CUTTING TOOL JIG DESIGN FOR BRAKE DISC SKIMMING MACHINE

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "Cutting Tool Jig Design For Brake Disc Skimming Machine" 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

There are many brake disc problems such as corrosion, warp, grooves and rust. Due to the problems some brake disc need to be change and some just need to be skimmed. A brake disc need to be skim when groove marks form at the surface of brake disc. Groove marks are marks that formed at the surface of the brake disc due to the effect of friction force such as rivet is in contact to the discs surface. In order to obtain a smooth performance on the skimming machine, an adjustable cutting tool jig is design. The study is to design an adjustable cutting tool jig for skimming machine so that it will be easier for the user to use. To design the jig, design method is used which includes the House of Quality, Product Design Specifications, and morphological chart. The House of Quality will be done based on customer requirements or voice of customers and the Product Design Specification will be done based on the datum of the product. Morphological chart will be used to generate a few ideas of the jig design. Based on the design method, three best design will be chosen by using weight selection. Before the three best design is to be inserted in SolidWorks for analysis, calculation to determine the cutting force applied will be done theoretically based on the formula obtain from trusted source. After the analysis is done, a few criteria will be considered and go through to select one design as a final design for the cutting tool jig of the skimming machine.

ABSTRAK

Terdapat banyak masalah brek cakra seperti kakisan, meleding, alur dan karat. Disebabkan oleh beberapa masalah, brek cakra perlu dikikis apabila terbentuknya alur pada permukaan brek cakra. Alur tersebut terhasil pada permukaan brek cakra akibat kesan geseran antara rivet dan permukaan brek cakra. Bagi mendapatkan prestasi yang lancer pada mesin kikis, jig alat pemotong boleh laras dihasilkan. Kajian bertujuan untuk menghasilkan jig alat pemotong boleh laras bagi memudahkan pengguna menggunakan. Kaedah kajian reka bentuk yang digunakan merangkumi Rumah Kualiti, Reka Bentuk Spesifikasi Produk dan carta morfologi. Rumah kualiti akan dihasilkan berdasarkan permintaan pelanggan atau suara pelanggan dan reka bentu spesikfikasi produk akan dibuat berdasarkan datum kepada produk tersebut. Carta morfologi akan digunakan untuk menghasilkan idea reka bentuk jig tersebut. Berdasarkan teknik reka bentuk, tiga reka bentuk terbaik akan dipilih menggunakan teknik pemilihan berat. Sebelum tiga reka bentuk terbaik dimasukkan di dalam SolidWorks bagi melakukan analisis, beberapa pengiraan akan dilakukan bagi mengenal pasti tekanan potongan yang dihasilkan secara teori berdasarkan rumus yang di dapati melalui hsil yang boleh dipercayai. Selepas analisis dilakukan, beberapa kriteria akan dipertimbangkan bagi memilih hanya satu reka bentuk terakhir bagi jig pemotong mesen pengkikis.

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LIST OF SYMBOLS

F	-	Force
P	-	Power
V	-	Velocity or cutting speed
Fc	-	Cutting force
V	-	Cutting speed
Q	-	Material removal rate
W	-	Specific power required to cut a material
HPc	-	Cutting horsepower
HP_{μ}	-	Unit horsepower, specific power required to cut a material
D	-	Diameter

LIST OF ABBREVIATION

CATIA	Computer Aided Three Interactive Application
US	United States
FEA	Finite Element Analysis
PDS	Product Design Specifications
HOQ	House of Quality

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Brake is a mechanical device that halts vehicles while brake disc is a disc that slows down the wheel of the vehicle by friction. In a brake system the friction force is the main excitation mechanism. Hydraulic concept is also applied to the brake system as it gives an equal braking force to all four wheels and lower wear rate.

Brake disc should be skim when it is corrode or when there is groove mark form at the surface of the disc brake. Groove mark formed due to the friction of rivet to the brake disc surface making the surface of the brake disc not smooth. Besides that, the brake disc also need to be resurfaced when there is judder or even vibration on the brake. As for the possible consequences, the brake disc might facing a low efficiency on the braking power an able to produce unpleasant noise while breaking. When brake disc facing problems such as corrosion and groove marks formation, skimming process should be done by using skimming machine.

The skimming machine normally use to remove a thin layer of the disc to eliminate minor damage occur on the brake disc surface. Machining the disc as needed will maximize the mileage out of the current disc on the vehicle (Swapnil R. Abhang, 2014). Skimming brake disc able to improve both disc and pad life and the brake efficiency.

In this project, the main focus is on the design of a cutting tool jig for the skimming machine. Engineering methods such as House of Quality and Morphological chart will be applied in the design process.

