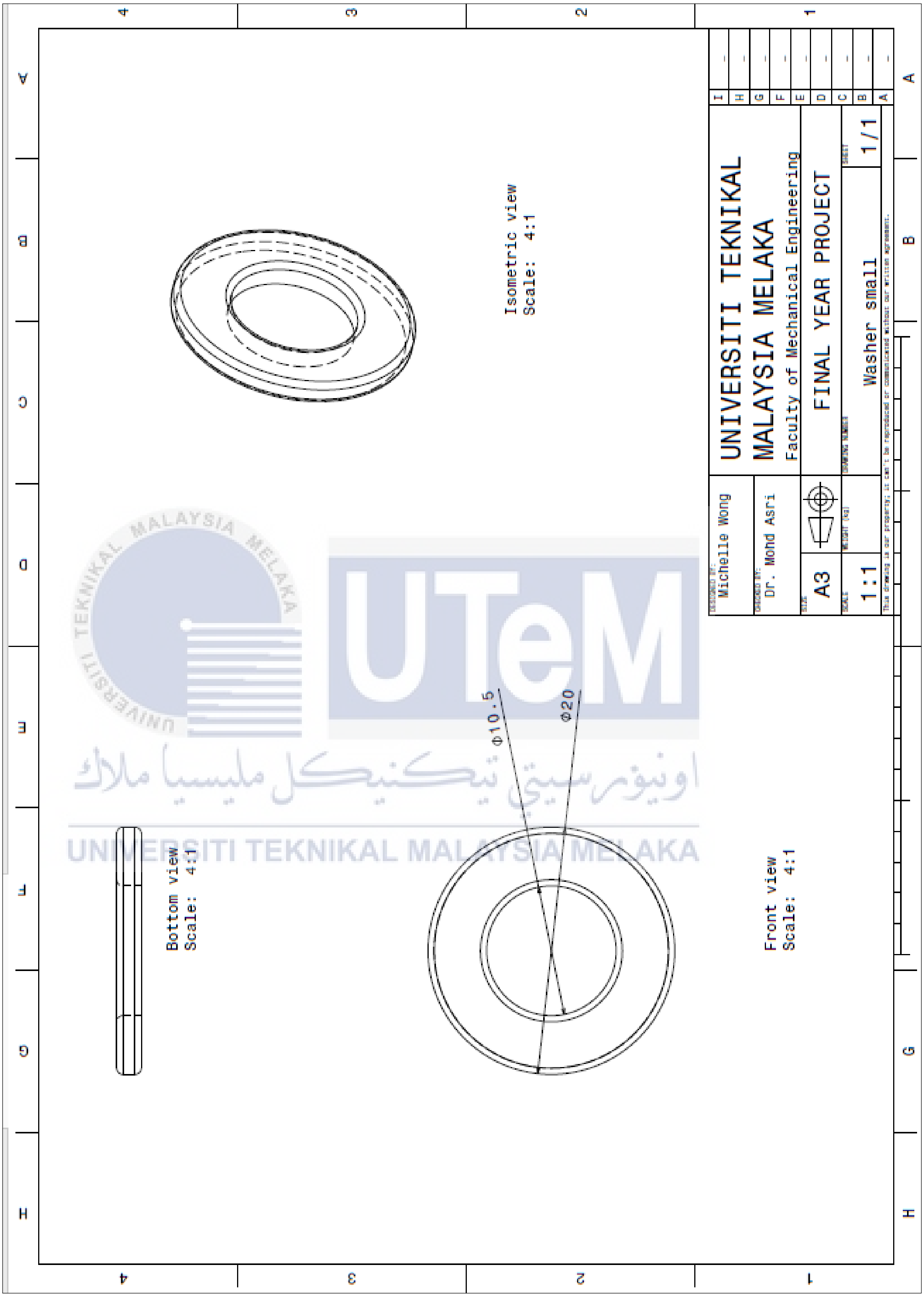
Appendix B18



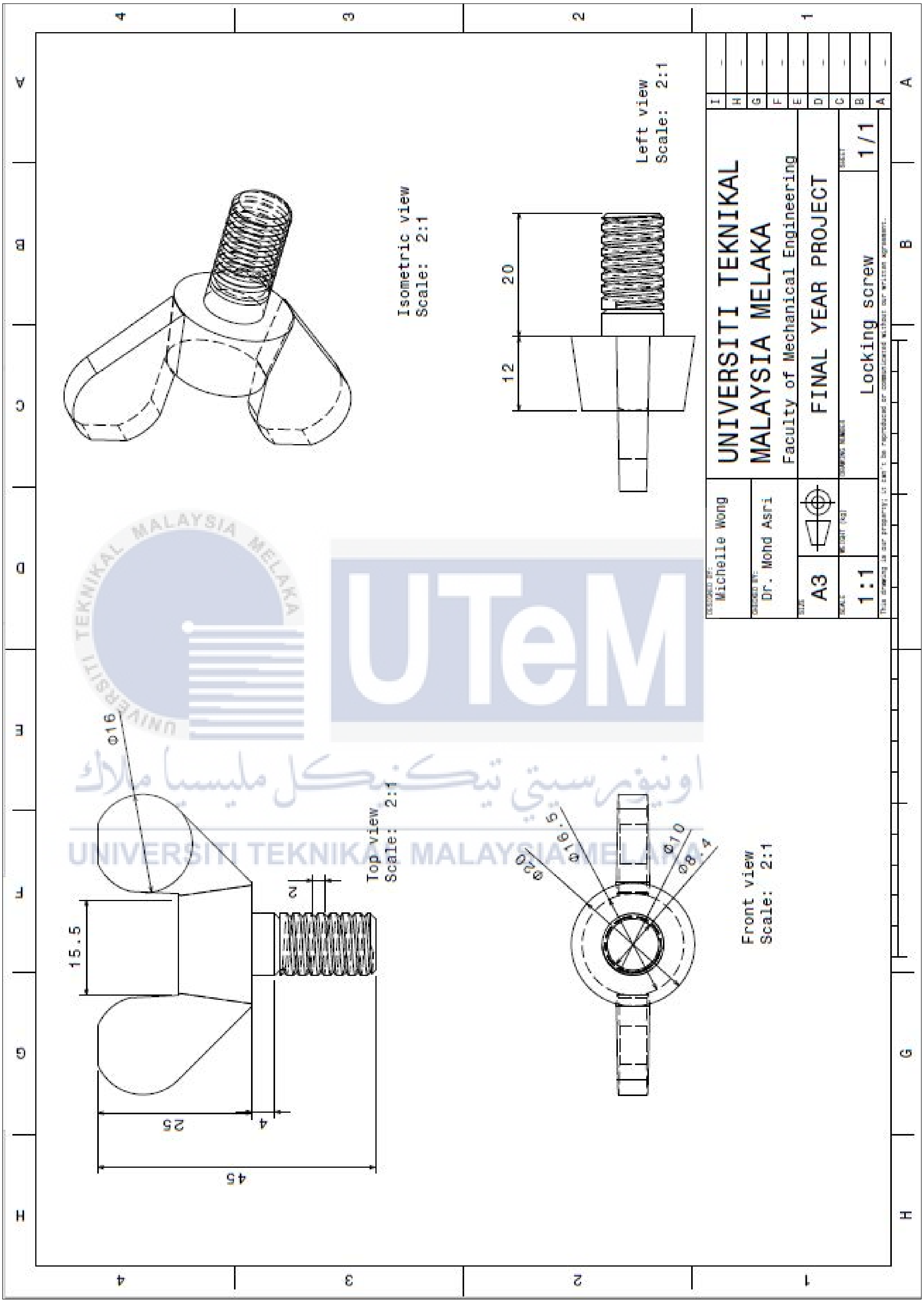
AppendixB19



