DESIGN AND FABRICATION OF TENSILE TEST SPECIMEN CUTTING EQUIPMENT FOR ELASTOMER COMPATIBILITY STUDY SUBJECTED TO PALM-OIL BASED BIODIESEL

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A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering with Honours

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this thesis entitled "DESIGN AND FABRICATION OF TENSILE TEST SPECIMEN CUTTING EQUIPMENT FOR ELASTOMER COMPATIBILITY STUDY SUBJECTED TO PALM-OIL BASED BIODIESEL" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : --

Name : --

Date : --

APPROVAL

I hereby declare that I have checked this report entitled “DESIGN AND FABRICATION OF TENSILE TEST SPECIMEN CUTTING EQUIPMENT FOR ELASTOMER COMPATIBILITY STUDY SUBJECTED TO PALM-OIL BASED BIODIESEL” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechanical Engineering with Honours

Signature :

Supervisor Name :

Date :

DEDICATIONS

To my beloved mother and father

ABSTRACT

Elastomer is a natural or synthetic polymer having elastic properties and the main components for the fuel delivery system. It can undergo degradation of their physical properties when directly contact with biodiesel. The specimen of elastomer need to be prepare first before proceed with the experiment. However, the tensile test specimen cutting equipment in the market are expensive, heavy and consume more time for shipment. Thus, to overcome this problem, the tensile test specimen cutting equipment has been invented. This machine are mini in size, portable, durable and consume reasonable costs. The purpose of this study is to develop conceptual and detail design of tensile test specimen cutting equipment and to fabricate the prototype of tensile test specimen cutting equipment. Literature review must be done to make sure the specimen need to cut according to ASTM D412-06 standard to ensure the test is valid. The design process planning are needed to identify, search and assemble all the information related in product design specification. From the morphological chart, few conceptual designs were made and evaluated using Pugh concept selection method to obtain the final design. The final design is then modeled by using Solidworks. The functionality of the 3D model was analysed using finite element analysis. The purpose of this analysis was to determine the product's strength and define the critical stress area so that design improvements can be made to achieve a safety factor of more than one for the entire model. Then further process of fabrication was executed.

ABSTRAK

Elastomer adalah polimer semula jadi atau sintetik yang mempunyai sifat elastik dan komponen utama untuk sistem penghantaran bahan bakar. Ia boleh mengalami penurunan sifat fizikal mereka ketika bersentuhan langsung dengan biodiesel. Spesimen elastomer perlu disediakan terlebih dahulu sebelum meneruskan eksperimen. Walau bagaimanapun, alat pemotong spesimen ujian tegangan di pasaran mahal, berat dan memakan lebih banyak masa untuk penghantaran. Oleh itu, untuk mengatasi masalah ini, alat pemotong spesimen ujian tegangan telah dicipta. Mesin ini bersaiz mini, mudah alih, tahan lama dan memakan kos yang berpatutan. Tujuan kajian ini adalah untuk mengembangkan reka bentuk konseptual dan terperinci alat pemotong spesimen ujian tegangan dan membuat prototaip alat pemotong spesimen ujian tegangan. Kajian literatur mesti dilakukan untuk memastikan spesimen perlu dipotong mengikut piawaian ASTM D412-06 untuk memastikan ujian itu sah. Perancangan proses reka bentuk diperlukan untuk mengenal pasti, mencari dan mengumpulkan semua maklumat yang berkaitan dengan spesifikasi reka bentuk produk. Dari carta morfologi, beberapa reka bentuk konseptual dihasilkan dan dinilai menggunakan kaedah pemilihan konsep Pugh untuk mendapatkan reka bentuk akhir. Reka bentuk terakhir kemudian dimodelkan dengan menggunakan Solidworks. Fungsi model 3D dianalisis menggunakan analisis unsur terhingga. Tujuan analisis ini adalah untuk menentukan kekuatan produk dan menentukan kawasan tekanan kritikal sehingga penambahbaikan reka bentuk dapat dilakukan untuk mencapai faktor keselamatan lebih dari satu untuk keseluruhan model. Kemudian proses fabrikasi selanjutnya dilakukan.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to Allah S.W.T., I am able to complete my Final Year Project with His blessing. It is a great opportunity to carry out this Final Year Project as I have learned a lot of new things.

My deep appreciation goes to my supervisor Ts. Dr. Muhd Ridzuan bin Mansor from Fakulti Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka (UTeM) for his ideas, advices, giving guidance and encouragement to conduct this research under her supervision. I am very grateful to have a supervisor such as Ts. Dr. Muhd Ridzuan Bin Mansor that has been very helpful to me, not just for current work, but also for my future career, for her patient guidance, enthusiastic encouragement and useful guidance throughout the whole project.

Special thanks to Fakulti Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka (UTeM) for the technical assistance provided, and the Malaysian Palm Oil Board under MPOB/2019/FKM-CARE/G0006----6 grant for the financial support in completing this project.

Special thanks to my family, especially my mother. I am indebted to my mother, Puan Norihan binti Mohd Noor for her tirelessness in raising me to be a successful person and for helping me by giving support and motivation. The project would not have been the same as described here without their ongoing support and involvement and also for the love that has no end of it.

Also, to my dearest friends for the immense moral support throughout my study here and not to be forgotten, to all the staff at university who were always helpful when I needed it.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
NBR	-	Nitrile Rubber
FAME	-	Fatty acid methyl ester
CAD	-	Computer Aided Design
UTM	-	Universal Testing Machine
IIR	-	Isobutylene-Isoprene Rubber
EPDM	-	Ethylene propylene diene monomer rubber
NR	-	Natural rubber
CR	-	Chloroprene Rubber
NBR	-	Nitrile butadiene rubber
Si	-	Silicone
MCO	-	Movement Control Order
Covid-19	-	Coronavirus disease 2019
FAEE	-	Fatty acid ethyl ester
HNBR	-	Hydrogenated nitrile butadiene rubber
FKM	-	Fluoroelastomer
PVC	-	Polyvinyl Chloride
FEA	-	Finite Element Analysis

CHAPTER 1

INTRODUCTION

1.1 Background

Biodiesel which is most often used as a blend with petroleum diesel fuel, can be used in many diesel vehicles without any engine modification because biodiesel shares same properties with diesel fuel. In addition, biodiesel also is renewable energy that will reduce the emission air pollution.

Elastomer is a natural or synthetic polymer having elastic properties for example, rubber. Elastomers as one of the most important groups of materials, used in fuel systems are of particular concern (Thomas, Fuller, Terauchi, & C, 2013). This is because the elastomers are vulnerable attack by various chemicals and can undergo degradation of their physical properties band stability (Mitra et al., 2006). The major concern for the biodiesel is that it may affect the elastomer which is the main components for the fuel delivery system. The fuel delivery system in a diesel engine is as shown in Figure 1.1.

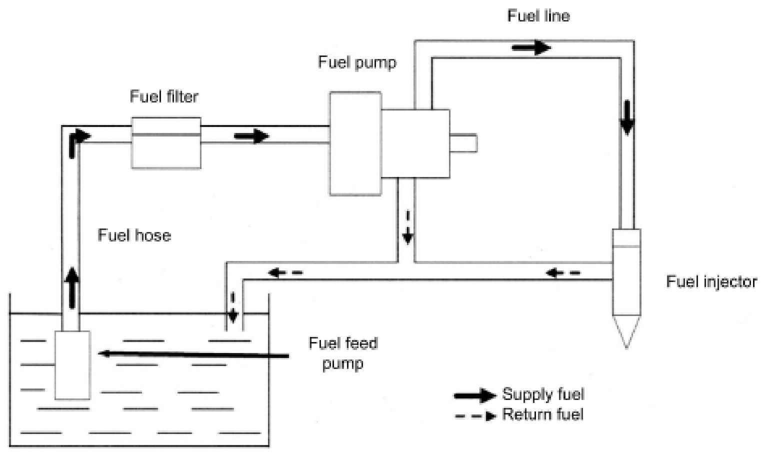


Figure 1.1: Fuel delivery system in a typical diesel engine (Chandran et al., 2016)

The fuel is stored in the fuel tank and the fuel pump draws fuel from the tank. It then travels through the fuel lines in order to support the combustion in the engine. This fuel lines are usually made of a few types of materials which are mainly from elastomer. The most common elastomer to be used in the engine is fluoropolymer elastomer (Chandran et al., 2018). The degradation will happen on the elastomer due to the chemical properties of biodiesel. This will cause the elastomer to be further degraded as the usage time increases. The elastomer hose in fuel line is considered as the specimen to be tested.

However, before the specimen need to be test, specimen need to be cut with specific size and cutting equipment. It is because the facilities do not have convenient cutting equipment for exact size of specimen. Thus, the cutting work done by previous researcher will use drawing of size specimen on a piece of paper and scissor to cut the specimen. As a result, there will be irregular shape and incorrect size of specimen are produced. Hence, design and fabrication of tensile test specimen cutting equipment for elastomer compatibility study subjected to palm-oil based biodiesel.

1.2 Problem statement

The dumbbell sample cutter for tensile test can be bought on the internet. It cannot be denied the dumbbell sample cutter for tensile test that bought on the internet is effective and give an accurate size with minimal error on the specimen. However, it is quite expensive and heavy. As a result of expensive price, previous researcher decided to cut it with scissor. It is also taken time to ship out the machine to the customer due to the machine was manufactured in another country. Figure 1.2 shows the dumbbell sample cutter for tensile test on the Alibaba.com website with price RM3467.20 - RM4334.00.

Figure 1.2: The dumbbell sample cutter for tensile test on the Alibaba.com website

Therefore, in this study will be done in order to design and fabricate cutting equipment for tensile test that can cutting the elastomer into desired size of specimen with minimal cost. This is important to produce first prototype so it can be improved in near the future.

1.3 Objectives of study

From the following problem stated in Section 1.2, this study is done in order to determine the solution of the problem. The objective of this study are as follows:

i. To develop conceptual and detail design of tensile test specimen cutting equipment.
ii. To fabricate the prototype of tensile test specimen cutting equipment.

1.4 Scopes of study

The outlined scope of this study are:-

i. To conduct literature review on existing dumbbell shape sample cutter in the market.
ii. To develop product design specifications for the dumbbell shape sample cutter machine.
iii. To develop new conceptual designs and select best conceptual design of the dumbbell shape sample cutter machine.
iv. To develop detail design of the dumbbell shape cutter machine including 3D CAD model, 2D detail drawings and Bill of Materials (BOM).
v. To perform structural analysis on selected critical components of the dumbbell shape cutter machine using FEA software.
vi. To purchase raw materials and components.
vii. To fabricate customized part and assemble the new dumbbell shape cutter machine prototype.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Nowadays, the quantity of fossil fuel, petroleum and coal are going decreasing and it is very important to make sure that the source of natural resources can be preserved. Coal and petroleum are called non-renewable resources because they cannot be formed quickly. They take a lot of time to form. They take even millions and billions of years to be formed. So, coal cannot be replenished within a given time. Resource of economic value that cannot be readily replaced by natural means at a quick enough pace to keep up with consumption. Therefore, it is considered to be non-renewable resources.

The diesel is one of the largest contributors to environmental pollution problems worldwide, and will remain so, with large increases expected in vehicle population causing ever-increasing global emissions. Diesel emissions contribute to the development of cancer, cardiovascular and respiratory health effects, pollution of air, water, and reductions in visibility.

The tension triangle provides more clarity on the tensions and relationships between fossil fuel derived equation use, climate change mitigation and well-being attainment and illustrating how fossil fuel derived energy use, well-being attainment, and climate change mitigation sit in tension to one another. The form of a triangle is shown in Figure 2.1. At each point on the triangle sits a process; fossil fuel derived equation use, well-being attainment or climate change mitigation, with each process sitting in relation to the adjacent processes. The negative relationship between fossil fuel derived equation use and well-being is climate change. It is well proven that the combustion fossil fuels and the greenhouse gas emissions, are the largest contributor to continuing climate change. Climate change continues to have well-being impacts throughout the globe including an increased frequency of severe weather events, disrupted weather cycles, and irreversible damage to provisioning ecosystems (Wood & Roelich, 2019).

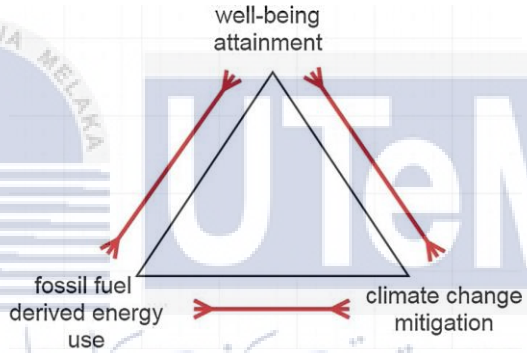


Figure 2.1: ‘The Tension Triangle’ (Wood & Roelich, 2019)

The focus of this study is to conduct experiment of elastomer tests soaked in B10 and B30 biodiesel to check the elastomer's mechanical-physical properties. The measurements were soaking test, mass test, hardness test and tensile test. This chapter discusses about the introduction, explanation of the equipment, testing method and materials used from other journal that is related to this study.