1.2 Problem Statement

Grooves are deep cuts at the brake disc surface where it follows the disc's curve rotation. It can be happen to one or both side of the brake disc. When brake pads are worn to the rivet, the rivet will be in contact with the brake disc and form groove marks. In order to solve the problem, skimming the surface of the brake discs by using skimming machine is required. Thus, this project will be focus on the design of cutting tool jig for the brake disc skimming machine in order to get a smooth surface of brake discs.

1.3 Objective

The objectives of this projects are :

1.3.1 To design a cutting tool jig for skimming machine that is easier for the user to use.

1.3.2 To produce an adjustable cutting tool jig.

1.3.3 To do analysis using SolidWorks 2016.

1.4 Scope of Project

The scopes of this project are as follows.

1.4.1 Focus on design study for the jig by applying engineering design method which are Product Design Specification, House of Quality, Morphological Chart and Weigh Decision Matrix.

1.4.2 Performing detail drawing of the product from the design selection method applied by using CATIA (V5R20).

1.4.3 Analysis of the cutting tool jig design by using Static Analysis in SolidWorks 2016.

1.4.4 Optimization of the selected final cutting tool jig design.

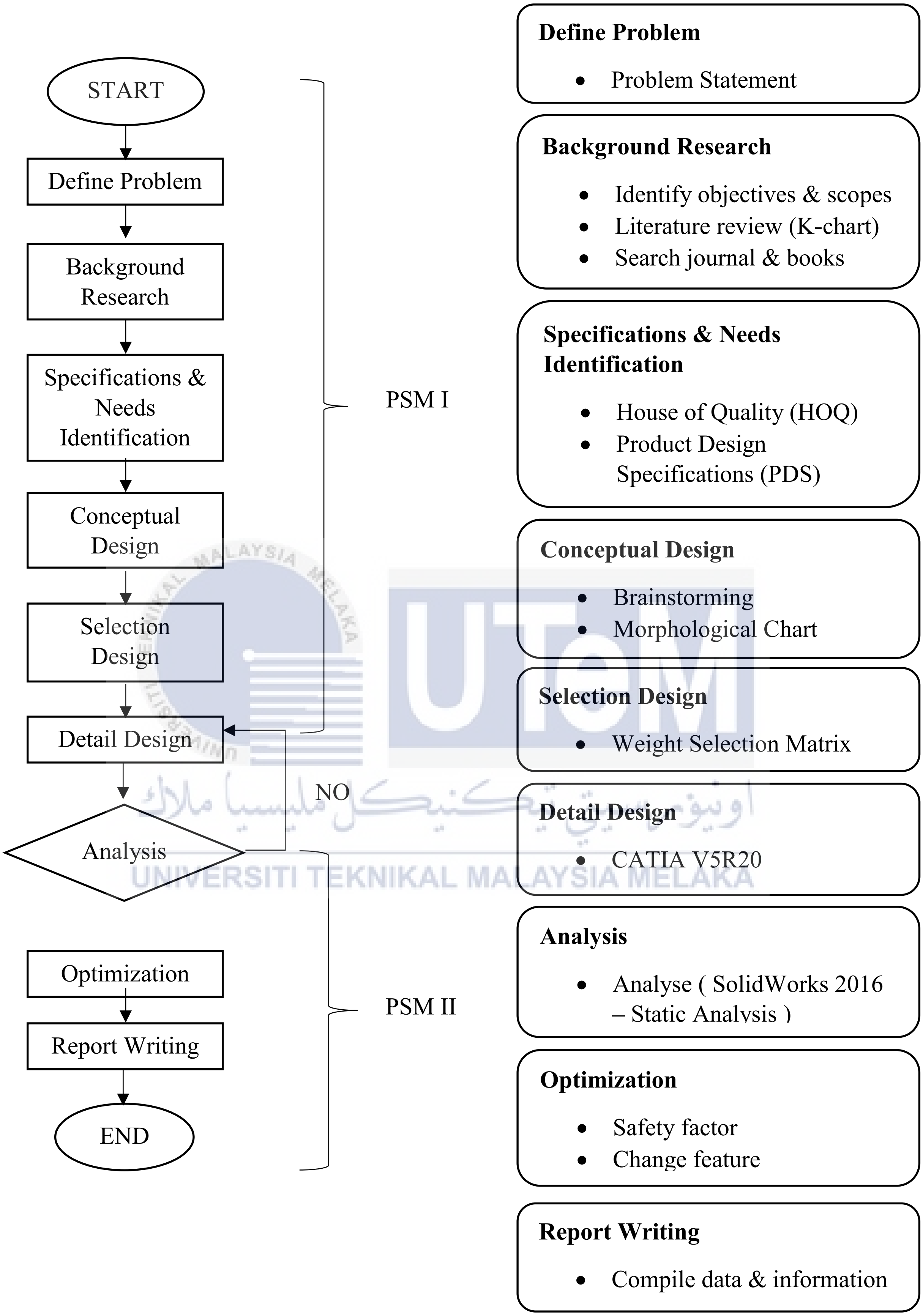


Figure 1.1 : Flowchart

CHAPTER 2

LITERATURE REVIEW

2.1 Brake Disc

Brake discs are brakes that uses force to stop vehicles. Friction force is applied to brake pads of both sides of the brake discs. The discs are normally turns with the wheel of the vehicle and it is overlap with the caliper. Once the brake pedal is pressed, the hydraulic fluid will automatically push the pistons and brake pads to the discs surface. This action will produce friction and tend to halt or slow down the vehicle. The function of the brake pads are to grip the disc until the vehicle slow down or stop (Knight, 2016).