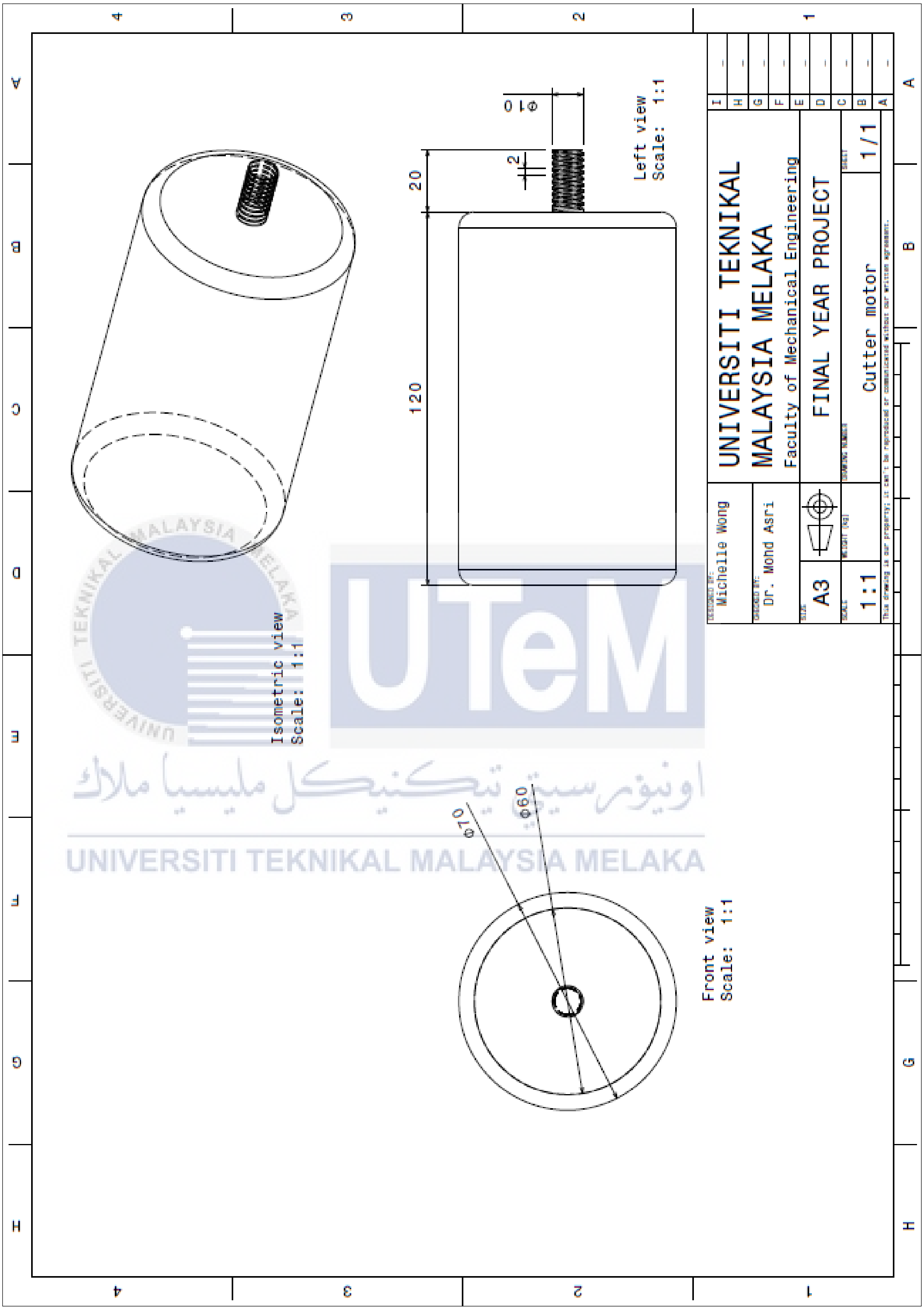
Appendix B20



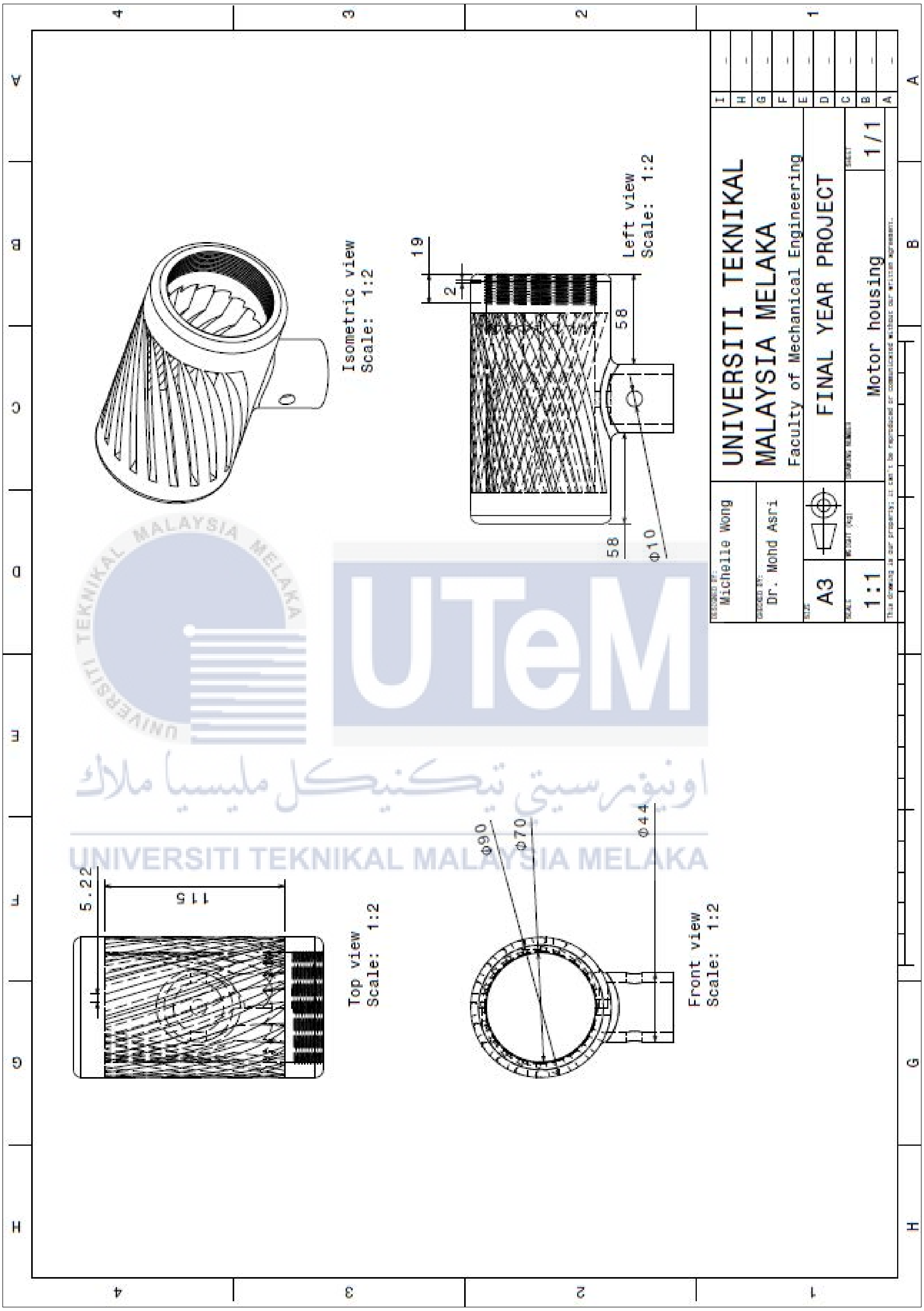
Appendix B21



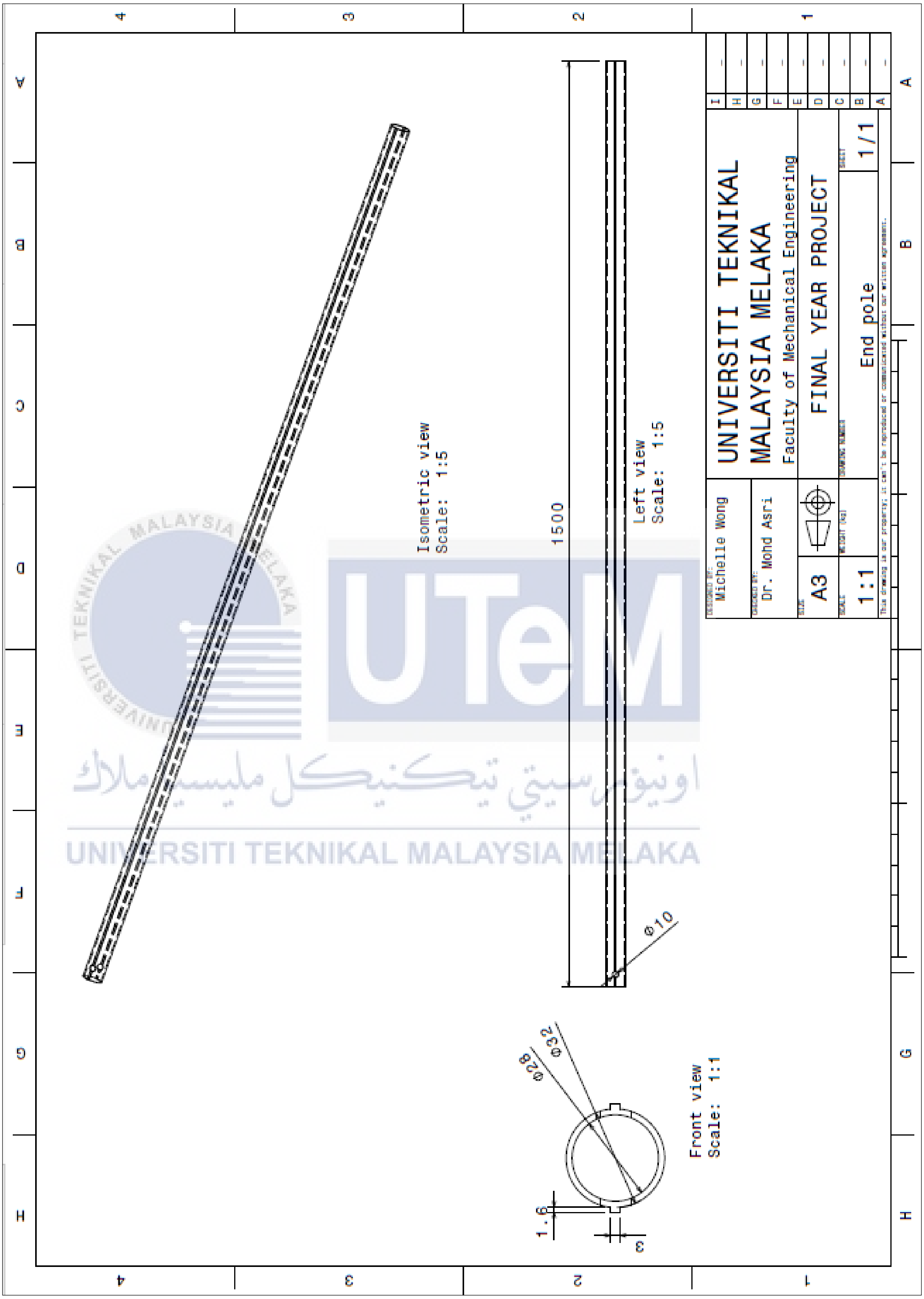