2.2 Biodiesel

Heavy vehicles such as lorry, busses, and trailer trucks typically use diesel as the power source to move the vehicles. Pure diesel has a lot of dangerous effects that can harm the environment. Moreover, diesel emissions contain numerous other compounds that are present in diesel emissions in smaller quantities, but still may be posing health threat to humans. The alternative fuels have been introduced to reduce the pollution. Some well-known alternative fuels include biodiesel, bio-alcohol (methanol, ethanol, butane), refuse-derived fuel, chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, propane and other biomass sources. The spotlight for this project is on biodiesel. Biodiesels are obtained from renewable resources and are biodegradable. Biodiesels also generate cleaner engine emissions, and offer superior lubrication (Boz et al., 2017)

Biodiesel is used as a fuel for hybrid electric vehicle. Therefore, two advantages could be obtained which are reducing the exhaust emission using the cottonseed oil as an alternative biodiesel fuel and improving the fuel economy (Mourad et al., 2014). Biodiesel usage has an effect that leads to a good potential and environmentally friendly solution to reduce the overreliance on the energy import. Biodiesel known as an alternative to diesel fuel produced by transesterification of vegetable oils or animal fats (Haseeb et al., 2010; Mourad et al., 2014). Biodiesel blend can be used in the diesel engine directly when mixed with diesel because it has the same physical properties of diesel fuel (Kumar et al., 2018).

The studies of many researchers on the study of vegetable oils on their properties and their impact on engine performance and exhaust emissions were well recorded. The particulate emissions were consistently reduced with increasing quantity of oxygen added, particulate emission reduction was not linear with oxygen content and additional oxygen resulted in diminished particulate matter emissions reduction (Guan et al., 2017). According to Lapuerta et al., (2008), biodiesel oxygen content could not lead to an increase in NOx formation as the combustion flow occurs in the oxygen-fuel region around the stoichiometric region, which is normally around 3.58 for standard diesel fuel and 2.81 for typical biodiesel fuels. The use of biodiesel results in lower particulate emissions, unburned hydrocarbons and carbon monoxide than diesel (Lapuerta et al., 2008; Silva et al., 2017).

2.2.1 Production of biodiesel

Biodiesel is produced by four basic methods that include blending with diesel, micro-emulsion, thermal cracking, and transesterification. It is an esterification reaction between an alcohol and the fatty acids abundant in the lipid feedstock. If methanol is used the product is FAME (fatty acid methyl esters) (Metawea et al., 2018). Biodiesel is intended to be used as a replacement for petroleum diesel fuel or can be blended with petroleum diesel fuel in any proportion. There is some requirement in order to be called biodiesel and receive certain tax credits specifically intended for biodiesel which are biodiesel must be produced from naturally occurring fats and oils using transesterification. Second, biodiesel must be composed of fatty acid methyl esters. Third, biodiesel must be refined to remove all trace impurities. Lastly, biodiesel must meet the ASTM standard D6751-07B “Specification for Biodiesel (B100)” (Pacific Biodiesel, 2013).

The purpose of transesterification process is to decrease the viscosity of the vegetable oil from $40mm^2s^{-1}$ into lower viscosity approximately about $5mm^2s^{-1}$ which is said to be suitable for use in diesel engine because biodiesel is becoming an important alternative fuel in the global fuel market due to factors such as declining air quality (Chandran et al., 2016).

2.2.2 Transesterification process

The most common process used in biodiesel production is transesterification, where the triglycerides in the oil react with alcohol to form mono-alkyl ester (biodiesel), with glycerol as the by-product (Chyuan & Silitonga, 2019). To be specific, triglycerides react with alcohols mainly methanol or ethanol and add catalyst to generate biodiesel and glycerol by-product in a transesterification reaction is shown in Figure 2.2.

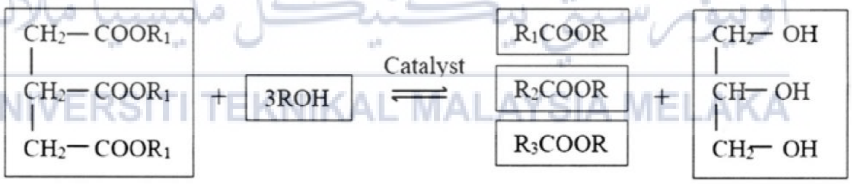


Figure 2.2: Transesterification process for biodiesel production from vegetable oil (Chandran et al., 2016).

When methanol (CH_3OH) is used, the biodiesel product will be fatty acid methyl ester (FAME). On the other hand, fatty acid ethyl ester (FAEE) is obtained when ethanol (C_2H_5OH) is used. Generally, methanol was used as a reagent for biodiesel production through transesterification reaction due to its suitable physicochemical properties, mild reaction conditions and easy phase separation.

However, the use of methanol also causes many problems such as toxicity, low boiling point, and corrosion of the reactor. On the other hand, ethanol was more frequently used as a reagent for the biodiesel synthesis because it is generally less toxic than that of methanol and ethanol can improve biodiesel production as the mixing between ethanol and oils (Roschat et al., 2018).

2.2.3 Type of biodiesel

Several nations have been looking for alternative energy sources to replace petroleum due to the unstable oil price situation on the world market. Vegetable oil is one of the alternatives that can be used in automotive engines, either as straight vegetable oil or as ethyl or methyl ester. Some of the biodiesel is made of cooking oil, soybean oil, rapeseed oil, palm oil, and jatropha oil. It is because all the above-mentioned vegetable biodiesel has almost the same properties as diesel. The properties of the vegetable biodiesel are shown in Table 2.1.

Table 2.1: Biodiesel properties of palm oil, jatropha, rapeseed and soybeans (Sisbudi, 2011)

Property	Palm Oil	Jatropha curcas	Rapeseed	Soybean	Fossil fuel	Biodiesel standard	
						Value	Method
Calorific value ($MJkg^{-1}$)	-	39.23	36.90	-	42	38.3	-
Pour point (°C)	-	20	-	-	-	>18	ASTM D 2500
Flash point (°C)	190	135	175	174	>68	>100	ASTM D 93
Density (kgm^{-3})	-	880	920	-	840	850-900	ASTM D 1298
Viscosity (mm^2s^{-1})	-	4.8	4.5	-	2.6	2.3-2.6	ASTM D 445
Cetane number	42	-	46	37.9	-	<51	ASTM D 613
Ash content (%)	-	0.20	0.01	-	0.17	<0.02	ASTM D 874
Water content (%)	-	0.073	0.075	-	<0.02	<0.05	ASTM D 2709
Acid value ($mgKOHg^{-1}$)	-	0.40	-	-	<0.08	<0.08	AOCS Cal 2-55
Carbon residue (%)	-	0.20	-	-	0.17	<0.30	-

Remark:

1. Calorific value, heat of combustion – Heating value or heat of combustion, is the amount of heating energy released by the combustion of a unit value of fuels.

2. Pour (melt) point – Melt or pour point refers to the temperature at which the oil in solid form starts to melt or pour. In cases where the temperature falls below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated.

3. Flash point (FP) – the flash point temperature of diesel fuel is the minimum temperature at which fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of diesel fuel.

4. Density – Is the weight per unit volume. Oils that are denser contain more energy. For example, petrol and diesel fuels give comparable energy by weight, but diesel is denser and hence gives more energy per liter.

5. Viscosity – Viscosity refers to the thickness of the oil and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specific size. Viscosity affects injector lubrication and fuel atomization. Fuel with low viscosity may not provide sufficient lubrication for the precision fit od fuel injection pumps, resulting in a leakage or increased wear.

6. Cetane number (CN) – Is a relative measure of the interval between the beginning of injection and auto-ignition of the fuel. Just as octane number determine the quality and value of gasoline (petrol). The higher the cetane number, the shorter the delay interval and the greater its combustibility. Fuels with low cetane numbers will result in difficult starting, noise, and exhaust smoke. In general, diesel engines will operate better on fuels with cetane numbers above 50.

7. Ash percentage – Ash is a measure of the amount of metals contained in the fuel. High concentrations of these materials can cause injector tip plugging, combustion deposits and injection system wear. The ash content is important for heating value, as heating value decreases with increasing ash content.

8. Sulfur percentage – The percentage by weight, of sulfur in the fuel sulfur content is limited by law to very small percentages for diesel fuel used in on-road applications.

Biodiesel can be blended and used in many different concentrations that indicated the percentage of the biodiesel in the fuel. This is indicated by the volume ratio of the biodiesel in the fuel. For example B5, it has 5 vol% of biodiesels mixed with 95% diesel, B10 has 10 vol% of biodiesel with 90 vol% of diesel, B20 has 20 vol% of biodiesel mixed with 80 vol% diesel, and B50 has 50 vol% of biodiesel mixed with 50 vol% of diesel. B0, the fuel is known as pure diesel because it has 0 vol% of biodiesel. This fuel has 100 vol% diesel without any mixing with the biodiesel which is why it is known as pure diesel (Fazal et al., 2019). It is rarely used as a transportation fuel.

Nevertheless, the use of incompatible fuel could accelerate the process of degradation, leading to significant early failure. This can be seen in the form of seal breakage and rupture of the tube, resulting in fuel leakage and compression loss (Chandran et al., 2016). Hence, until recently, only fuel that has a maximum concentration level of 20 vol% of biodiesel with 80 vol% diesel (B20) is permitted to be used (Chandran et al., 2018).

2.3 Elastomer

Elastomers as one of the most important groups of materials, used in fuel system are of particular concern. This is because the elastomers are vulnerable attack by various chemicals and can undergo degradation of their physical properties and stability (Haseeb, Jun, Fazal, & Masjuki, 2011). Elastomer is any material such as natural or synthetic rubber that are capable to return to its original shape after a force that is deforming removed from the material (Elastomer definition and meaning, 2018).

Elastomer is composed of long chainlike molecules, or polymers and it can recover their original shape after being stretched to great extents. Therefore, the name is derived from elastic polymer. Without any force applied, the condition is called normal conditions. During this condition, the long chain of molecules is coiled irregularly. This is because there is no force applied on the elastomer and the molecules are arranged in a random configuration. As the force is applied to the materials, the molecules will straighten out in the direction it is being pulled. This will also cause the molecules to stretch according to the direction of the force applied onto the elastomer while it is being stretched. Spontaneously, when the force is released, the molecules return to their normal compact and random arrangement (Gent et al., 2016). Therefore, elastomer can be stretched and turns back to its original position and having elastic properties. However, if the force applied is too big and the molecules cannot withstand the tensile force applied, it will snap into two pieces, causing the failure to occur.

2.3.1 Types of elastomer

There are many types of elastomers available on the market such as Butyl (IIR), EPDM, Natural Rubber (NR), Neoprene (CR), Nitrile (NBR), Polyisoprene (IR), SBR, and Silicone (Si). These materials are commonly used in the fuel systems (Mitra et al., 2006). In this project, the type of elastomer used is Nitrile Rubber (NBR).

2.3.2 Properties of elastomer

Every different type of elastomers mentioned in Section 2.3.1 has different properties of the elastomers. Each type of elastomer has their properties that can withstand certain condition based on the application of the elastomer. For each type, the properties are shown in Table 2.2.

Table 2.2: Properties of elastomer (Properties of Elastomer - Rubber Compounding, 2018).

Common Name	**Designation**	**Composition**	**General Properties**	**General chemical resistance**	
				Resistant to:	**Attacked by:**
Butyl	IIR	Isobutyleneiso prene	• Very good weathering resistance. • Excellent dielectric properties. • Low permeability to air. • Good flex properties. • Poor resistance to petroleum based fluids.	Animal and vegetable fats, oils, greases, oxygenated solvents, alkalis, ozone, strong and oxidizing chemicals, silicone fluids and greases, ammonia, phosphate ester type hydraulic fluids.	Petroleum oils, fluids and solvents, coal, tar and diester based lubricants and solvents; aliphatic and aromatic hydrocarbon s
EPDM	EPDM, EPM	Ethylene Propylene Diene Modified	• Excellent ozone • Chemical • Weather • UV • Aging resistance • Poor resistance to petroleum based fluids	Animal and vegetable oils, ozone, strong and oxidizing chemicals, alkalis, brake fluids, phosphate ester type hydraulic fluids	Mineral oils and solvents; petroleum oils, fluids, or solvents; aliphatic and aromatic hydrocarbons

Common Name	Designation	Composition	General Properties	General chemical resistance	
				Resistant to:	Attacked by:
Neoprene	CR	Chloroprene	• Good weathering resistance, resilience, and abration strength • Flame retarding • Moderate resistance to petroleum based fluids		
Natural Rubber	NR	Isoprene, natural	• Excellent physical properties including abrasion and low temperature resistance. • Poor resistance to petroleum based fluids	Most moderate chemicals, wet or dry organic acids, alcohols, ketones, aldehydes	Ozone, strong acids, oils, fuels, solvents, petroleum derivatives, hydraulic fluids, greases, most hydrocarbons

2.3.3 Effect of biodiesel on elastomer

There are a few effects that can be caused by the usage of biodiesel on elastomer. One of the changes is change in volume and mass of elastomer on the usage of biodiesel compared to what is caused by diesel. Biodiesel and its blends cause a greater swelling of CR and NBR compared with that caused by diesel. It is observed that the compatibility, in terms of changes in weight and volumes, for both EPDM and SR are higher in biodiesel as compared to that in diesel. Instead, CR and NBR are less compatible with biodiesel (Haseeb et al., 2011).

The use of a biodiesel that has a high kinematic viscosity may lead to poor atomisation during fuel spraying and result in engine deposits and wear in the fuel system components, in addition to increasing the required energy for fuel pumping. Furthermore, the acid value of the blended biodiesel diesel fuel decreases with the increasing diesel fuel ratio in the blend, indicating that mineral diesel acts as diluent for palm oil methyl ester (Ali et al., 2015).