A disc brake consists of rotor, caliper, brake pads and other hardware such as bolts, springs and also clips. Brake disc or brake rotor are normally made up of cast iron where it applies friction to stop or slow the vehicle. Brake rotor can be either solid type where the ventilated rib disc allows air to circulate inside the disc to cool. Brake caliper is a nonrotating part in braking system that is attached to the spindle where it supports the rotor. It comprises of piston, dust boot, caliper housing, piston seal, brake pads and bleeder screw. As for brake pads are thin blocks that clamp the brake rotors to halt or slow down the vehicle. It consists of riveted brake lining that is made of semi metallic friction material or asbestos (Integrated Publishing, n.d.).

2.1.1 Brake Disc Problem

Brake disc normally facing with noise and vibrations. Noise can be categories into two which are low frequency vibration (100-1000 Hz) and medium and high frequency vibration (1000-18000 Hz). Low frequency vibration are due to dimensional variations in brake components and rigid body oscillation of caliper and its mount where it can cause brake roughness, judder and groan. Meanwhile, medium and high frequency vibration is due to the variation in thickness of the rotor which result in squeal or squeak. Besides that, brake disc also face problems such as warp, groove, worn, channels and scratch (United States Patent Patent No. US 7,334,510 B2, 2008).

2.1.1.1 Warp

Brake discs can be warped when there is a vibration or perhaps judder when braking. The uneven thickness of the brake discs also shows that it is warped (Grant, 2016). Due to Caroll Smith in the article of "The Warped Brake Disc and Other Myths of the Braking System" states that the warped brake discs is mostly friction pad material that is transferred unevenly to the brake discs surface. (Smith, n.d.).

2.1.1.2 Noise

The brake system need to fulfil the customer requirements in term of its noise, durability and performance. Brake disc noise has been a concern especially to the manufacturers of the brake disc systems and the friction materials. Squeal is one of the noise produced by brake disc where it is caused by an increase of coefficient of friction due to the speed decreasing when braking. Besides that, squeal is also caused by the system instability of the structural components of the brake system itself (S. K. Rhee, 1989). The noise produced by brake disc can be categorised into three which are low frequency noise, low frequency squeal and high frequency squeal. The low frequency noise is less than 1000 Hz, low frequency squeal is from 1000 Hz to 5000 Hz while a high frequency squeal is more than 5000 Hz (P., R., & P., 2014).

2.1.1.3 Wear

Wear can cause brake disc to become thinner. Due to that, the manufacturers set a minimum thickness for the brake disc. Therefore, when the thickness reach this limit, the brake disc need to be change and normally brake disc need to be replaced in pairs (Brake Problems : Wear, corrosion, distortion and other common causes of failure, 2011).

2.1.1.4 Groove

The disc will undergoes wear normally in a form of grooves where brake pads or rivet in contact against it (Ofria, 2016). Groove marks or scoring are deep cuts on the rotor surface where it follows the curve rotation of the rotor. This is due to the worn brake pads exposing the rivet. When the rivet meets the brake disc groove marks will produce either on one side or both side of the brake disc surface. Therefore, skimming process by using brake lathe is required to obtain a smooth surface of brake disc (Disc Brake Service).

2.1.1.5 Corrosion

Brake discs are made up of cast iron where it a material that can corrode easily. Light corrosion can be remove by heavy breaking but braking is lower on light vehicle and may not be enough to remove the corrosion from the brake disc surface (Brake Problems : Wear, corrosion, distortion and other common causes of failure, 2011).

2.2 Brake Lathe (Skimming Machine)

There are two types of brake lathe which are the normal brake lathe and on-car brake lathe. The normal brake lathe is the brake lathe that need the brake disc to be taken to the lathe machine and do the skimming process. Meanwhile, the on-car brake lathe is the machine itself is place to the vehicle to do the skimming machine. It means the skimming process is done without taking out the brake disc from the vehicle (Brake Lathes, 2016).

2.3 Jig

It is easy to use in locating and supporting the components (Abouhenidi, 2014). Jig does not only facilitate the productivity of the machine but also reduce cost and time. It is easy to assemble and saves labour cost. (Introduction to Jigs and Fixtures).