Appendix B22



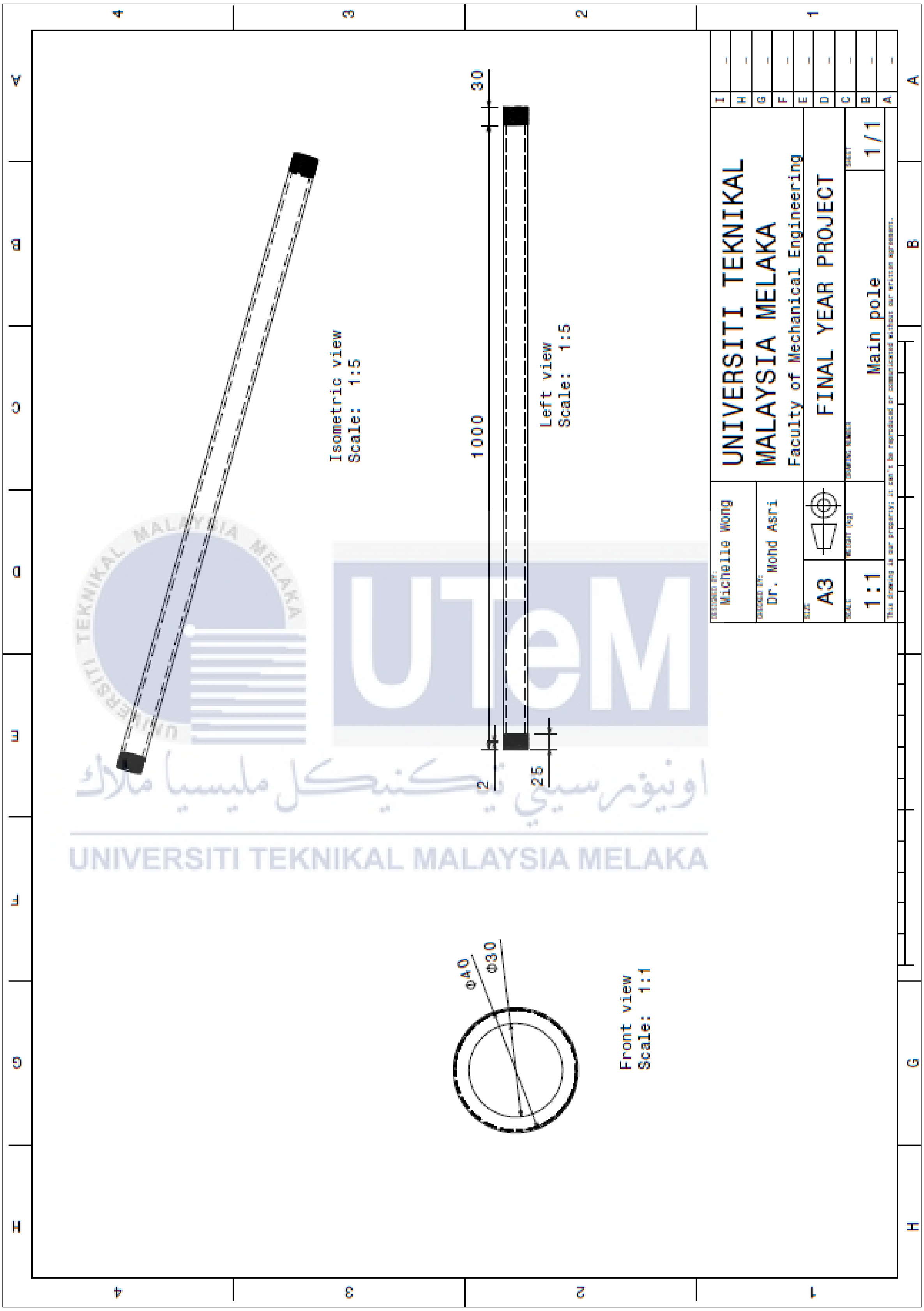
Appendix B23



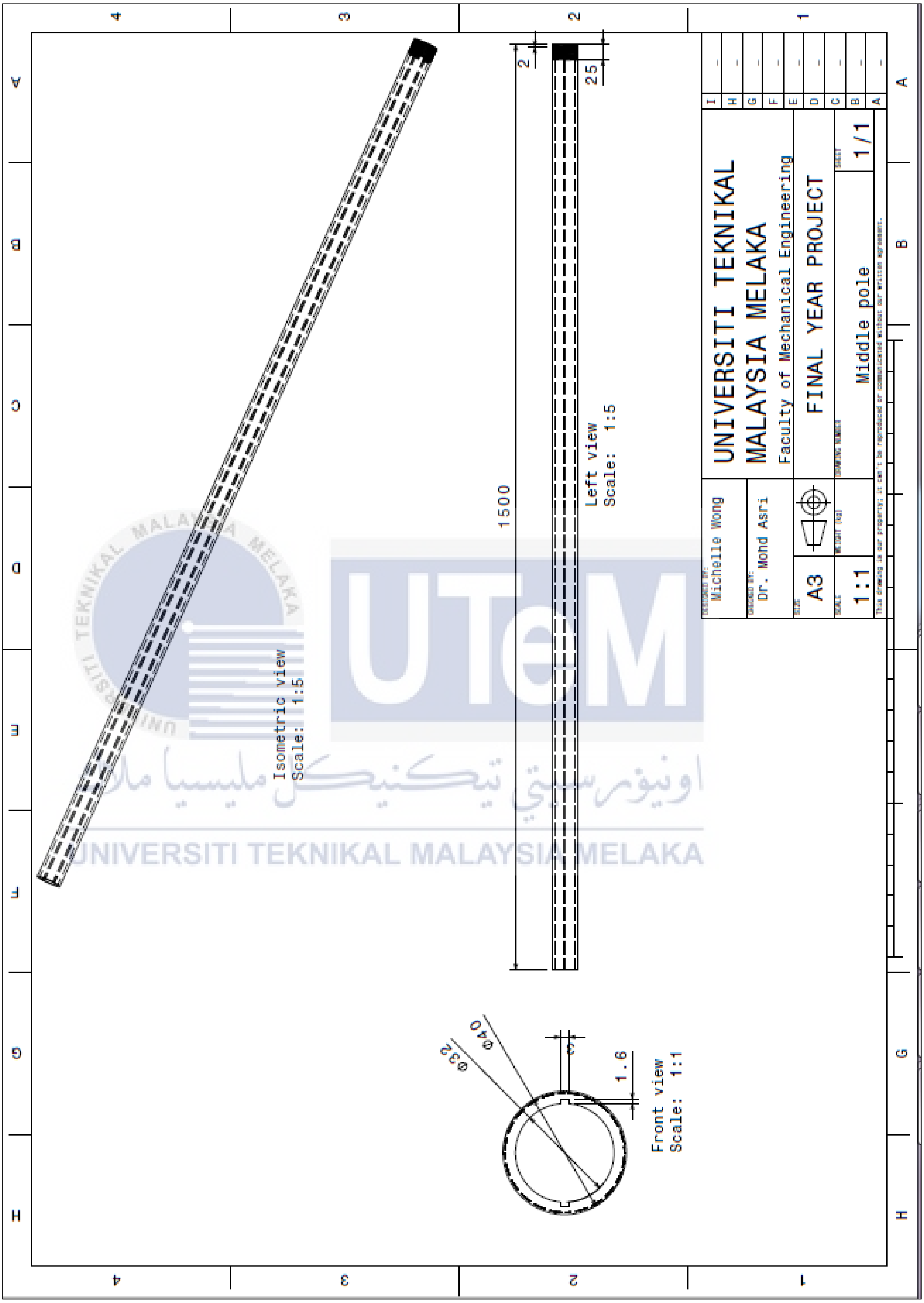