The methyl ester groups which make up biodiesel are known to be more polar than petroleum diesel. As a result, biodiesel is likely to cause higher swelling in polymers, many of which have moderate to high polarity. For polymers compatibility generally refers to the level of swelling induced by the fluid (or solvent). Because polymers, especially elastomers, are used universally in fuel storage and distributing systems as hoses and seals, it is important to understand their compatibility with fuel chemistries to prevent failure and leakage. For NBR, the addition of formic acid to biodiesel caused a significant increase in the measured volume (Kass et al., 2018).

It was found that fuel delivery materials degradation factors such as the presence of oxidized biodiesel, total acid number and water content were unaffected under common rail diesel engine operation. In contrast, dissolved oxygen concentration and conductivity changed significantly under common rail diesel engine operation, and conductivity was shown to be positively correlated to the deterioration level of biodiesel (Chandran et al., 2016).

Table 2.3 shows the summary of research works about effect biodiesel to the physical and mechanical properties of elastomer.

Table 2.3: Summary on effect of biodiesel to the physical and mechanical properties of elastomer.

Author	Biodiesel type	Blend	Effect to physical properties
Haseeb et al. (2011)	Diesel and palm biodiesel	B10, B20, B50 and B100	• Biodiesel and its blends cause a greater swelling of CR and NBR compared with that caused by diesel. On the other hand, EPDM and SR swelled to a greater extent in diesel compared with that in biodiesel and its blends. • PTFE showed a reduction in volume with an increase in the concentration of biodiesel. • Changes in weight and volumes, for both EPDM and SR are higher in biodiesel as compared to that in diesel. On the other hand, CR and NBR are less compatible with biodiesel. • tensile strength values are decreased to a greater extent for EPDM, CR, NBR than SR and PTFE elastomers.
Ali et al. (2015)	Palm oil biodiesel	B10, B20, B30, B40, B50	• High biodiesel fuel density can influence the engine power output due to the difference in fuel injected mass. • High kinematic viscosity may lead to poor atomisation during fuel spraying and result in engine deposits and wear in the fuel system components. • The acid value of the blended biodiesel diesel fuel decreases with the increasing diesel fuel ratio in the blend.

Author	Biodiesel type	Blend	Effect to physical properties
Kass et al. (2018)	Diesel and palm oi biodiesel	B0, B5, B10, B15, B20	• NBRs having 20% acrylonitrile have the highest solubility (swell). • For each NBR, the addition of formic acid to biodiesel caused a significant increase in the measured volume.
Chandran et al. (2016)	Palm oil biodiesel	B10, B20, B50, B100	• The copper corrosion rate and NBR volume change increased by 9% and 13%. • Due to 96% reduction in biodiesel dissolved oxygen concentration, the copper corrosion rate and NBR volume swelling reduced by 91% and 27%, respectively. • copper corrosion and NBR volume change underwent higher degradation by 62% and 8%, respectively due to biodiesel exposure under modified immersions at 25 °C. • Copper corrosion and NBR degradation were lowered by up to 93% and 85%, respectively, under modified immersion as compared to standard immersion. • Under standard immersions, the copper corrosion rate and NBR volume change increased by 9% and 13%, respectively.
Trakarnpruk et al. (2008)	Palm oil biodiesel	B10	• Hydrogenated nitrile butadiene rubber (HNBR), acrylic rubber, co-polymer fluoroelastomer (FKM), and terpolymer FKM mass and volume increased with respect to time for all test samples except NBR and NBR/ PVC. • NBR and NBR/PVC mass and volume were decreased with time.
Haseeb et al. (2010)	Palm oil biodiesel	B0, B10, B100	• Nitrile rubber and polychloroprene swelled and degraded in biodiesel. • The mass and volume of fluoro-viton A remained almost unchanged in biodiesel.

			• Swelling increased with increase in biodiesel content in the fuel. • Increasing temperature had varying effect on elastomers. While increased swelling was observed in nitrile rubber, decreased swelling was observed in polychloroprene and almost no change was observed in fluoroviton A at 50 ◦C. • A decrease in tensile strength was observed in nitrile rubber and polychloroprene. However, no change in tensile strength was observed in fluoro-viton.
Alves et al. (2013)	Biodiesel of palm and soybean oil	B0, B5, B20, B100	• Increase of biodiesel concentration it was possible an increase in the weight of NBR for both biodiesels (soybean and palm), while for FKM this behaviour was lighter; these weight changes were kept almost constant for all fuels. • NBR elastomer changes in weight are higher in biodiesel (B100) when compared to those in diesel (B0). • The different biodiesels of different sources (soybean and palm oils) that show the same behavior of swelling, so it can conclude that little differences in raw oil composition and consequently biodiesel composition do not affect the swelling ability of elastomers. • NBR proved susceptible to biodiesel, increasing the biodiesel concentration the weight change increases. • FKM has good compatibility, in terms of mass loss, with diesel and biodiesel. • NBR was less compatible with biodiesel. The results indicated high NBR mass loss for B100 in both biodiesels. However, this result is more significant for soybean oil biofuel.

Chai et al. (2011)	Palm oil biodiesel	B0, B25, B75, B100	• The swelling in rubbers increases with the increase of palm biodiesel content and decreases with the increase of pre-compressive strain. Also, it was observed that the presence of biodiesel significantly reduces the mechanical strength of the rubber. • The fuel uptake is affected by the compression with compressive stress leads to a decrease in the swelling of elastomer. • Both NBR and CR show increase in mass and volume change when the exposure time is increased from 30 days to 90 days. Swelling began with absorption of liquid into the surface layer of the rubber (adsorption) until a certain concentration and was followed by further penetration of liquid into the rubber by diffusion until the sample achieved equilibrium swelling. • The swelling in rubbers increases with the increase of palm biodiesel content and decreases with the increase of pre-compressive strain. The
Coronado et al. (2014)	Waste vegetable oil biodiesel	B5, B10, B20	• Mass change depended on biodiesel concentration: higher the biodiesel content, higher the mass change. • Elastomers when immersed in a solvent like biodiesel tend to swell or degrade. • It could be suggested to use B5 blends or even lower in contact with nitrile rubber based materials, but in case of higher blend levels, it will be imperative a change of material.

Loo et al. (2015)	Palm biodiesel and conventional diesel	B0, B100	• The decrease in hardness for swollen B100 nitrile rubber was slightly higher than swollen B0 while the decrease in mass for both is comparable. • The exposure of nitrile rubber to solvents leads to a decrease in the hardness. • The mechanical loading magnifies the effect of swelling instead of depreciating the hardness of rubber. Since mechanical loading does not induce any additional swelling, the chain scission mechanism seems to be the main rea- son for the declining values of hardness. • The uniaxial cyclic test have shown that the swollen B100 F-NBR attained higher stress levels than the swollen B0 at a given value of swelling.
Sorate et al. (2015)	Free fatty acid biodiesel and diesel	B100	• Natural rubber, nylon and EPDM showed an increase in weight, and • exception being natural rubber immersed in diesel, which showed 3.4% loss of weight. EPDM showed the greatest weight change among the three specimens, the change being around 123%. • In all the three elastomers, in both diesel and biodiesel, an increase in volume was seen after immersion. • All three elastomers showed a decrease in hardness. Hardness of EPDM decreased more in comparison to Nylon and Natural rubbers. It was seen that the decrease in hardness was greater in biodiesel than diesel. • Significant decrease in tensile strength was observed in case of EPDM when compared to Nylon and Natural rubber.

2.4 Diesel fuel system

For the combustion to occur, fuel and air must be present. Today, the automotive industry, mainly the automobile engines, requires combustion to produce power. Air can be pumped into the engine from the intake manifold. On the other hand, for the combustion to take place, the fuel must be delivered to the engine. In this project, the fuel system studied is the diesel fuel system. The function of diesel fuel system is to inject exact amount of atomized and pressurized fuel into the engine cylinder at a correct time and there is no spark involved during the combustion process. This is because the combustion occurs when the compressed fuel is mixed with compressed air.

The diesel fuel system involves a few parts. Fuel tanks are the most important component. This is used to store diesel fuel. The fuel lines are another element to ensure that diesel can be transported from the fuel tank to the engine. In addition, fuel filters, fuel pumps, fuel injection systems as well as fuel injectors are also available in fuel line. The basic layout of a fuel delivery system of diesel engine shown in Figure 2.3.

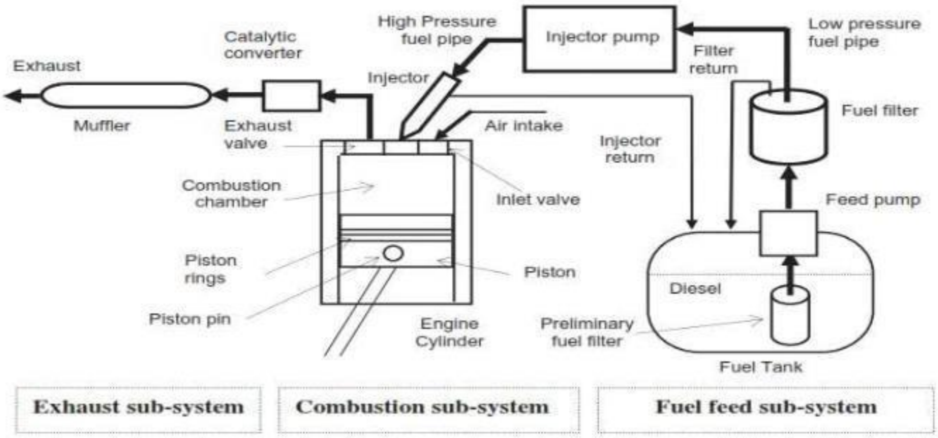


Figure 2.3: Schematic diagram of typical diesel engine fuel system (Bhardwaja, Guptab, & Kumarc, 2014)

The component in the system has its own purpose and is made up of according to their respective functions of various types of materials. This is because different component functions require different materials to ensure the material is suitable for component function. This also means that the products can last longer and reduce the cost of maintenance. For example, the fuel storage system, fuel transfer system, and fuel filtration system can provide clean operating fuel to the engine. The component materials are as shown in Table 2.4.

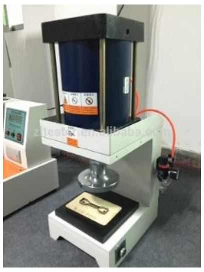
Table 2.4: Material used for the fabrication of fuel storage and delivery components (Chandran et al., 2016)

Parts	**Materials**
Fuel tank	Steel, plastic
Fuel feed pump	Aluminium alloy, iron-based alloy, copper-based alloy
Fuel lines	Steel, plastic, rubber
Fuel filter	Aluminium alloy, iron-based alloy, copper-based alloy
Fuel injector	Stainless steel
Nozzles	Steel
Gasket	Elastomer, paper, cork, copper

2.5 Market analysis on existing tensile test specimen cutting machine

The market analysis on existing tensile test specimen cutting machine will be observed to grab some ideas about the machine. This method is used because it can improve and make a better the machine. Table 2.5 shows analysis on tensile test specimen cutting machine in market.

Table 2.5: Analysis on tensile test specimen cutting machine in market

	 **TensileMill CNC MINI**	 **Precision Sample Cutters Model F215**	 **Dumbbell Tensile Test Sample Cutter**
Type of machine	Automatic CNC Milling Machine	Manual Cutters	Automatic Cutter
Manufacturer	TensileMill CNC	Testing Machine, Inc.	Zhongli Instrument Technology Co., Ltd
Cost	Price quotation	Price quotation	US$800.00 - US$1,000.00
Weight	680kg	31.8kg	59kg
Dimension	1130 x 1066 x 1778mm	736 x 432 x 457 mm	450 x 300 x 670 mm
Application	Stainless steel, Mild steel, Bronze, Aluminium	Paper, Light carton board, Film, Foil	Rubber, Adhesive tape, Leather
Advantages	- Fast process. - Automatic.	- Precise cutting edge.	- Easy and safety to operate.

	- Better precision. - Has control system.	- Case hardened steel cutting edge last longer. - Adjustable depth of cut. - Requires little or no maintenance.	- Automatic. - Better precision.
Disadvantages	- Expensive. - Large size. - Need a machinist to operate.	- Moderate expensive. - Manual operation.	- Need connect to the air pressure source.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is particular methods or procedures used for project execution. The chapter will clarify the methodology used during the study and the process needed to complete the report on the research project. Methodology is important as the sequences and the flow of methods used in this project are described in detail.

3.2 Overall project flowchart

Good planning is very important to ensure that the project can run smoothly and also to estimate the time required to complete the project is sufficient depending on the requirement. The Gantt chart is attached in Appendix section and the flowchart in Figure 3.1 shows the beginning of the project to determine the objective until the test results are analyzed.