2.3.1 Material

Selection of materials are important to resist tear and wear. Materials such as phosphor bronze and other non-ferrous metals including composites and nylons helps in preventing damage to manufacturing part used and reduce wear for certain parts (Okpala & C., The Design and Need for Jigs and Fixtures in Manufacturing, 2015).

2.3.1.1 Gray Cast Iron

Cast irons has been used widely including economical manufacturing processes and it is excellent in friction and wear characterisctics (J.O.Agunsoye, 2014). Majority of industrial automobiles companies manufactured brake disc parts out off gray cast iron. The material is different from the standard steels with more carbon (C) and silicon (Si) (A, 2010). Gray cast iron has a good performance of machining qualities making easily disposed of chips and yielding surface with good wear characteristics (Krause, 1969).

2.3.1.2 Cast Carbon Steel

Most of the steel products starts with castings where it is made from melted iron in electric furnace and recycled steel. Steel is cast into various of sizes and shapes forming from machining, forging or rolling. Besides that, it can be also cast to produce complex components designed from custom moulds (David , Monroe, & Thomas, 2015).

2.3.2 Twin Cutter

The function of this device is to resurface both sides of the brake disc simultaneously. An accurate measurement in both millimetre micrometres and inch set the depth of the cut for inner and out of the rotor surfaces. The twin cutter increases the brake disc face size that can be cut up to 3 to 0.75 inch. A high quality twin cuter can handle a larger diameter of the brake disc (AMMC0, 2008).

2.4 Design Method

2.4.1 Product Design Specifications

This design method is the preliminary need in designing a product that will be the design objective. The main reason for the product design specifications is to make sure the subsequent design and also the development of the product meets the customer requirements (Bermudez, Garcia, & Lozano, 2015). Product Design Specifications is considered as the reference document in designing and manufacturing a product. It should have relevant and realistic constraints to the design and avoid design influence towards a certain concept (Dieter & Schmidt, 2009).

2.4.2 House of Quality (HOQ)

In order to make the product impress the customer, the structure for customer needs in House of Quality is made. That specific section is made through the importance weight for the customer requirements from the experience of customers or the findings from surveys (K. G. Durga Prasad, 2010).

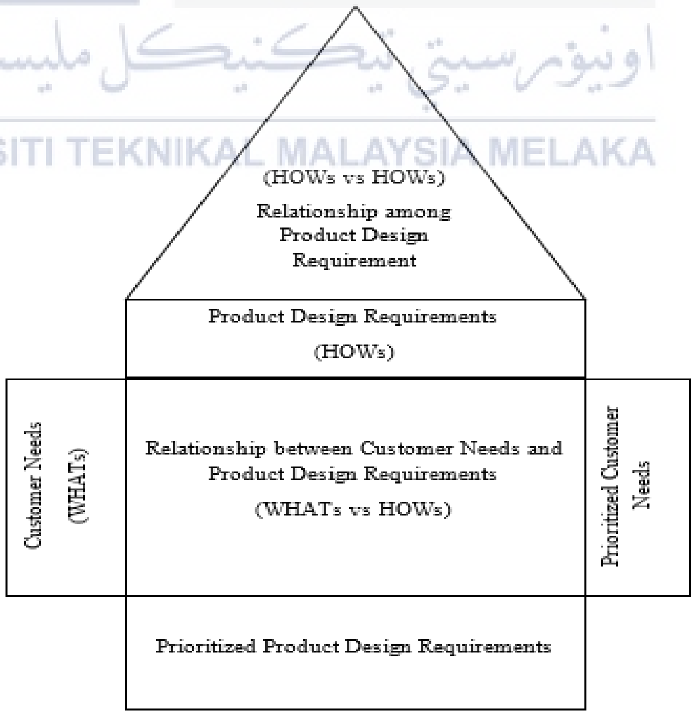


Figure 2.1 : House of Quality

House of quality has a few components which includes the product design requirements (HOWs), customer needs (WHATs), highlighted customer needs, connection from all product design requirements (HOWs vs HOWs), relationship between customer needs and product design requirements (WHATs vs HOWs), connection from all product design requirements (HOWs vs HOWs) and prioritized design requirements (K. G. Durga Prasad, 2010). The relation of design requirements and the customer needs forms the main body of the roof of the HOQ (Rafikul Islam *etal*, 2007). In questionnaire, there is a score need to be given by customer from 1 to 5. Score "1" is the lowest importance while "5" is the highest importance. The level importance is calculated from the customers' answers to the customer requirements. The correlation matrix can be made when the weights of the questionnaire results is obtained for the relation between the voice of customers and the technical requirements (B. Cerit, 2014).

2.4.3 Morphological Chart

The technique to generate idea uses both combination and generation stages for the conceptual design. The combination and generation stages for conceptual design is used in idea generation methods. Morphological chart or concept combination table can be shown in table 2.1 (J. L. Richards, 2011).