Appendix B24



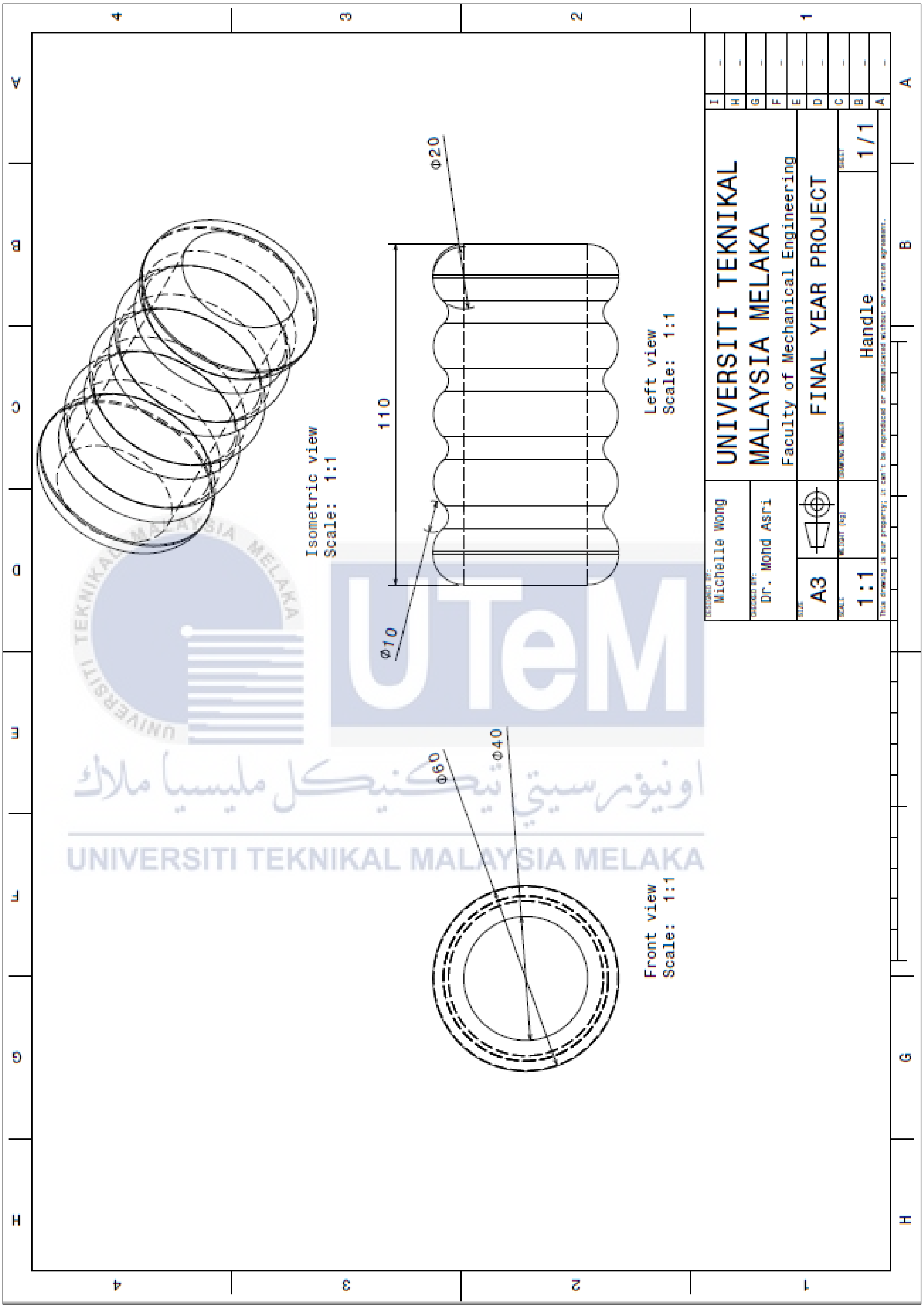
Appendix B25



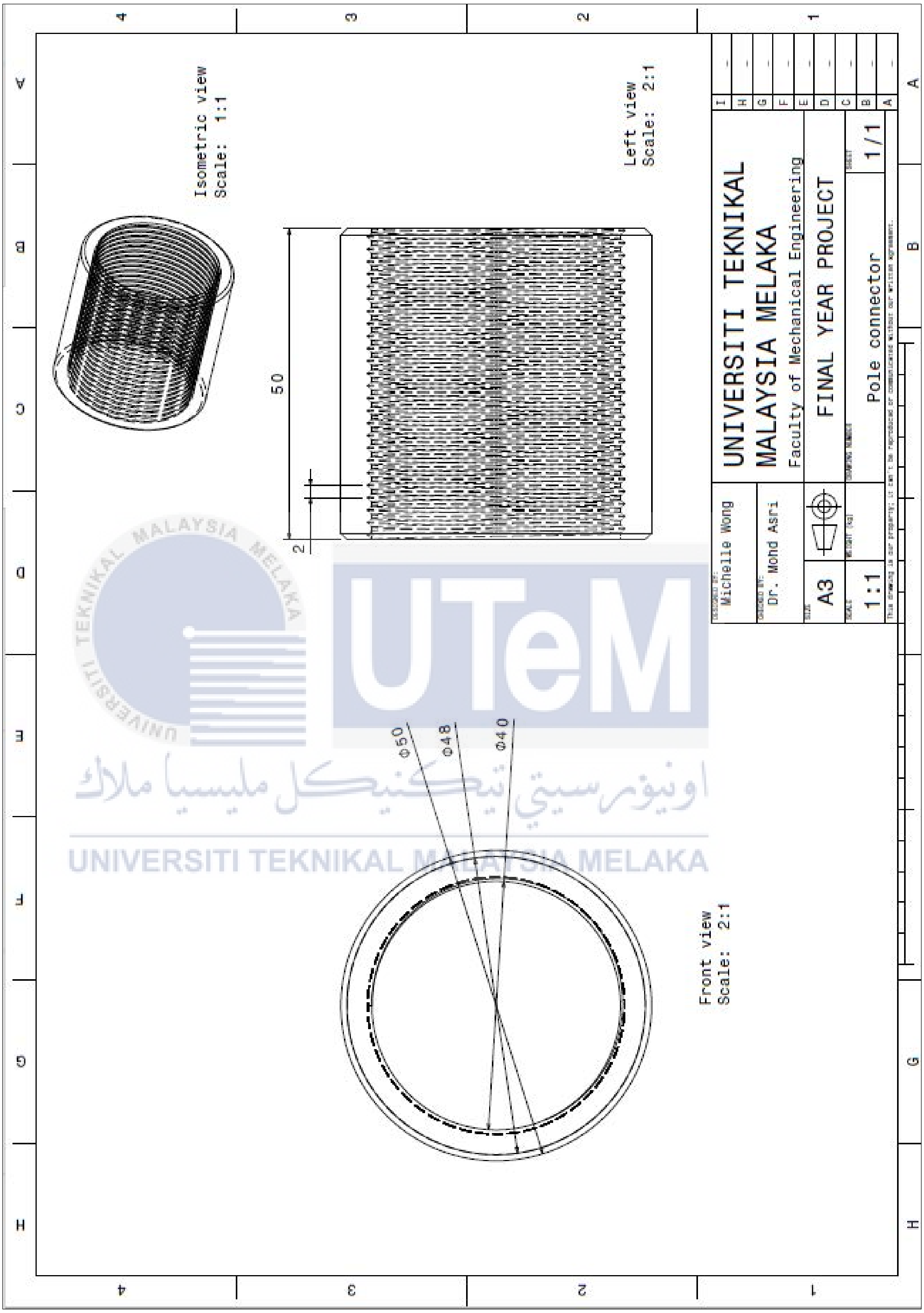
Appendix B26