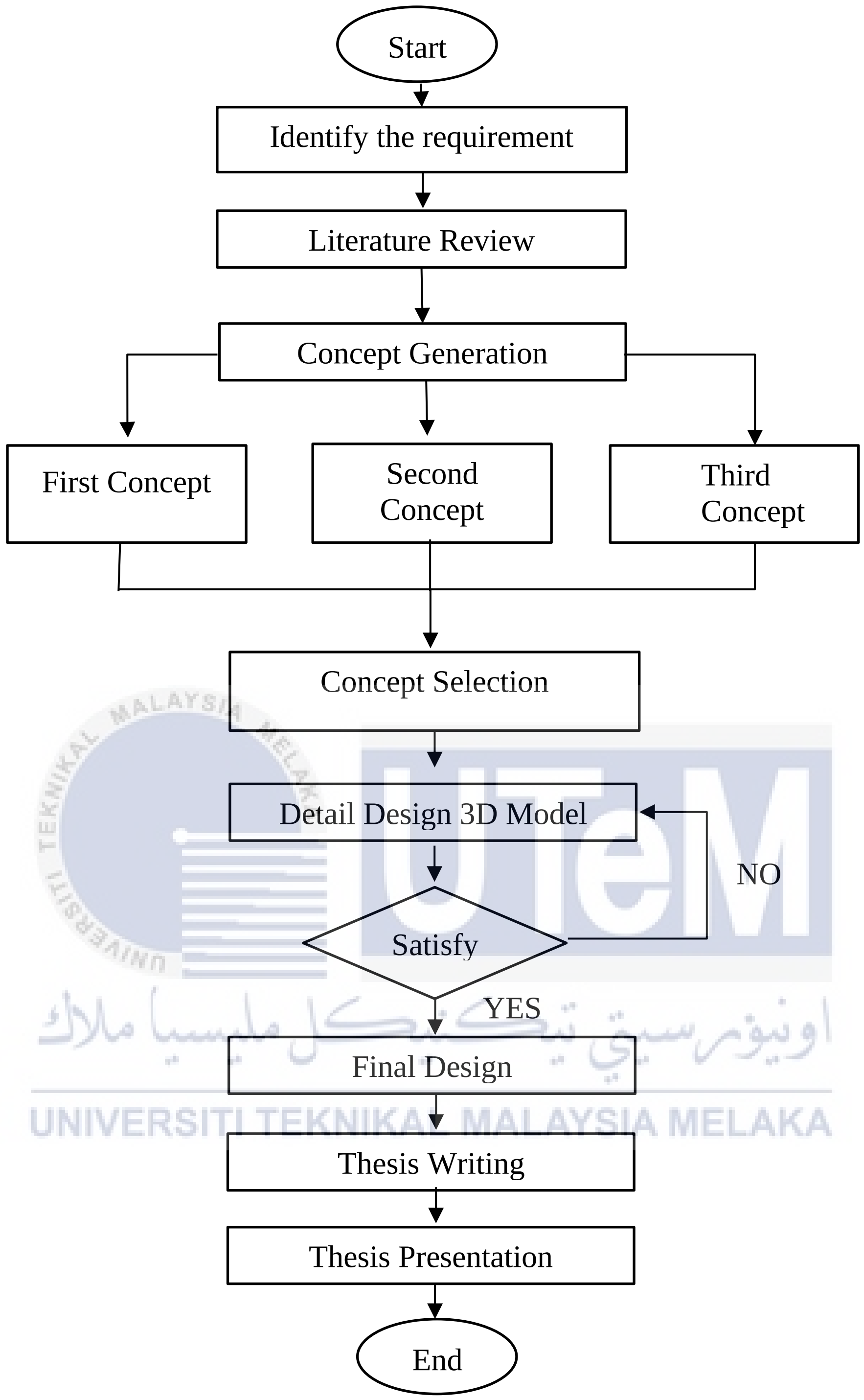


Figure 3.1: Flowchart of the Project

From Figure 3.1, the flow chart shows the overall process from the start of the project until the end. First, the Final Year Project in University Teknikal Malaysia Melaka is by choosing the project titles from a supervisor of the university. Then, the supervisor will explain in detail the basis of the project such as objective, scope and others related stuffs correlated to the study. Then, the project's progress began with finding the customer requirement is based on the project's title. In this matter, the customer is author himself. The information's finding is based on the research and observation on the product or machine on internet.

After that, the project was started by gathering information by doing literature review on the tensile test that needs to be done. Then, the project planning was done in order to make sure that the project can be done smoothly without any delay. This is because delayed in project can cause the result of the project to be affected. Other than that, the test rig for tensile test was designed according to respective ASTM standards. Therefore, planning is very important so that the tests can be done without any problem. Next, a few conceptual designs will generated using morphological chart and all conceptual designs will be evaluated using concept screening.

The 3D design of the final conceptual design of every parts will be developed by using CAD software. After that, The 3D design will be analysed by using stress simulation analysis to get its safety factor and to focus on modifying critical stress area on selected parts. Then, the materials for the product will be prepared and the product will be fabricated. After that, the machine will be assemble and test. Lastly, a report will be written at end of project. The Gantt chart for this project are attached in Appendix section.

3.3 Material Preparation

The materials need to be prepared first before starting the project to ensure that everything is organized. The materials part of machine such as square hollow bar were obtained from Fakulti Kejuruteraan Mekanikal laboratory at FASA B and others parts obtained from other stores. The elastomer was purchased from the store that sells fuel hoses.

3.4 Elastomer Specimen

After purchasing the elastomer, which is hose fuel line in the supplier, the specimen needs to be cut by the machine that will fabricated into a proper standard dimension according to ASTM D412-06 for tensile test to ensure that the test is valid.

3.4.1 Tensile Test

For tensile test, according to ASTM D412-06 the specimen needs to be cut. This requires the specimen to be in a specific dimension of a dumbbell shaped elastomer. Therefore, the material needs to be cut into proper shape and dimension according to the ASTM. Firstly, a drawing of the outline for the specimen was drawn using Computer Aided Design (CAD). The dimension was taken from die C according to ASTM D412-06. The drawing of the specimen is as shown in Figure 3.2.

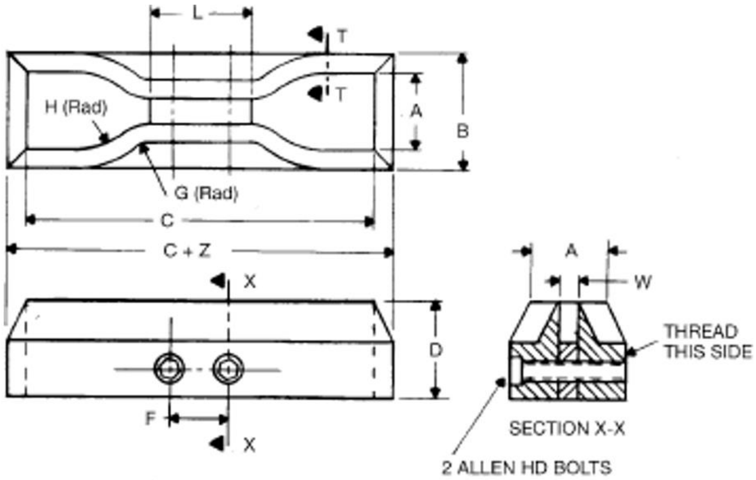


Figure 3.2: Standard dies for cutting dumbbell specimens

Table 3.1 below shows the dimension for standard dumbbell dies for the elastomer. For this test, the die used is Die C. The dimension of Die C is highlighted in the Table 3.1

Table 3.1: Dimensions of standard dumbbell dies (ASTM D412-06, 2006)

Dimension	Units	Tolerance	Die A	Die B	Die C	Die D	Die E	Die F
A	mm	±1	25	25	25	16	16	16
B	mm	max	40	40	40	30	30	30
C	mm	min	140	140	115	100	125	125
D	mm	±6[B]	32	32	32	32	32	32
D-E	mm	±1	13	13	13	13	13	13
F	mm	±2	38	38	19	19	38	38
G	mm	±1	14	14	14	14	14	14
H	mm	±2	25	25	16	16	16	16

L	mm	±2	59	59	33	33	59	59
W	mm	±0.05, -0.00	12	6	6	3	3	6
Z	mm	±1	13	13	13	13	13	13

The drawing was drawn on scale 1:1 to ensure that the dimension is on a proper scale in order to slice the sample into a correct shape and size. The size of die C important because it will become cutting die for the machine to cut the elastomer. The tensile test cutting die design and drawing was discuss in Chapter 4 and Appendix.

3.5 Detail Design and Analysis

The final conceptual design has been selected and then the design will be put into 3D detail design. The 3D information design was produced using Solidworks 2016, one of the Computer Aided Design (CAD) tools. The CAD is a technology commonly used today to create a computer-generated design based on the actual model in the reality world. This CAD design is a crucial process for process analysis and product development. In CAD modelling there are two types which are two-dimensional and three-dimensional diagrams. The graphic model in CAD gives more details for the analysis process regarding the engineering design.

The tensile test specimen cutting equipment has been designed in the CAD process part by part and will then be fully assembled to create a full model of product design. The specific measurements used are based upon the standard scale of design. The assembled concept is to be used for data analysis. For Von-misses Stress and the safety factor analysis, the full concept design will be subjected to stress analysis.

3.6 Theoretical calculation

Factor of safety also known as safety factor can be defined the ratio of a structure's absolute strength (structural capability) to actual applied load. Basically, the minimum value of the safety factor is 1.0. In this project, for the value less than 1.0 it should be declare as failed since it cannot support load more than the target. The equation of safety factor have been illustrated in Eq. (3.1).

$$FS = \frac{S\,yt}{\sigma\,Von\,Misses} \tag{3.1}$$

where FS is factor of safety, $S\,yt$ is yield tensile strength, and $\sigma\,Von\,Misses$ is maximum of material stress.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Product design specification

The objective of design process planning is to identify, search and assemble all the information to decide whether the tensile test specimen cutting equipment development is safe to use. The design specification consists of all information related to the outcome of the tensile test specimen cutting equipment developing due to requirement.

Product Design Specification: The Tensile Test Specimen Cutting Equipment

Product Identification

- Mini in size.
- Durable and portable.

Key Performance Target

- The machine must be mini in size.
- The durability of machine at least 3 year.

- The machine must be portable.

Physical Description

- Machine size approximately 400mm length, 250mm width, and 500mm height.
- Material: Steel, mild steel
- Weight Target: < 15kg

Financial Requirement

- Target manufacturing cost: RM 500

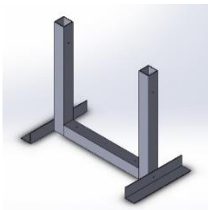
Life Cycle Targets

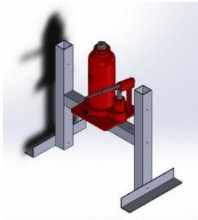
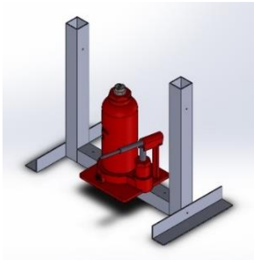
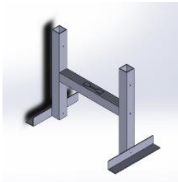
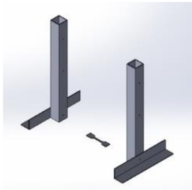
- Useful life 3 years
- Maintenance schedule: Twice a month
- Reliability (mean time to failure): 5 years
- End of life strategy: Machine will be recyclable

4.2 Morphological method

Morphological analysis is a method for representing and exploring all the relationship in multidimensional problems. It can generate product design concepts from a given set of components that can satisfy the same functionality required in a new product. Table 4.1 shown morphological method for tensile test specimen cutting equipment.

Table 4.1: Morphological method for tensile test specimen cutting equipment

Component \ Option	1	2	3
Shape of body frame			
Stand			

Support of hydraulic jack			
Position base of specimen			

In order to design 3 design options, all the layout is combined and well considered in order to create the tensile test specimen cutting equipment which usually will meet the requirements. Section below will discuss more about the conceptual design.

4.3 Conceptual design

4.3.1 First concept design (Concept A)

In this design from the morphological chart, the shape of body frame is rectangular in option 1. The machine will be more stable because a rectangular structure with a long side on the bottom is very stable when resting on the ground. For stand, option 1 was selected because the impact force between the ground and cutting die which is place under the hydraulic jack is stronger. Option 1 was selected for support of hydraulic jack because it can move up and down to create inertia. Position of base specimen will be on the ground which is option 2. The design shown in Figure 4.1.

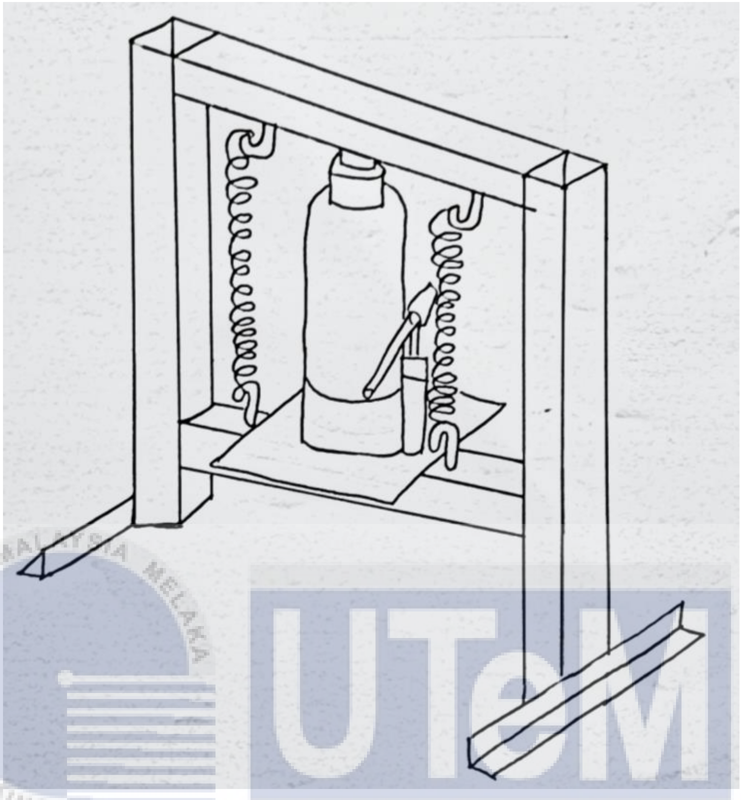


Figure 4.1: Concept design A

4.3.2 Second concept design (Concept B)

In this design from the morphological chart, the shape of body frame is circle in option 2. However, the machine is not stable because its saddle is not place in flat surface when it is extending. For stand, option 2 was selected because to support the base of shape of body frame. Option 2 was selected for support of hydraulic jack. Position of base specimen will be on the ground which is option 2. The design shown in Figure 4.2.