Table 2.1 **:** Morphological chart

Function	Means			
F_1	$M_{1,1}$	$M_{1,2}$	$\cdots$	$M_{1,m}$
F_2	$M_{2,1}$	$M_{2,2}$	$\cdots$	$M_{2,m}$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
F_n	$M_{n,1}$	$M_{n,2}$	$\cdots$	$M_{n,m}$

Table 2.1 shows the decomposed sub-functions for the design problem and also the potential of the solutions for the each sub-functions. The answers for the functions can be denoted as means. The table has the coordinate made out of $n \times m$ where n is for the sub-functions and m is for the means. When the means and each

functions is combined, a concept can be produced. By doing the same step with every possible groupings can create a list of concepts (J. L. Richards, 2011).

2.4.4 Weighted Decision Matrix

This method evaluates the concept generated by criteria ranking with the scoring and weight factor. Normally, the design criteria will be ranked firstly with the 5-point scale. The 5-point scale is not very detailed based on the ranking. Then, the ranking will be continued to the 11-point scale where the criteria will be judge more specifically when the information is more complete and this can be referred to table below (Dieter & Schmidt, 2009).

Table 2.2 : Evaluation scheme for design alternatives or objectives

11-point scale	Description	5-point scale	Description
0	Totally useless solution	0	Inadequate
1	Very inadequate solution		
2	Weak solution	1	Weak
3	Poor solution		
4	Tolerable solution	2	Satisfactory
5	Satisfactory solution		
6	Good solution with a few drawbacks	3	Good
7	Good solution		
8	Very good solution		
9	Excellent (exceeds the requirement)	4	Excellent
10	Ideal solution		

2.5 Calculation

2.5.1 Cutting Force

The power required is estimated is for the machine operations, optimizing the specifying the machines (Kutz, 2002). The power used up for cutting can be seen as,

$$F = \frac{P}{V} \quad \textbf{(2.1)}$$

where,

F = Force (N)

P = Power (watt)

V = Velocity (m/s)

$$P = F_C V \quad \textbf{(2.2)}$$

Or

$$P = QW \quad \textbf{(2.3)}$$

where,

P = Power (watt)

F_c = Cutting force (lbf)

V = Cutting speed (sfpm)

$= \pi DN/12$ (rotating operations)

Q = Material removal rate (in^3/min)

W = Specific power required to cut a material (mm^3/sec)

$$HP_C = \frac{F_C V}{33{,}000} \quad \textbf{(2.4)}$$

Or

$$HP_C = QHP_\mu \quad \textbf{(2.5)}$$

where,

HP_c = Cutting horsepower (in^3/min)

F_c = Cutting force (lbf)

V = Cutting speed (sfpm)

$= \pi DN/12$ (rotating operations)

Q = Material removal rate (in^3/min)

HP_μ = Unit horsepower, specific power required to cut a material (mm^3/sec)

From (4)

$$F_C = \frac{HP_C \times 33{,}000}{V} \qquad \textbf{(2.6)}$$

where,

F_c = Cutting force (lbf)

HP_c = Cutting horsepower (in^3/min)

V = Cutting speed (sfpm)

= $\pi DN/12$ (rotating operations)

Since V is in sfpm,

$$rpm = \frac{spm \times 12}{D \times m} \qquad \textbf{(2.7)}$$

where,

D = Diameter (inch)

Therefore from (7),

$$sfpm = \frac{rpm \times D \times \pi}{12} \qquad \textbf{(2.8)}$$

Thus,

$$F_C = \frac{HP_C \times 33{,}000}{\dfrac{rpm \times D \times \pi}{12}} \qquad \textbf{(2.9)}$$

where,

F_c = Cutting force (lbf)

HP_c = Cutting horsepower (in^3/min)

D = Diameter (inch)

Therefore the cutting force should be,

$$F_C = \frac{HP_C \times 33{,}000}{\dfrac{rpm \times D \times \pi}{12}} \qquad \textbf{(2.10)}$$

In order to obtain the cutting force, the value cutting horsepower is needed. Therefore, it can be obtained from the average values of energy per unit material removal rate based on the material used and the Bhn (Kutz, 2002) .

Table 2.3 **:** Average Values of Energy per Unit Material Removal Rate (Kutz, 2002)

Material	Bhn	$HP_c/in.^3\ per\ min$	$W\ /mm^3 per\ sec$
Aluminium alloys	50-100	0.3	0.8
	10-150	0.4	1.1
Cast iron	125-190	0.5	4.4
	190-250	1.6	3.0
Carbon steels	150-200	1.1	3.0
	200-250	1.4	3.8
	250-350	1.6	4.4
Leaded steels	150-175	0.7	1.9
Alloy steels	180-250	1.6	4.4
	250-400	2.4	6.6
Stainless steels	135-275	1.5	4.1
Copper	125-140	1.0	2.7
Copper alloys	100-150	0.8	2.2
Leaded brass	60-120	0.7	1.9
Magnesium alloys	40-70	0.2	0.55
	70-160	0.4	1.1
Nickel alloys	100-350	2.0	5.5
Refractory alloys (Tantalum, Columbium, Molybdenum)	210-230	2.0	5.5
Tungsten	320	3.0	8.0
Titanium alloys	250-375	1.3	3.5

Speed and reference table are the suggested speed and feed ranges based on the diameter of the workpiece or the brake disc. These are only the suggestions and need adjusting in order to find the suitable setting for the application (AMMCO, 2008).