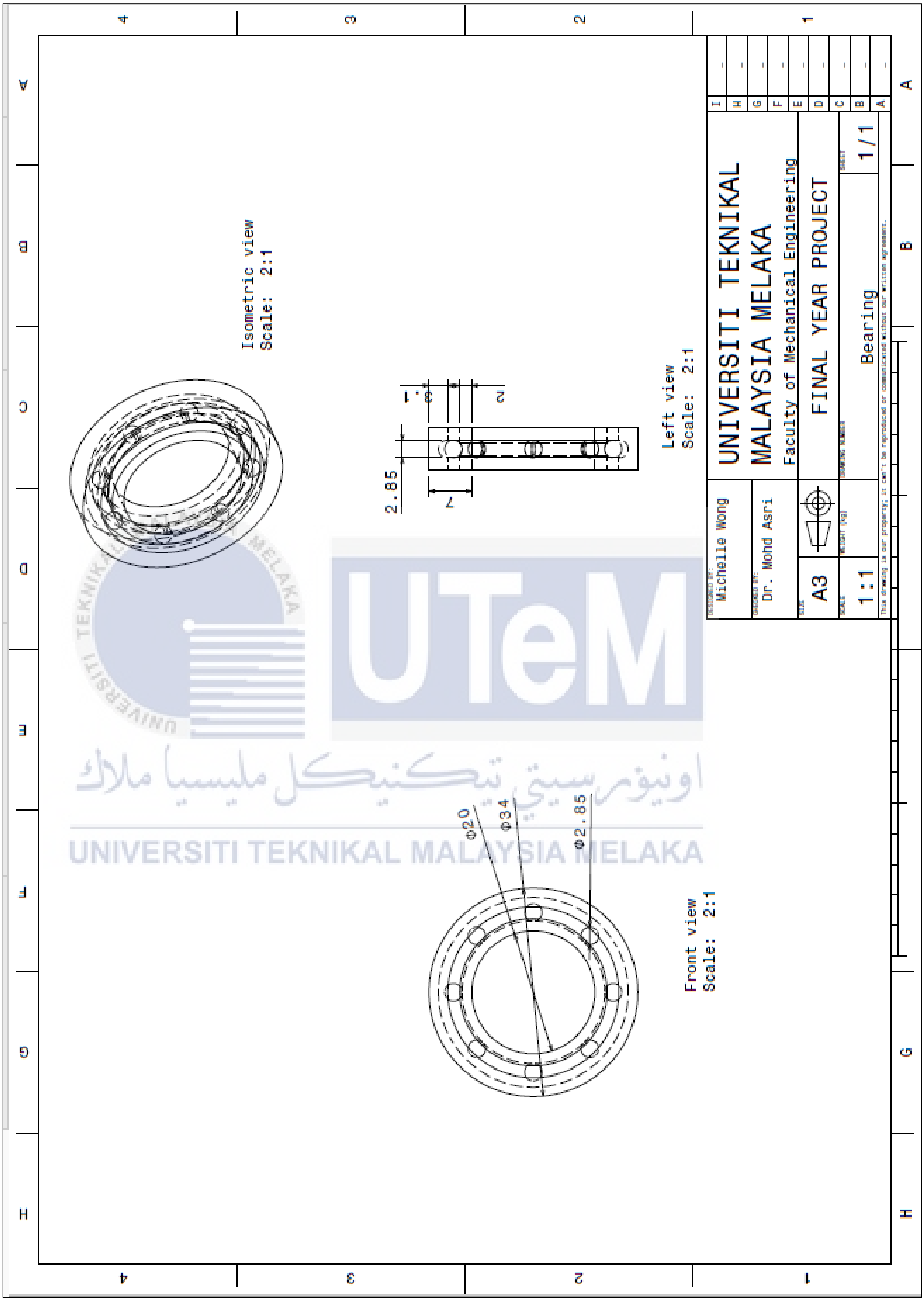
Appendix B27



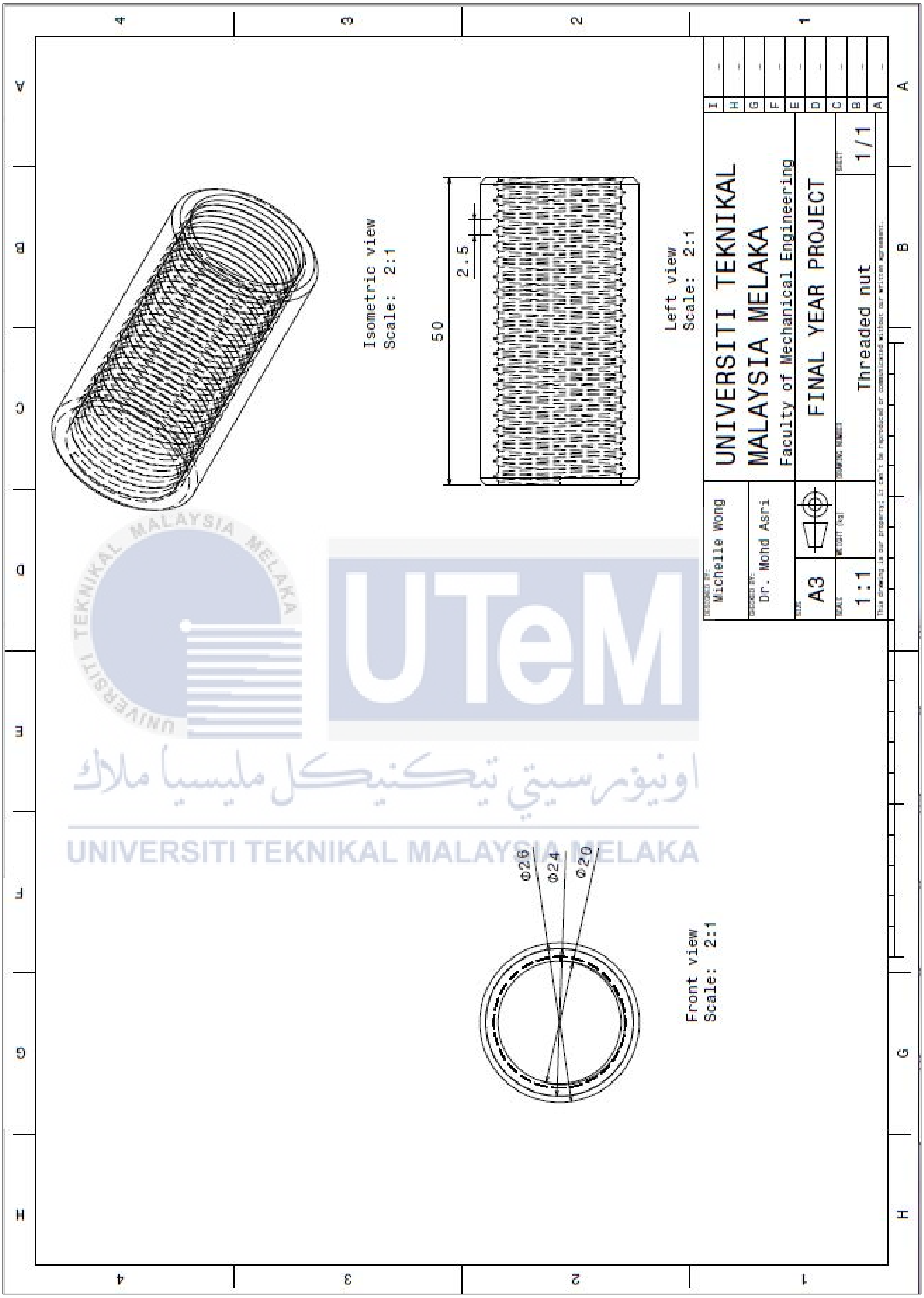
Appendix B28