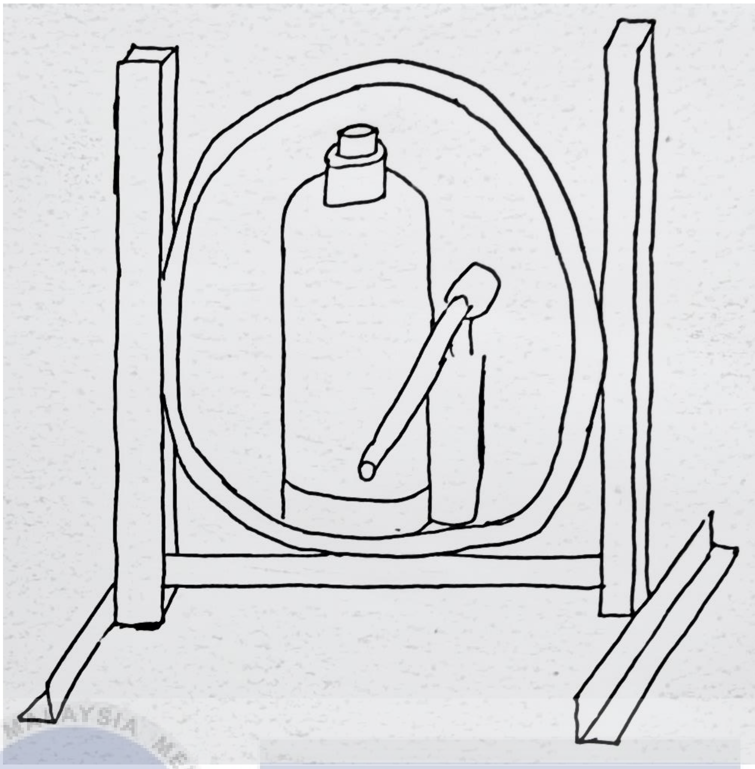


Figure 4.2: Concept design B

4.3.3 Third concept design (Concept C)

In this design from the morphological chart, the shape of body frame is rectangular in option 3. For stand, option 1 was selected. Option 1 was selected for support of hydraulic jack because hydraulic jack can move up and down to create inertia. Position of base specimen will be on the bar which is option 1. The design shown in Figure 4.3.

Figure 4.3: Concept design C

4.4 Pugh concept selection method

Pugh concept selection method will discuss about the evaluation process of new product ideas in order to determine either the new concept design achieve the key performance target. Table 4.2 shown the simple code used to evaluate the design concept (+ for 'good than', ++ for 'better than', and – for 'worse than'). So, ++ is better than + and + is better than -.

Table 4.2: Pugh concept selection method

Selection Criteria	Datum	Concept		
		A	B	C
Easy to use	++	++	+	+
Easy to handle	++	++	–	+
Portability	++	++	–	+
Durability	++	+	–	–
Mini in size	++	++	+	–
Sum ++’s	5	4	0	0
Sum +’s	0	2	2	3
Sum –’s	0	0	3	2
Net score	5	2	–1	1
Rank		1	3	2
Continue		Yes	No	No

Regarding to the result in Table 4.3, the value of net score for concept design A is 5. Based from the observation, concept A is the best design because it is easy to use, easy to handle, portable, durable, and mini in size. The status for the concept design will be continue which means that concept A accomplish the requirement.

4.5 Concept selection

Concept selection is the process to identify the best concept design regarding to the demand of customer and fulfils the standard specification. Concept design A will be chosen and continue because it has more stable because a rectangular structure with a long side on the bottom is very stable when resting on the ground, the impact force between the ground and cutting die which is place under the hydraulic jack is stronger and support of hydraulic jack can move up and down to create inertia to create more force. Figure 4.4 shown concept design A.

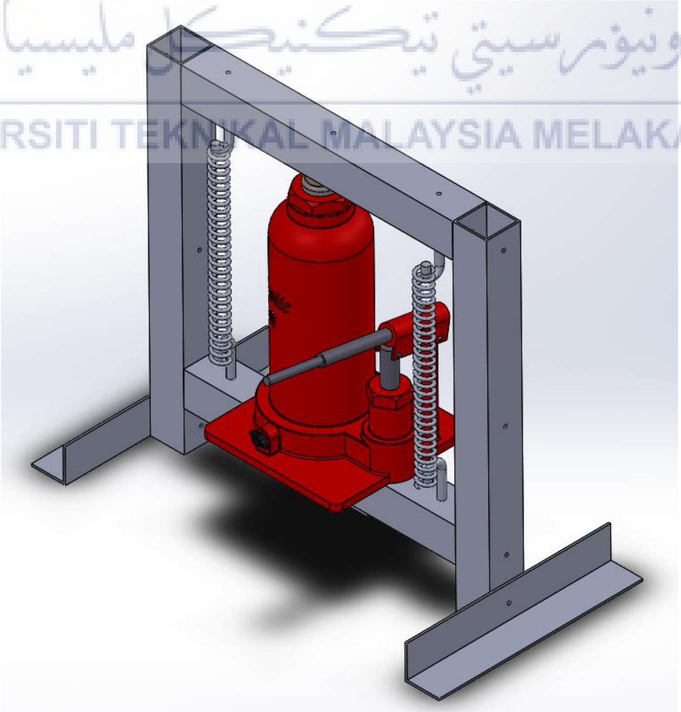


Figure 4.4: Concept A chosen

Concept design A has been selected and proceed with CAD by using Solidworks 2016. Figure 4.5 shown orthographic view, Figure 4.6 shown exploded view and Figure 4.7 shown bill of material of Concept A by using Solidworks.

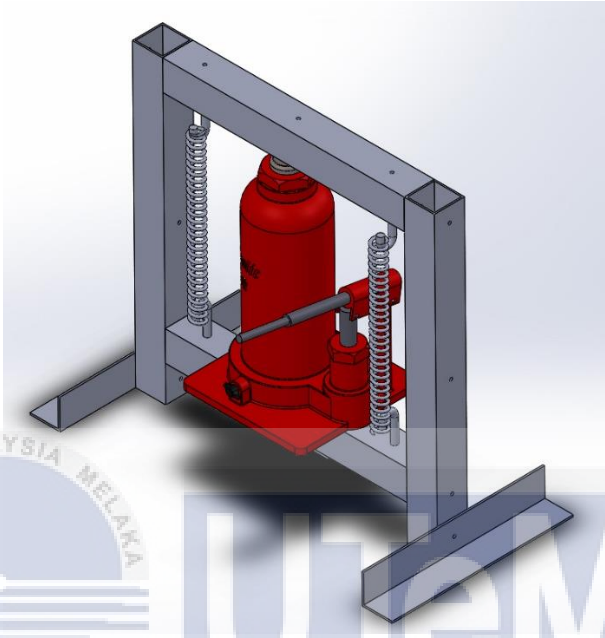


Figure 4.5: Assemble view of Concept A

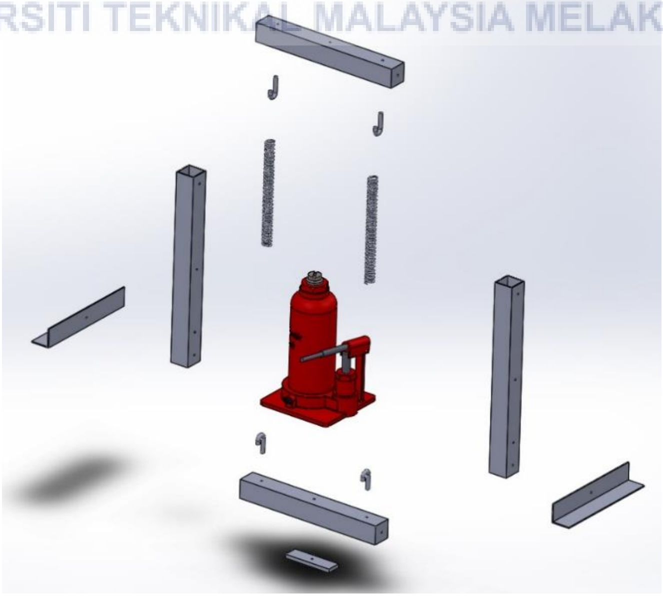
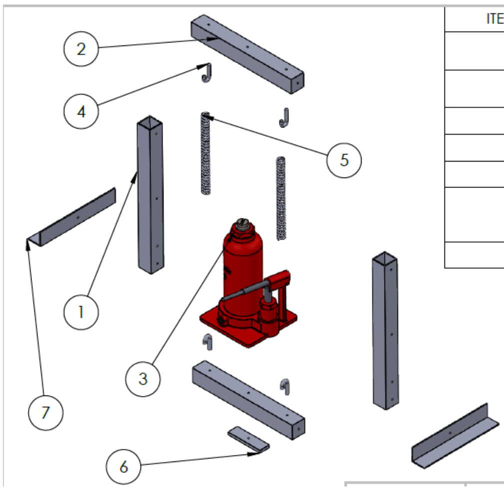


Figure 4.6: Exploded view of concept A



ITEM NO.	DESCRIPTION	QTY.
1	HOLLOW BAR 500mm	2
2	HOLLOW BAR 400mm	2
3	jack	1
4	HOOK	4
5	SPRING	2
6	TENSILE TEST SPECIMEN CUTTING DIE	1
7	L bar	2

Figure 4.7: Bill of material of concept A

A bill of materials is a complete list of the raw materials, assemblies, sub-assemblies, parts, and components required to manufacture a product. There are seven item that are required to build this tensile test specimen cutting equipment. Hollow bar 500mm and 400mm from mild steel was used to make it as a frame or body of the machine. Besides that, hydraulic jack was used to move down and up with force to cut the specimen. Hook and spring will be support for the hydraulic jack while L bar will support the whole machine from falling. Lastly, cutting die was used to make cut on the specimen. All detail drawings for the design is attached in Appendix section.

4.6 Finite element analysis (FEA) of tensile test specimen cutting equipment

Finite element analysis is performed using Solidworks software. It is to predict the region of stress occurs in the components that are involved in the analysis. This analysis is able to calculate the Von Mises Stress, principle stresses, and factor of safety.

4.6.1 Limitation applied in finite element analysis

Finite element analysis can only be calculated when the load or force and the fixed object is defined. In this design, the base of frame should be fixed to hold the load. The force are applied direct to the top and bottom of the square bar which is the placement of hydraulic jack. This prototype should be able to withstand at least 1000kg of load, and able to deliver enough force to cut the specimen. Figure 4.8 and Figure 4.9 shows the direction of forces and the fixed components applied.