Table 2.4 : Speed and reference table

Workpiece Diameter (inches)	6 to 9	8 to 15	15 & Up
Spindle RPM	200	150	100
Rough Feed	90	50	30
Finish Feed	16	14	12

2.5.2 Factor of Safety

The allowable strength can be obtained from the yield strength that is divided with safety factor (Gope, 2012). Strength is the ability in order to resist failure based on the stress applied. the yield point of a material is a point that shows where a material begins to deform plastically (O.O. Tairu, 2014).

Table 2.5 : Factor of Safety table based on application (The Engineering Toolbox, n.d.)

Equipment	Factor of Safety
Aircraft components	1.5 - 2.5
Boilers	3.5 - 6
Bolts	8.5
Cast-iron wheels	20
Engine components	6 - 8
Heavy duty shafting	10 -12
Lifting equipment – hooks	8 – 9
Pressure vessels	3.5 – 6
Turbine components – static	6 – 8
Turbine components – rotating	2 -3
Spring, large heavy-duty	4.5
Structural steel work in buildings	4 – 6
Structural steel work in bridges	5 – 7
Wire ropes	8 - 9

2.6 Software

2.6.1 Computer Aided Three Interactive Application (CATIA) V5R20

This software is widely used in design engineering where it is from France Dassault Systemes from 1977. Initially, it is used to design the Dassault Mirage fighter jet and then throughout the years it is develop into more than just a Computer Aided Design (CAD). It is capable to do Computer Aided Design (CAD) that allows both two dimensional and three dimensional design, Computer aided Manufacture (CAM) which is related to manufacturing process and Computer Aided Engineering (CAE) that verify analysis of three dimensional models (Patel, 2014).

2.6.2 SolidWorks 2016

SolidWorks simulation of finite element analysis (FEA) is used to analyse the reaction of applied load to a component. FEA enables engineers or designers to analyse and refine designs in a short period of time. Problems such as heat transfer, fluid flow and more an be analyse easily. Mostly, structural analysis problem is used in FEA (SolidWorks Simulation Tutorial, 2012). SolidWorks static simulation of analysis for elastic bodies is a full product line that includes a huge scope of analysis areas. The simulation provide tools for the linear stress analysis for any parts or assemblies that applies static loads (Corporation, 2010). A modelling go through a static analysis in SolidWorks in order to obtain the distribution of static stress at the structure and also the displacement after load is applied to the structure. The process is then followed by the calculation of the safety factor (M.Z.A. Rashid, 2015).

CHAPTER 3

METHODOLOGY

3.1 Product Design Specifications (PDS)

Figure 3.1 **:** Shark A6950 Ammco Style Twin Cutter (Amazon, 2016)

Ammco brands from Hennessy Industries is a USA company that manufactures and sells automotive service equipment and tools including brake lathes. It is one of the most popular brands that manufactures a wheel service equipments. Ammco focuses more on brake lathe and its accessories. Twin cutter (jig) is one of the parts in the brake lathe instead of spindle, shaft and gearbox. Figure 3.1 shows the Shark A6950 Ammco Style twin cutter. This type of twin cutter is used in Ammco model 3850, 4000 and 7000. Figure 3.2 below shows the exploded drawing of the twin cutter. In figure 3.2, an exploded drawing of twin cutter is shown. The drawing labels each components with numbers and tabulate the data in table 3.1. The table contains the number labelled for each component, the part number and its description. It consist f 20 components in total which includes carbide insert, screw, holder, gib, housing, spring, nut, plug, rod, washer, dial and knob.

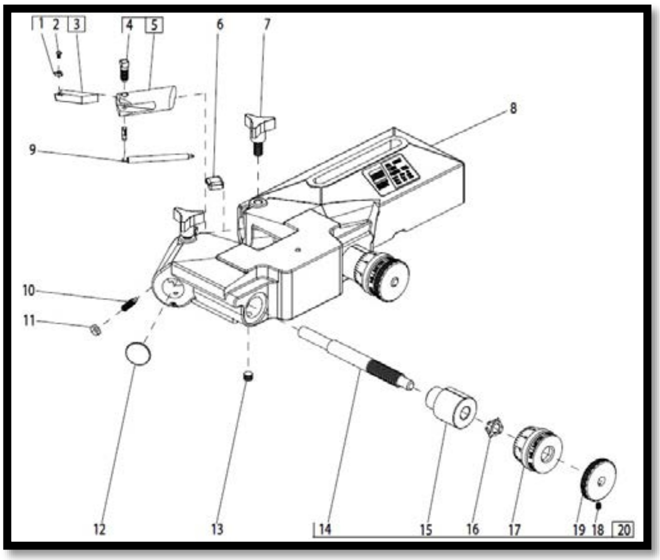


Figure 3.2 : Exploded drawing of A6950 Ammco Style Twin Cutter (Ammco Model 4000E Drum & Disc Brake Lathe, n.d.)