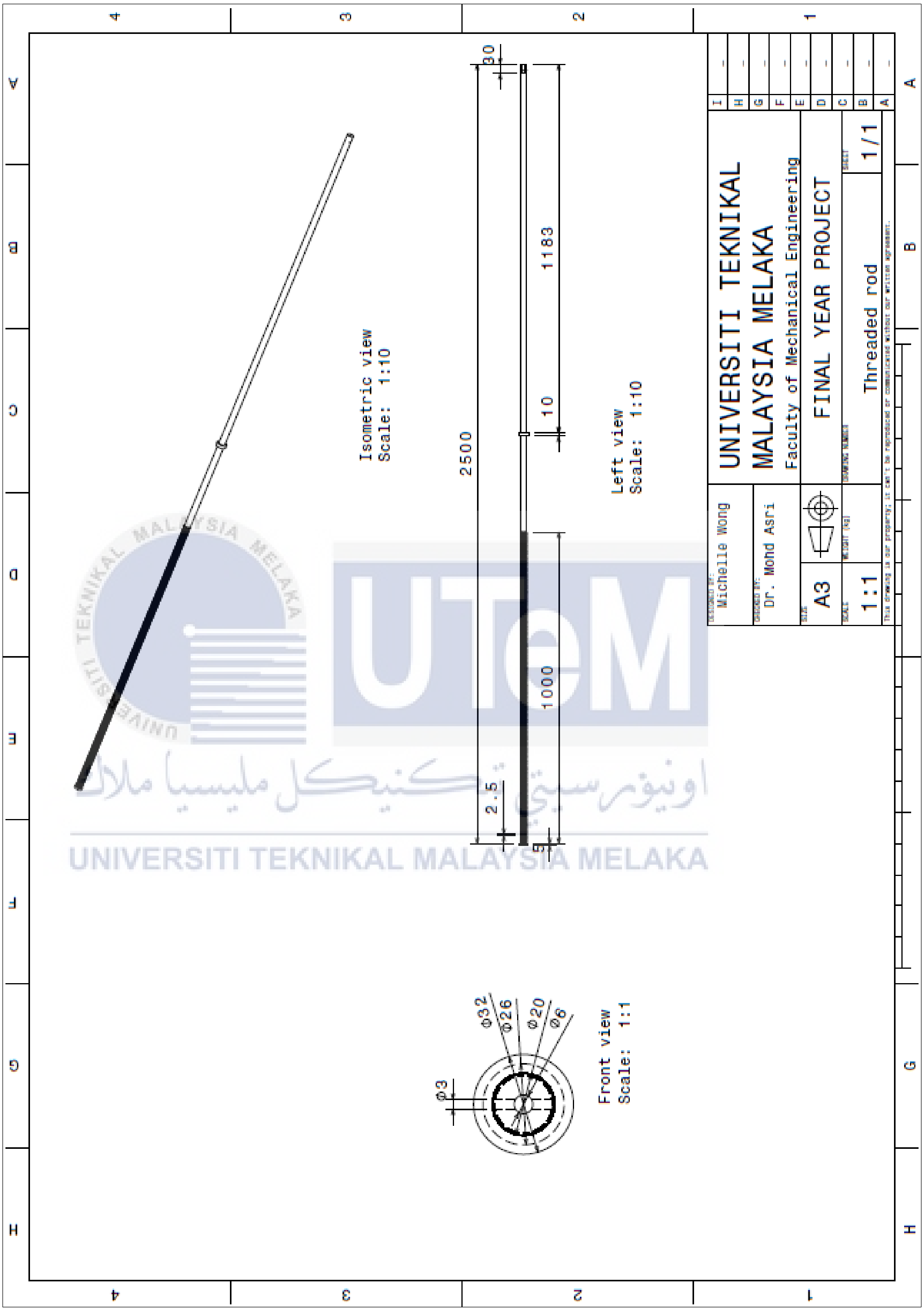
Appendix B29



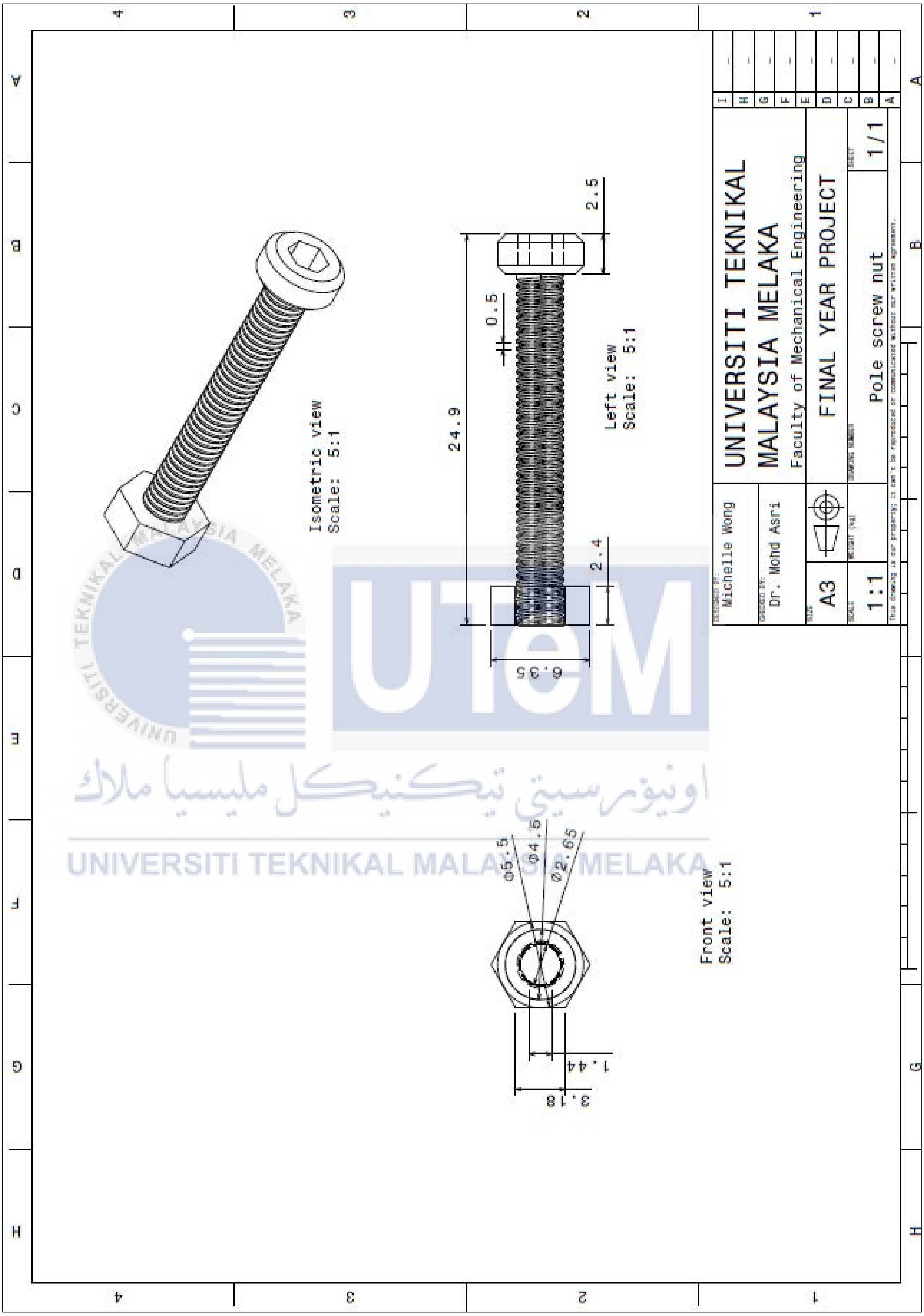
Appendix B30