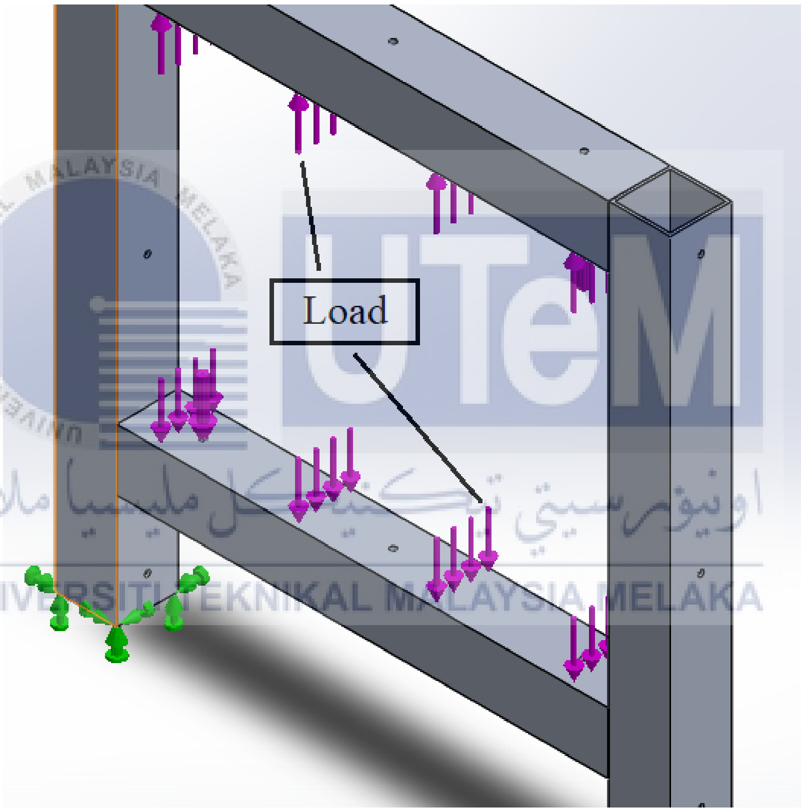


Figure 4.8: The direction of force or load

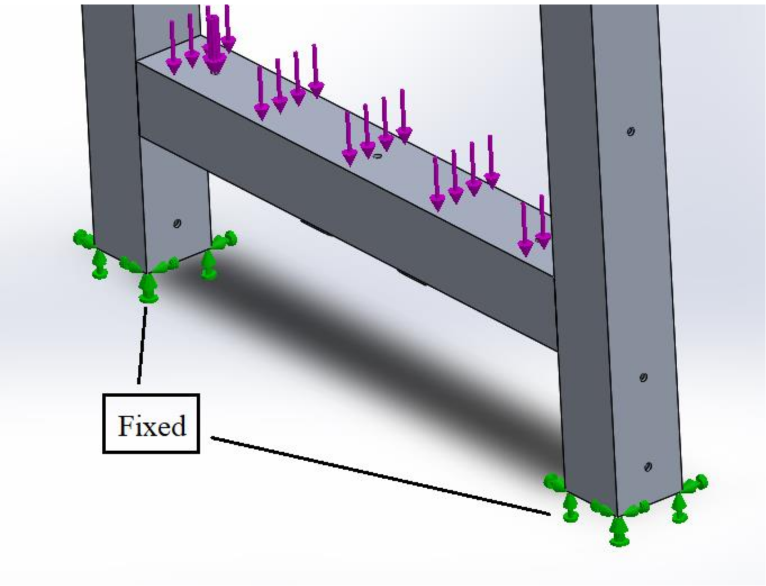


Figure 4.9: The direction of fixed component

4.6.2 Material applied and characteristics

In this analysis, the stress calculated is based on the material applied each components. The material of the cutting die is D2 steel also known as SKD11 that was purchases from PHH Special Steel Sdn Bhd about RM40.00. D2 steel plate can be used to produce cold work mold with a high impact force, and high wear resistance. It is a high-carbon and high-chromium cold work mold steel. Table 4.3 below show the characteristics of D2 steel. The material are applied in the in the cutting die that took place in the simulations.

Table 4.3: The properties of D2 steel

Name	**Properties**	**Metric**
D2 steel	Density	$7700\ \frac{kg}{m^3}$
	Tensile Strength	$4.825x10^8\ \frac{N}{m^2}$
	Yield Strength	$2.481x10^8\ \frac{N}{m^2}$
	Elastic Modulus	$2x10^{11}\ \frac{N}{m^2}$
	Poisson's ratio	0.32
	Shear Modulus	$7.6x10^{10}\ \frac{N}{m^2}$
	Thermal Expansion Coeffiecient	$9.8x10^{-6}\ K^{-1}$
	Compressive Strength	2140MPa

4.6.4 Von Mises Stress and factor of safety

The result are shown in Figure 4.10 is an simulation analysis of the machine when load is applied. The maximum stress calculated is 18.57 MPa. It is observed that most of the surface of frame bar are in blue region. Thus, it is durable on the blue region because the minimum stress region are applied. However, some of the suface of region is green colour. It is because stress are increase in that area due the the force applied.

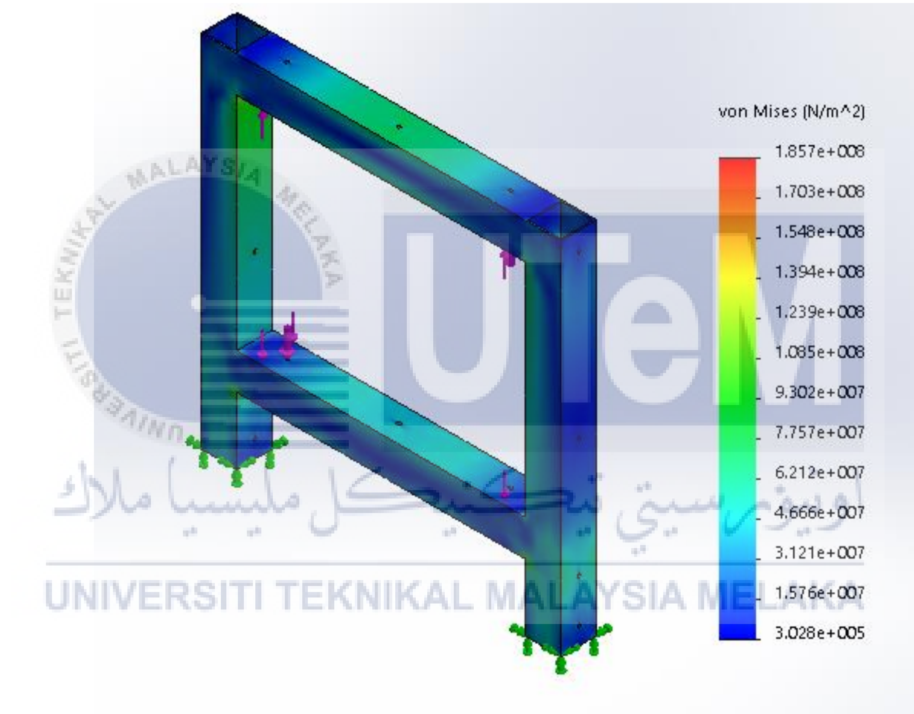


Figure 4.10: Result of Von Mises Stress

Next, the factor of safety varies with the load or force are applied at the machine are done to observed the maximum force exerted on the cutting die. The applied load are divided by two because there are two frame which is top and bottom frame so the load are applied equally on both frames. The constant value for yield strength of aluminium material is $186x10^6 \frac{N}{m^2}$. Table 4.4 show the observation result from analysis of the load varies with the factor of safety.

Table 4.4: The load varies with the factor of safety

Load (kN)	Von Mises (MN/m2)	Factor of safety
10	15.48	12.0
20	30.95	6.0
30	46.44	4.0
40	61.90	3.0
50	77.39	2.4
60	98.87	2.0
70	108.4	1.7
80	123.8	1.5
90	139.3	1.3
100	154.8	1.2
110	170.3	1.1
120	185.7	1.0
130	201.2	0.9

The observation from Table 4.4 that when the load applied to the tensile test specimen cutting equipment increases, the factor of safety are decrease. The factor of safety must be higher than 1.0 otherwise it indicate that frame has fail or not safe. For example, the 130kN load applied are consider fail because the factor of safety are less than 1.0. A safety factor of 1.0 on the frame indicates that the frame material has just begun to fail. The example calculation of factor of safety from Eq. (3.1) are shown below.

Example for load =120kN

$$FS = \frac{\text{S yt}}{\sigma \text{ Von Misses}}$$

$$FS = \frac{186x10^6 \frac{N}{m^2}}{185.7x10^6 \frac{N}{m^2}}$$

$$FS = 1.0$$

4.7 Prototype development

Prototype is an early version or model of a product intended to test a concept. The prototype for this machine has been planned and developed. The machine was fabricated according to detail drawing and follow working procedure carefully in order to fabricate the machine and minimize any mistakes or hazard at workplace. The tensile test cutting die had been design using Solidworks and Figure 4.8 and 4.9 shows design of the tensile test cutting die in 3D dan 2D respectively.

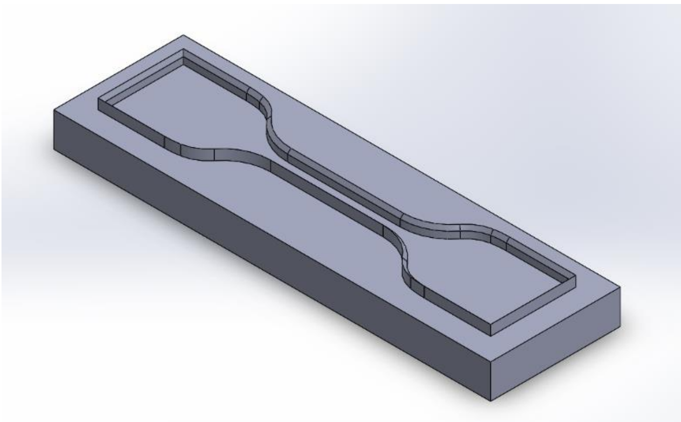


Figure 4.11: Design of the tensile test cutting die in 3D

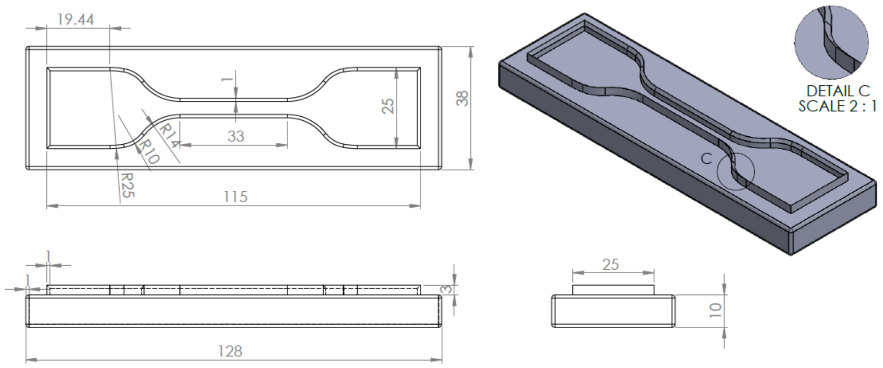


Figure 4.12: Design of the tensile test cutting die in 2D

Prototype is important because it can provide a better understanding of the intended design. Not only does prototyping offer a clear representation of the concept to consider the final product's look and feel. It also helps identifying prospective and collecting ideas to improve it. Figure 4.10 below shows the prototype of tensile test specimen cutting equipment. All detail drawings for the design is attached in Appendix section.

Figure 4.13: The prototype of tensile test specimen cutting equipment

The prototype already 90% complete fabricated. However, the only thing left to do is to produce tensile test cutting die by milling it using CNC milling machine and then assemble with the prototype. The milling work was delayed because of pandemic crisis that happen all over the world; Covid-19 also known as Corona Virus which make the government announced Movement Control Order (MCO).

The prototype has been tested by replace the cutting die with food shape mold and it is working properly. The hydraulic jack was able to push down and deliver force, but the food shape mold cannot withstand the force and it became fracture. However, the actual cutting die was made from high-carbon and high-chromium alloy tool steel that is used for making long-life high-precision cold-work dies. So, it can withstand the force with the proper care.

4.8 Budget and costing

The faculty can only provide material of aluminum square hollow bar and iron L-bar. All other material must be purchase either online or get in hardware shop. The hydraulic jack was purchased using Shopee. For fastener, spring, and J-hook was bought in hardware shop. Table 4.5 shows tha price list of each components.

Table 4.5: The price of components

No.	Component	Price (RM)
1.	Hydraulic jack	73.15
2.	Spring (2 pieces)	28.60
3.	Fastener	3.60
4.	J-hook	4.00
5.	Paint	18.00
6.	Paint brush	3.50
7.	D2 steel	40.00

The total cost for purchasing material of this project is RM170.85. The budget allocated for PSM students is RM200 per person. The budget is only valid for consumable materials for the project fabrication.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In the nutshell, the objective of this study are to develop conceptual and detail design of tensile test specimen cutting equipment. The detail design of tensile test specimen cutting equipment are developed using morphological method. Concept design A, B, and C are the result from these method. After that, concept screening are use to determine either the new concept design achieve the key performance target. Next, concept design A has been selected because fullfilled the requirement and carry on with detail design of the machine. The objective of this study are successfully achieved.

Futhermore, the another objective of this project are to fabricate the prototype of tensile test specimen cutting equipment. Based on the project done, the tensile test specimen cutting equipment already done 90% fabricated. Therefore, the objective is not achieved because fabricate the prototype of tensile test specimen cutting equipment is not done yet due to Movement Control Order because of COVID-19. However, once MCO have be lifted, only a minor work need to be perform that is milling cutting die and assemble it with the machine.

5.2 Recommendation

For future research, other material such as stainless-steel bar should be used to improve the strength of the machine. Furthermore, the placement of specimen needs to prepare or fabricate so it can hold the rubber hose securely and produce a nice cutting specimen. Lastly, the precaution steps need to be practiced carefully during the planning and fabricate because the result that is caused by the error may affect the whole the machine.