Table 3.1 : Components of the twin cutter (Ammco Model 4000E Drum & Disc Brake Lathe, n.d.)

Item No.	Part No.	Description
1	907681	Carbide Insert, Positive Rake
2	906499	Screw, #4-40 X .25 Oval Head
*3	940559	Holder, Tool Bit, RH, Positive Rake
*	940560	Holder, Tool Bit, LH, Positive Rake
4	909249	Screw, Square Head Set
5	910650	Toolholder, Left Hand
	910651	Toolholder, Right Hand
6	928584	Gib, Brass, Tool Holder
7	906854	Screw, Lock
8	928572	Twin Cutter Housing
9	906905	Spring
10	906879	Screw, Locating
11	903528	Nut, Hex
12	906977	Plug, Dot
13	906109	Screw, 3/16-16 Set
14	906908	Rod, Dial
15	906906	Plug, Dial
16	906929	Washer, Spring
17	906907	Dial, Micrometer
18	903338	Screw, Set
19	906923	Knob, Dial Rod
20	906901	Dial

Table 3.2 **:** Table of specifications for the datum (Ammco Model 4000E Drum & Disc Brake Lathe, n.d.)

Specifications	Parameters	
	Datum	Modified
Model	4000	-
Weight	38.6 pounds / 17.5 kg	33.07 pounds / 15.0 kg
Dimension	Width = 12.90 " / 0.328 m Length = 18.50 " / 0.470 m Height = 8.20 " / 0.208 m	Width = 11.81" / 0.3 m Length = 13.78" / 0.35 m Height = 5.91" / 0.15 m
Properties	• Has two adjustment knob • Has cross slide	• Clamping system • Has cross slide

The main function of twin cutter is to resurface the brake disc surface. Since it is called twin, the brake disc can be clean both surface simultaneously. For this type of twin cutter, it has an Inch and Millimeter micormeters set to adjust the depth of the cut of both brake disc surface. Brake lathe have cutting tools that are used to handle a very hard metals due to its materials. Twin cutter does a more faster job compared to normal single cutter brake lathe there are more than one tools used in the machine when doing the work. Table 3.3 states the specifications of the datum chosen and modified design and the explanation for each specifications are as follows :

1. Model

   This type of twin cutter is used not only in Ammco twin cutter model 4000 but also in 3850 and 7000.

2. Weight

   The 4000 model of twin cutter weights as much as 38.6 pounds which is equal to 17.5 kg and the modified design has the estimation of 15 kg which is lighter than the datum.

3. Dimension

   The datum twin cutter has the width of 0.328 m (12.90 "), length of 0.470 m (18.50") and the height of 0.208 m (8.20"). As for modified design, the size is estimated to be 0.35 m (13.78") in length, 0.3 m (11.81") in width and 0.15 m (5.91") in height.

4. Properties

   As for datum, it has two adjustment knob to adjust the cutting tool and cross slide for the movement of the twin cutter. Meanwhile, the modified jig has a simple clamping system to adjust the cutting tool and a cross slider for the jig movement.

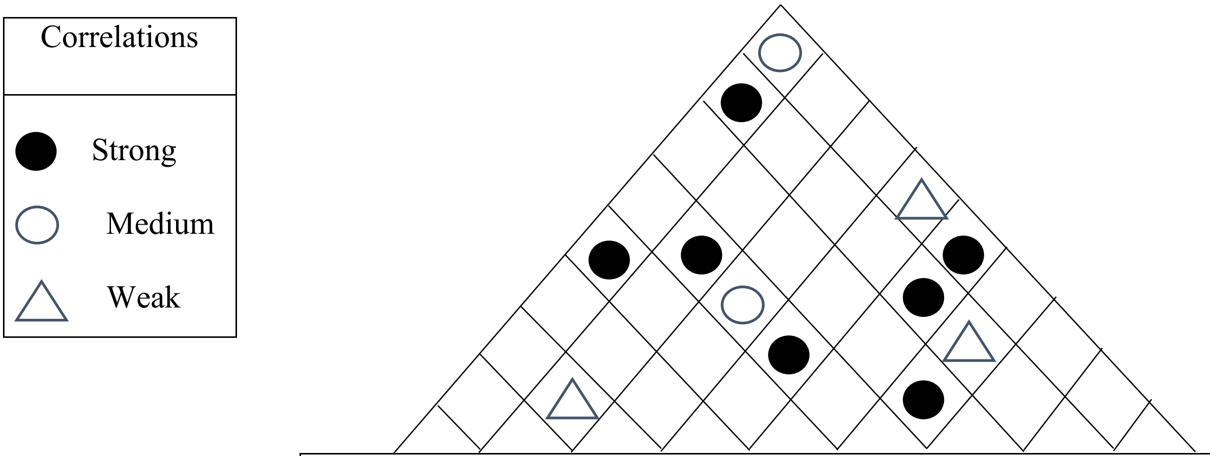
3.2 House Of Quality (HOQ)