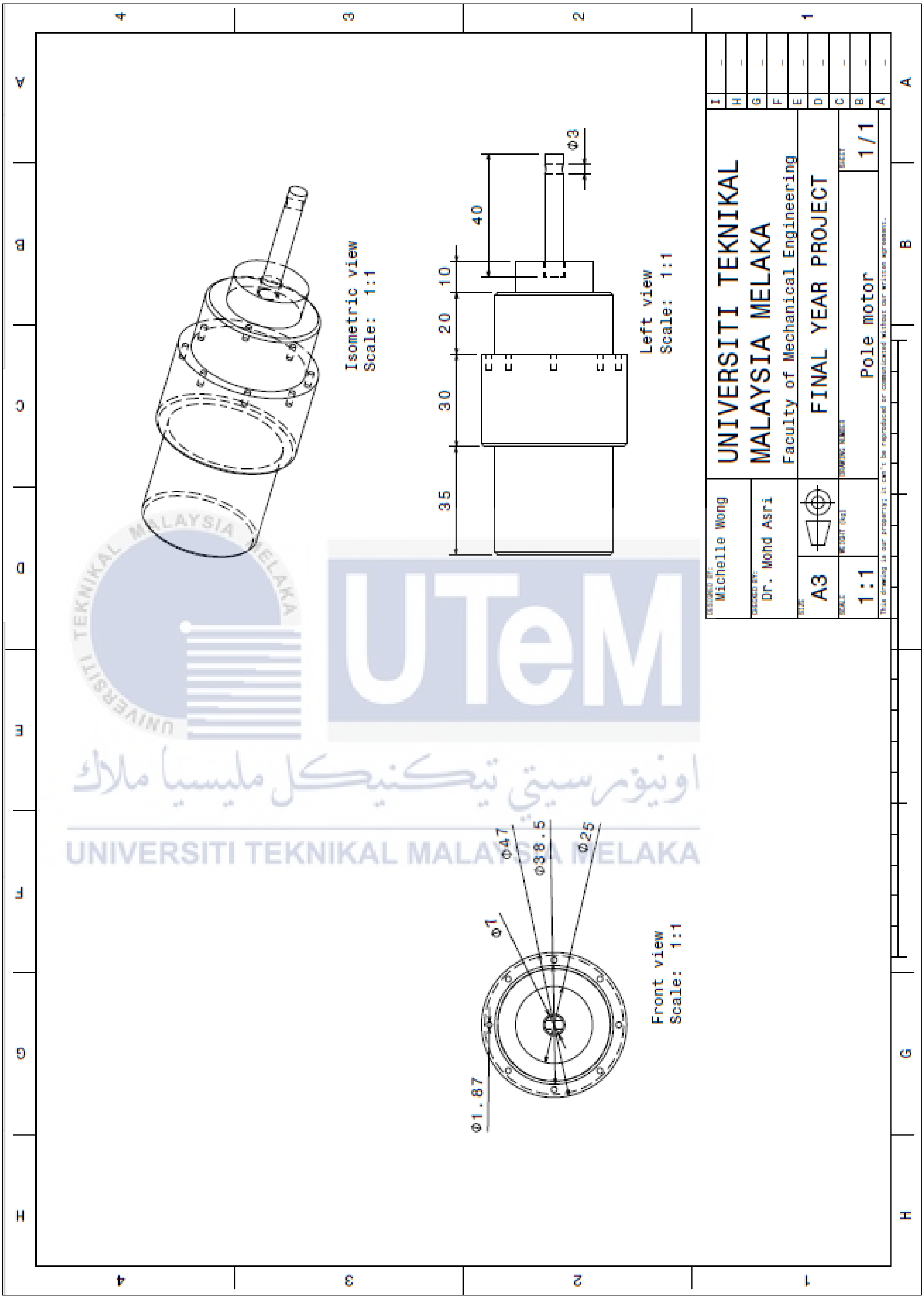
Appendix B31



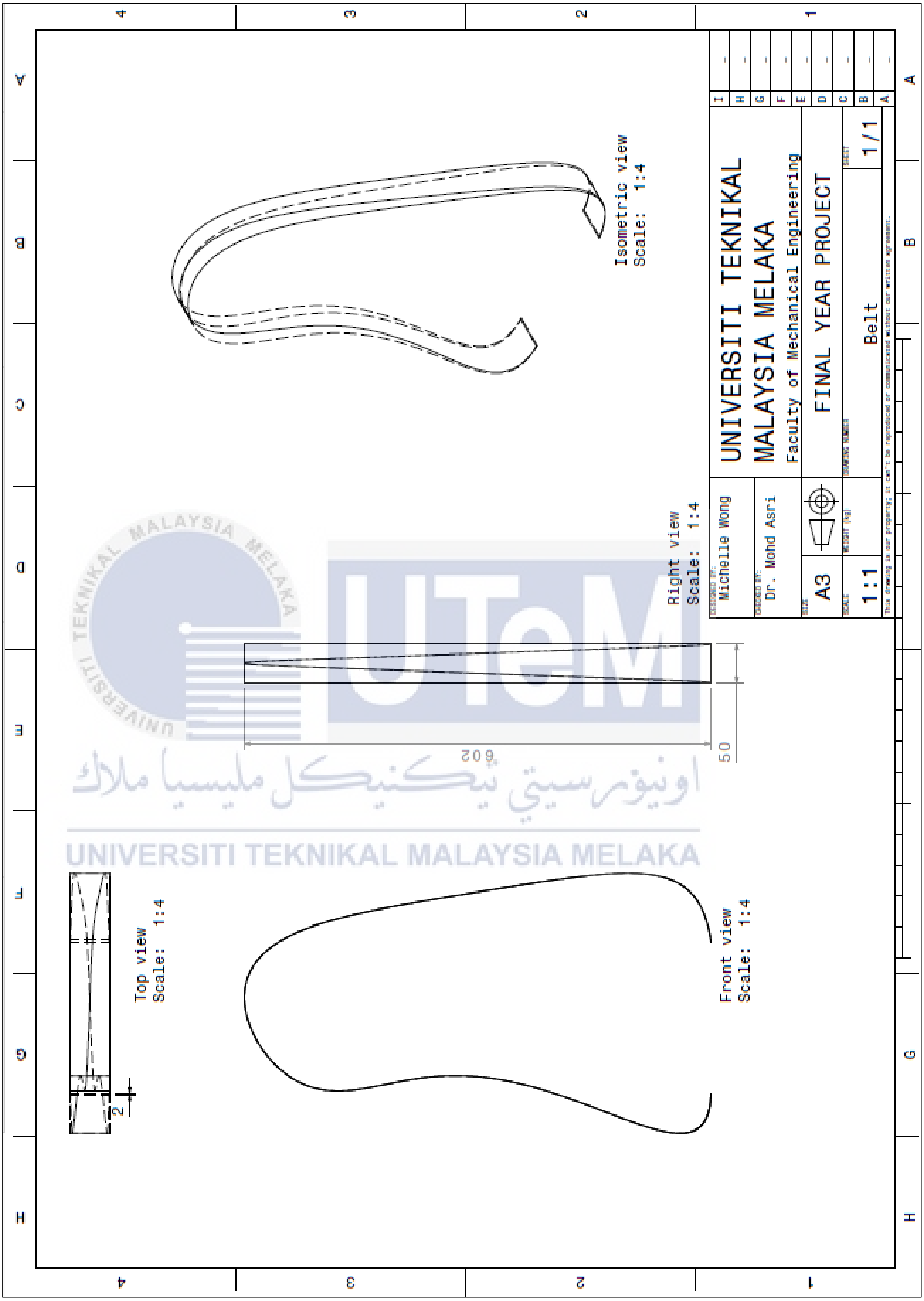
Appendix B32



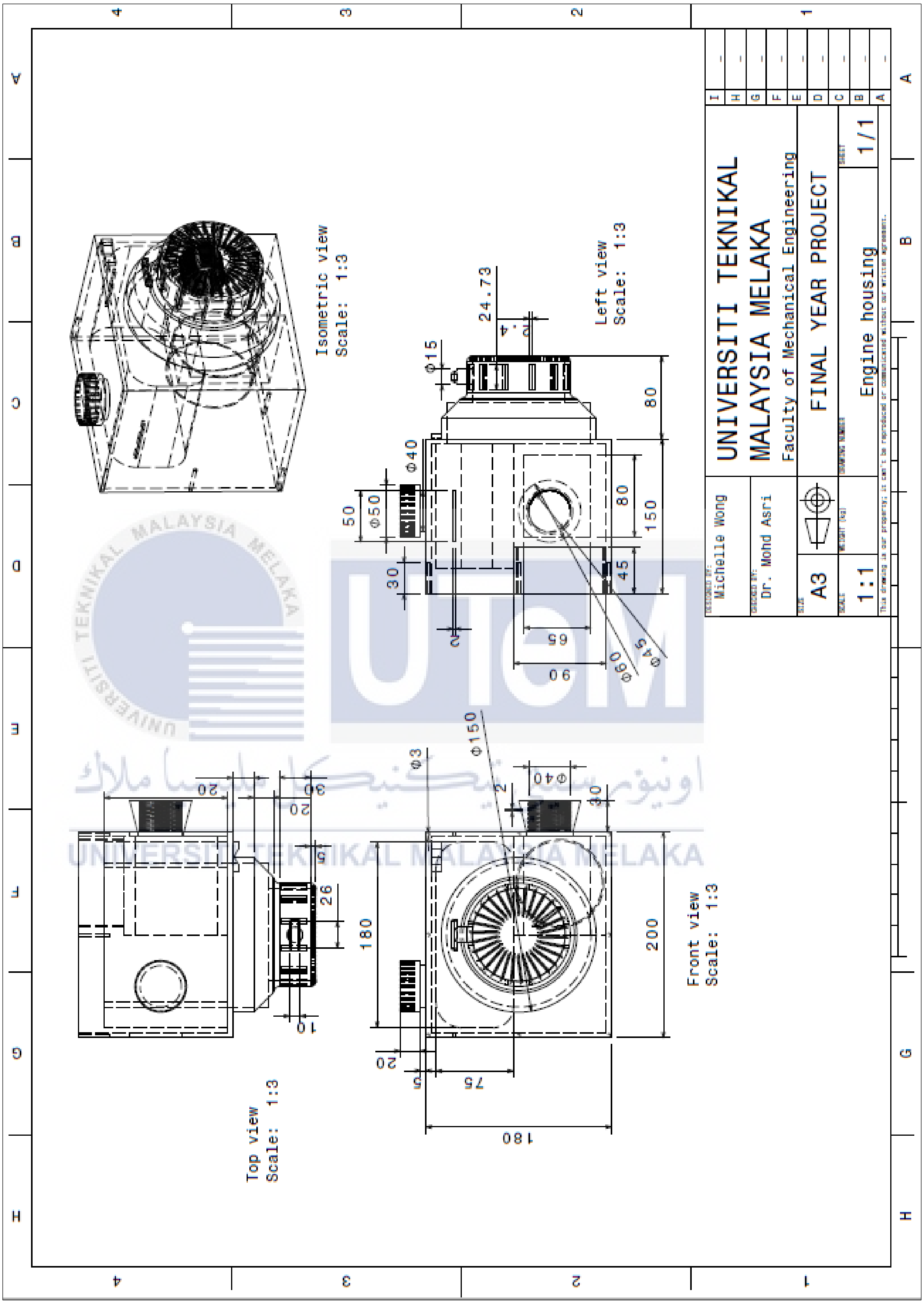