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APPENDICES

APPENDIX A1

Gantt chart of Projek Sarjana Muda 1

Task	PSM 1													
	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Received and discuss title with supervisor	■													
Literature review		■	■											
Concept generation				■	■	■								
Concept selection						■	■							
Part design								■	■	■	■			
Report PSM1 submission											■	■	■	
PSM1 presentation														■

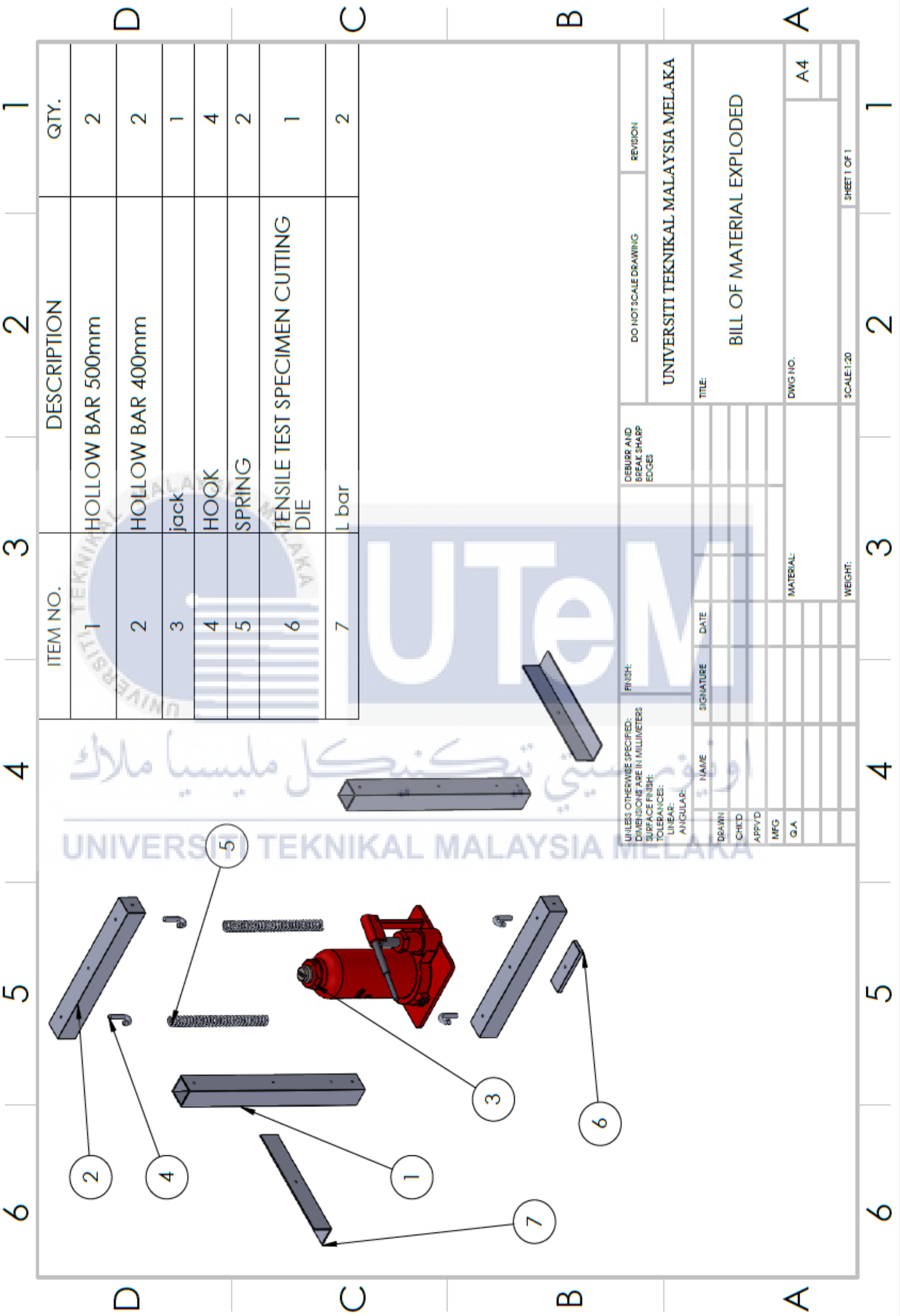
APPENDIX A2

Gantt chart of Projek Sarjana Muda 2

Task	PSM 2													
	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Detail design and analysis	■	■	■											
Fabrication		■	■	■	■	■	■							
Assembly				■	■	■	■	■	■					
Testing								■	■	■	■			
Full report writing									■	■	■	■		
Report PSM2 submission												■	■	
PSM2 presentation														■

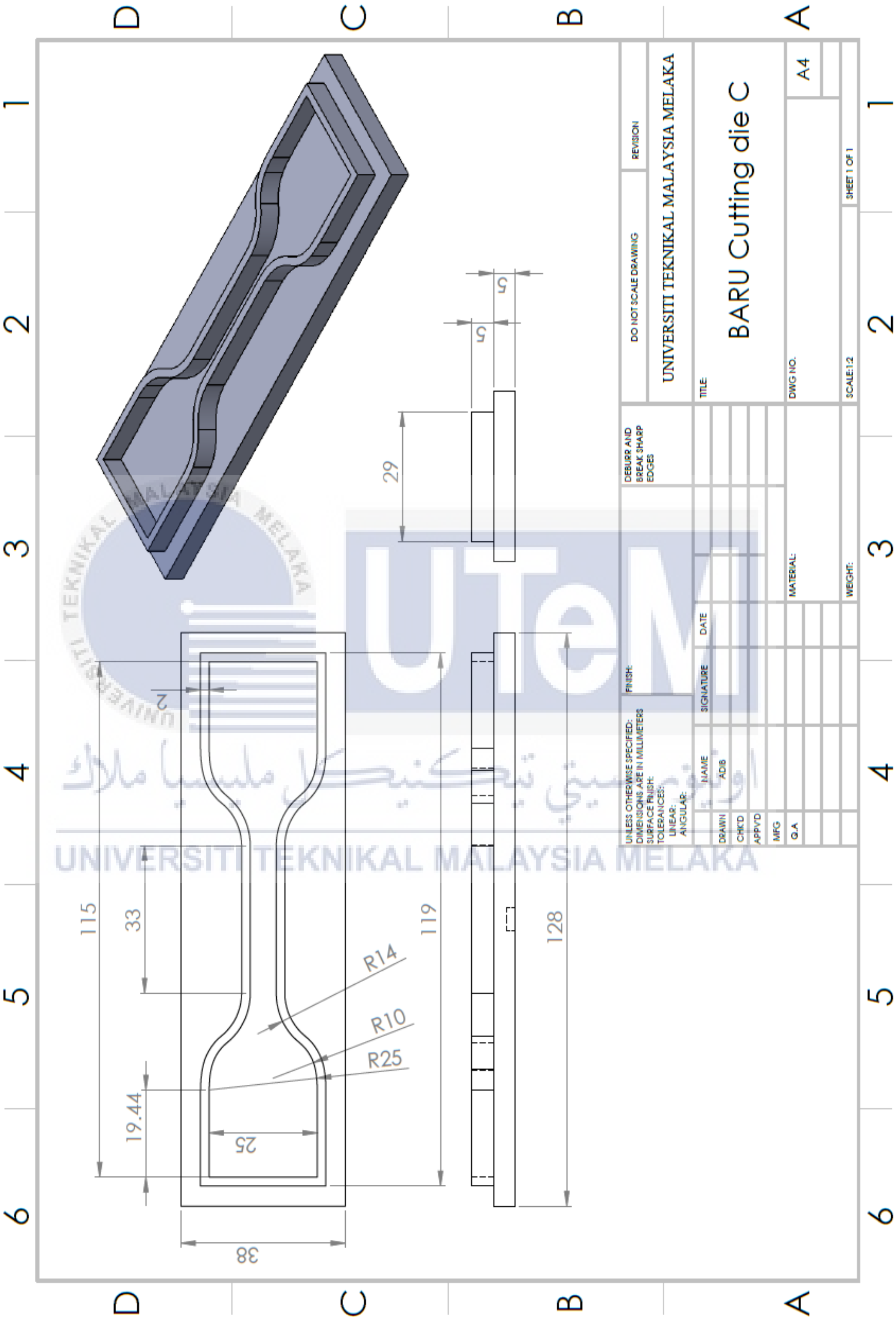
APPENDIX B1

Bill of material drawing



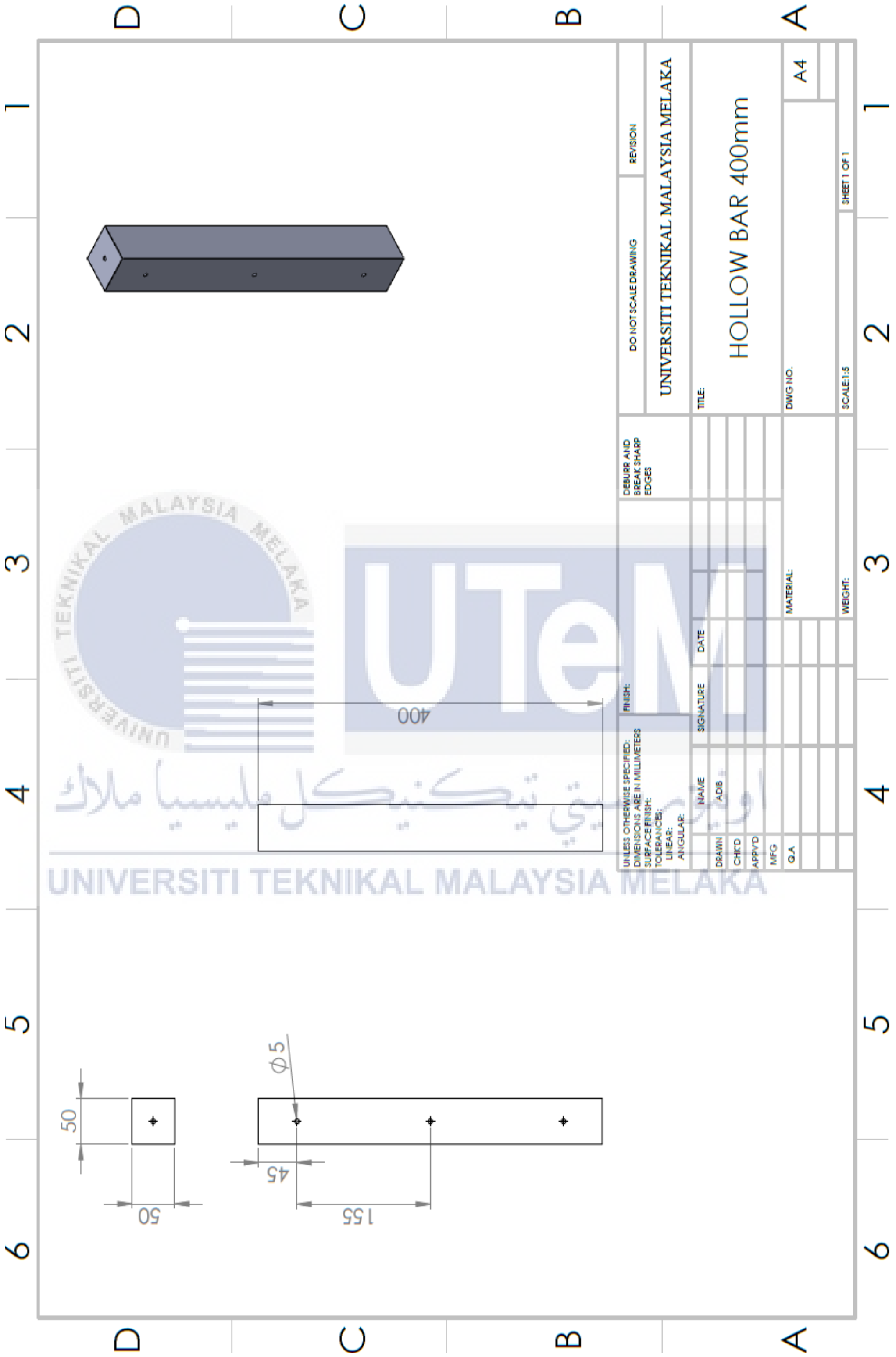
APPENDIX B2

Cutting die drawing



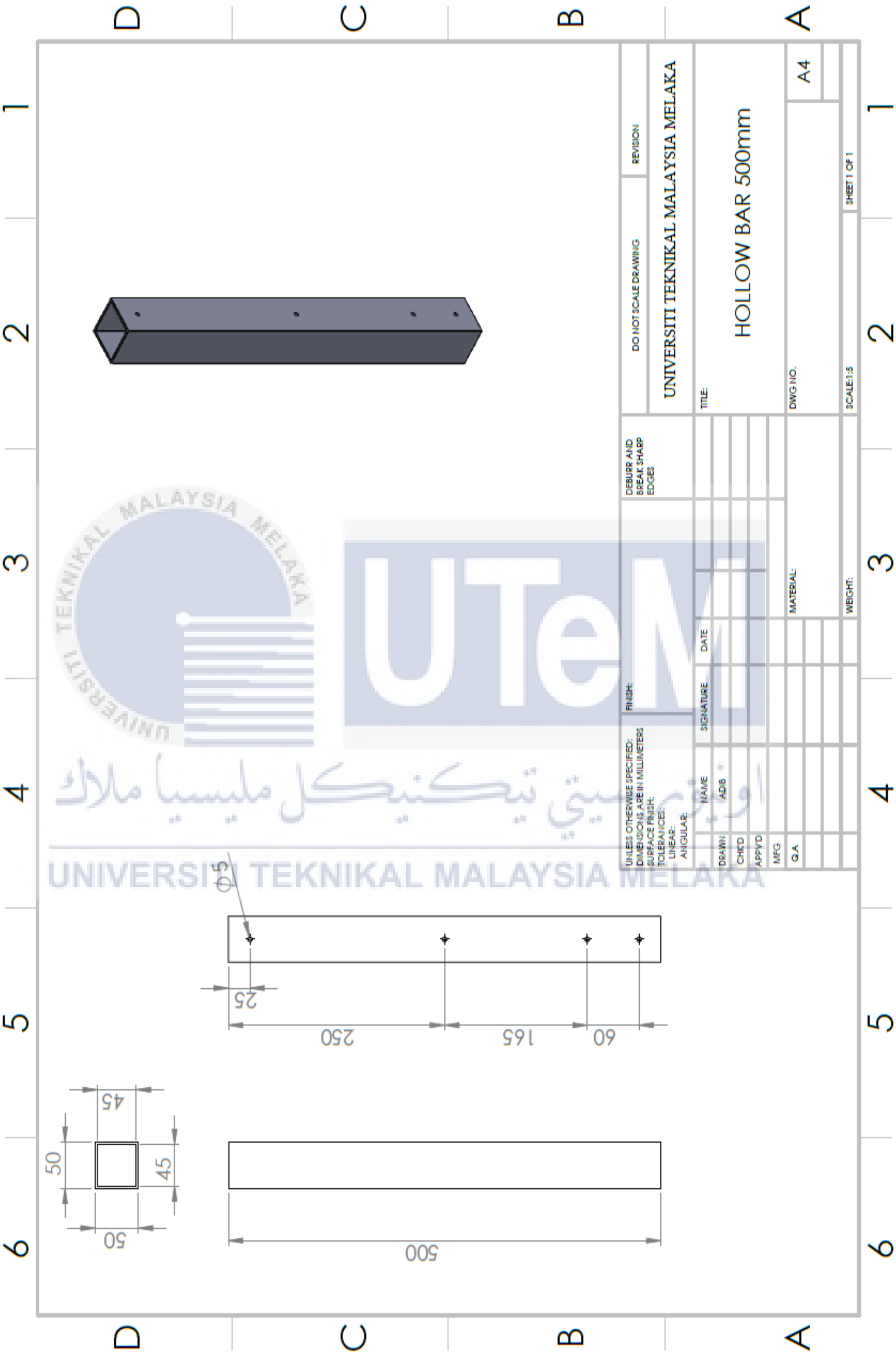
APPENDIX B3

Hollow bar 400mm drawing



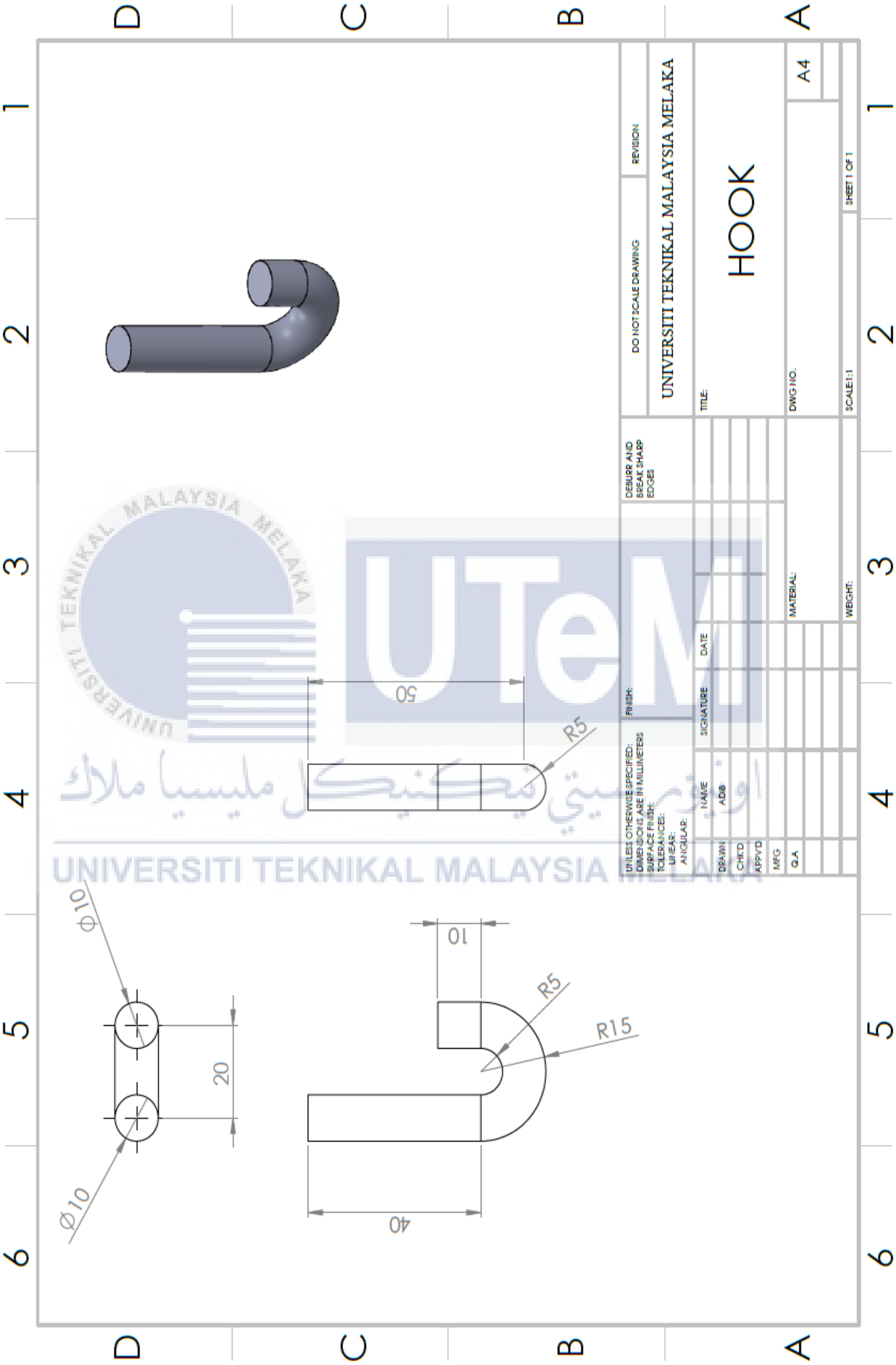
APPENDIX B4

Hollow bar 500mm drawing



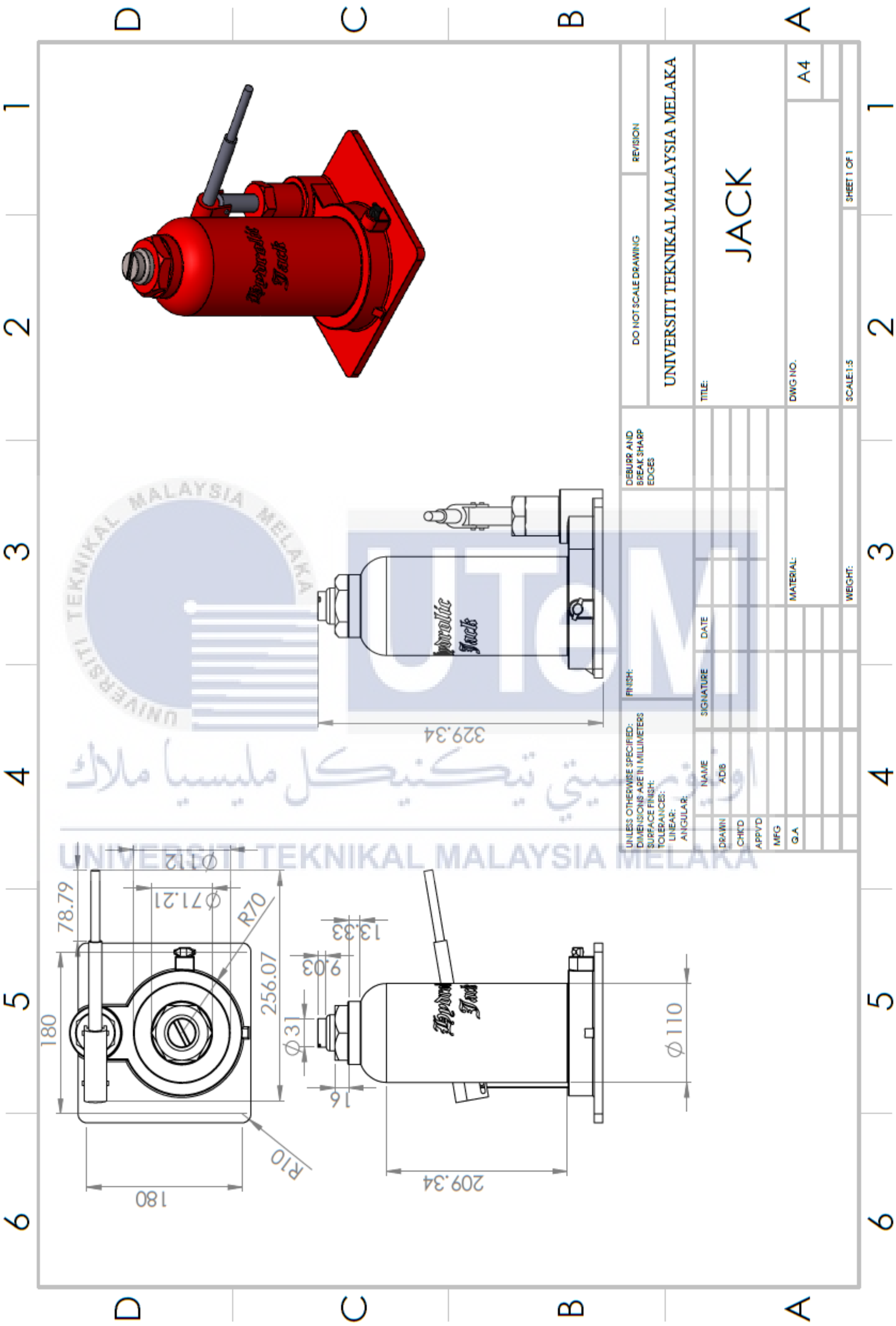
APPENDIX B5

J-hook drawing



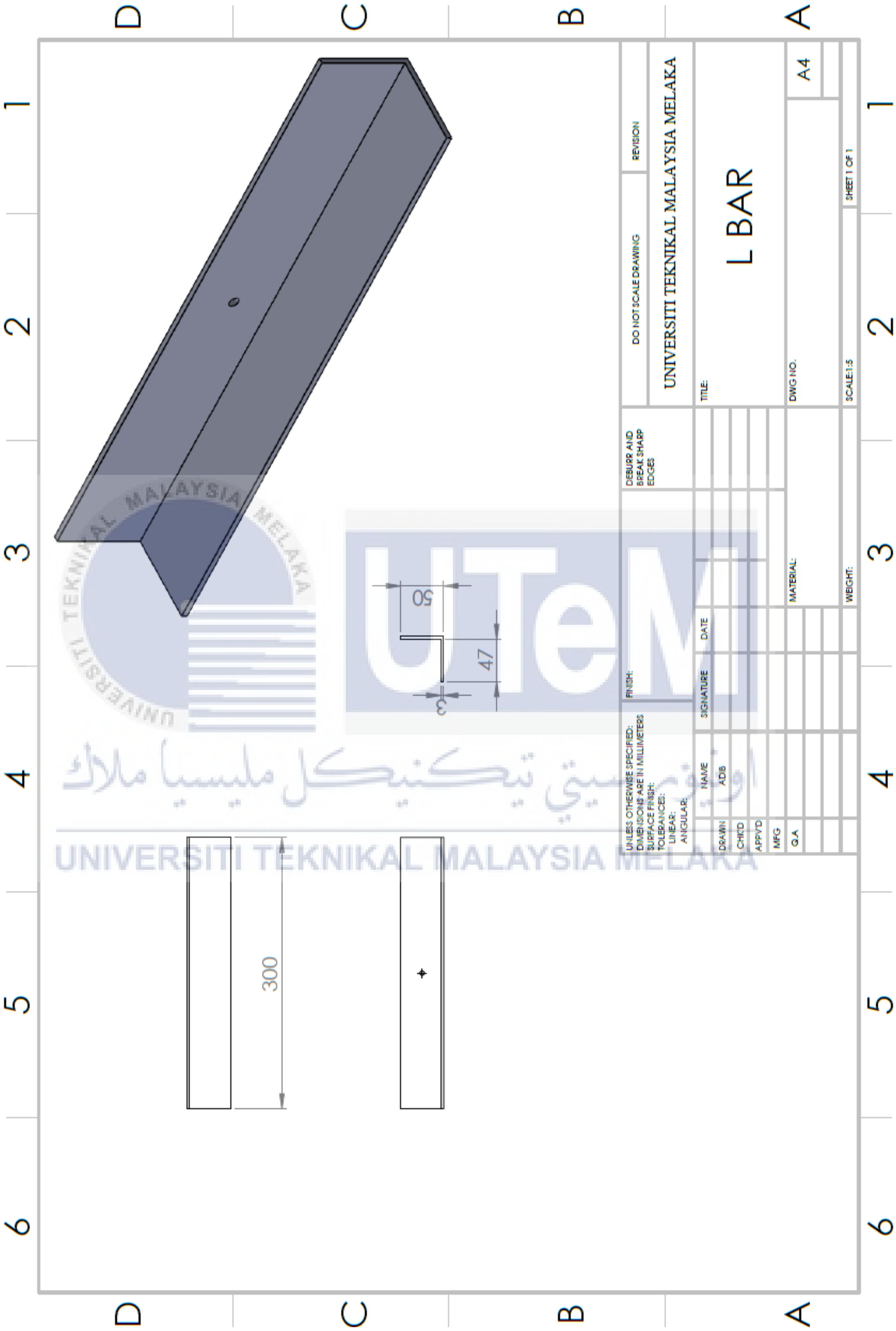
APPENDIX B6

Hydraulic jack drawing



APPENDIX B7

L-bar drawing



APPENDIX B8

Spring drawing