Appendix B33



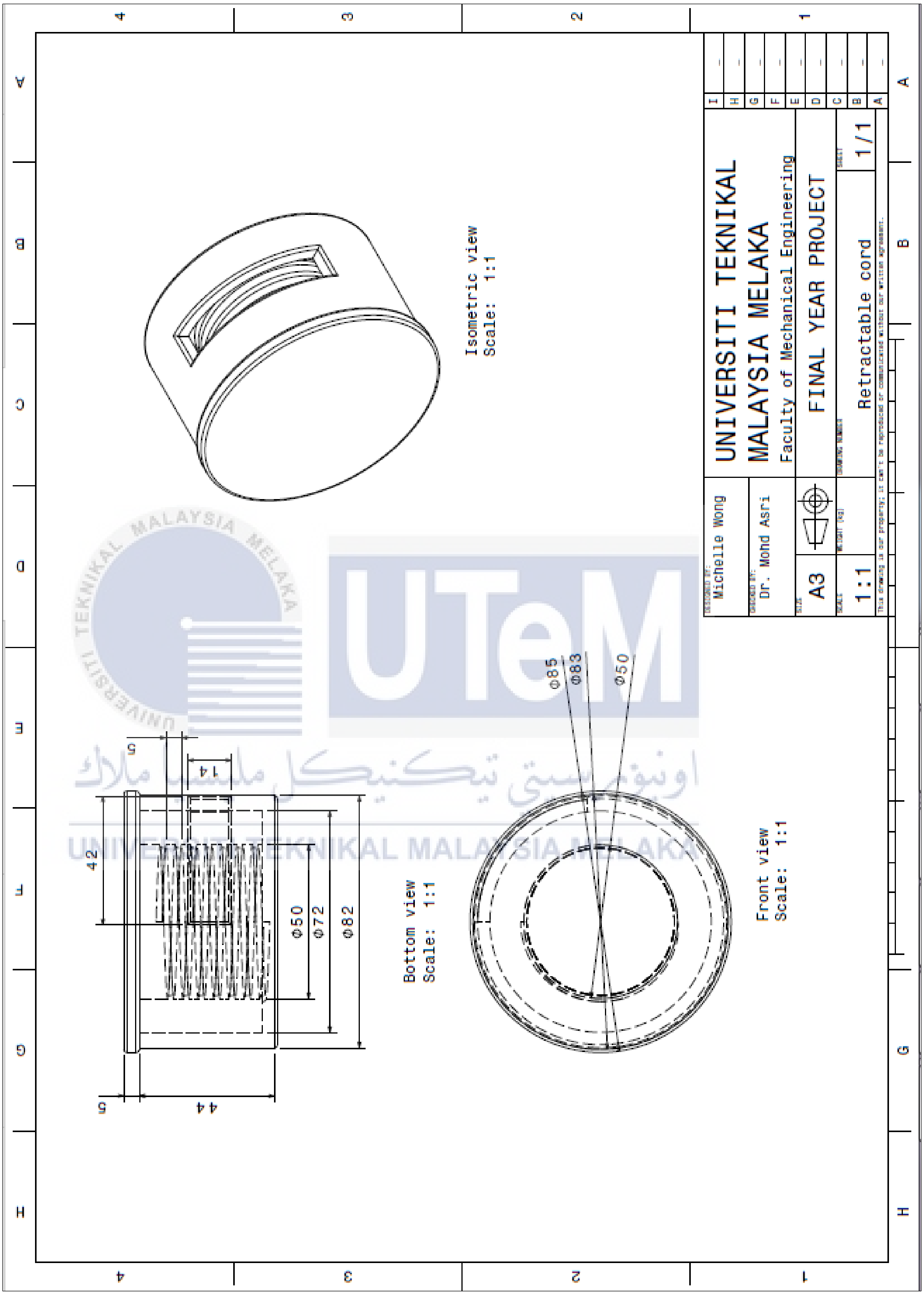
Appendix B34



Appendix B35



Appendix B36



Appendix B37