House of quality is important to determine the customer needs. In this table, the customer needs or voice of customers need to be match with the engineering characteristics. It converts the customer requirements based on marketing research and benchmarking data into engineering targets that need to be met in designing a product. For the importance of weight, a scale of one to five is made. One shows the least important while five shows the most important. Meanwhile the relationship strength code are measured from a scale of one to nine where one is considered weak, three is medium and nine is strong.

Conflicts matrix is a triangular matrix highlights the relationship among the engineering characteristics. There are symbols indicates the strength of relationship. It tells either it is negative and positive supporting relationship. It is located at the top of the chart. The relationship matrix is the relations between the Engineering Characteristics and customer requirements. The evaluation must be done thoroughly based on consumers response regarding on the product, engineering field experience and the findings from studies and experiments. There are different level of strength of relationship and it uses symbols to notify. There are strong relationship, medium relationship and weak relationship (Jimenez, 2007).

Engineering characteristic importance rating is the strength of the relationship between engineering characteristics and customer requirements. The correlations value are 9 shows a strong relationship, 3 is medium relationship and 1 as weak relationship (Jimenez, 2007).

Table 3.3 : House of Quality table



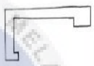
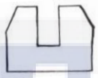
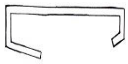
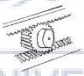
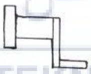
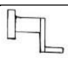
Customer Requirements	Importance weight	Durability	Less hand operation	Adjustable	Cost	Material	Design	Reliability	Robustness	Resistance to corrosion
	Engineering characteristics									
Long lasting	6	9			1	3	3	9	3	3
Easy grip on disc brake	7		1				9		1	
Difficulty of making	5				3	1	9			
Easy to handle	6		3	3			1		1	
Suitable in size	4		1				3			
Ease of maintenance	4	3						3		
Ease of mobility	3		1	3			9			
Raw score		66	32	27	21	23	171	66	31	18
Relative weight %		14.5	7.0	5.9	4.6	5.0	37.6	14.5	6.8	4.0
Rank order		2	3	5	6	7	1	2	4	8

The relationship strength code are then calculate into raw score and find its percentage in relative weight. As a result, rank order is obtained. To obtain the raw score, the correlation of the relationship matrix is multiplied by the importance weight and total at the section provided. The relative score is the raw score divided by total raw score and multiple by 100%. The rank order is arranged based on the value of relative weight from the highest value to the lowest value. Based on table 3.1, the highest rank goes to the design and followed by the durability, less hand operation, robustness, adjustable, cost, material and finally resistance to corrosion.

3.3 Morphological Chart

The term 'morpho' brings the meaning of shape. It is a method of analysis that creates new form. Different components combinations can be found that can fulfil the same function in a new product. This method helps the designers to discover the combinations of the components before it is generated. Firstly the overall design will be divided into simpler problems. Then, solution concepts will be generated for each simpler problems. Finally, the simpler problem will be combine into a few different solutions systematically. This approach into engineering design starts with functional composition of the problems into a more detail structure (Dieter & Schmidt, 2009).

Table 3.4 **:** Morphological chart

Criteria	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Body						
Lock	With lock	Without lock				
sMotion system (cutting tool)						
Motion system (jig)		None				
Cutting tool	Single	Twin				

In this cutting tool jig design, there are five criteria tabulated which consists of body, lock, motion system for the cutting jig and jig body and the cutting tool. The jig body has six options in total with different shapes. Lock criteria is about the presence of locking system at the adjustment of the cutting tool. This means, after the cutting tool is adjusted its position is there any presence of locking system in order to fix the cutting tool position. For motion system of the cutting tool, there are three options which applies the double rack gear for the first option, clamping system for the second option and manual adjust for the third option.

The double rack gear system involves two cutting tools that adjusted simultaneously in one input motion. The clamping system has the same application to the workpiece clamp table for fabrication. As for manual, the cutting tool is adjusted manually by hand. In motion system for jig is about what kind of approach used by the concept for the movement of the jig body either clamping system or none (based on the morphological chart). Lastly, cutting tool has two options either a single cutting tool is used or twin type or two cutting tool used.

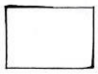
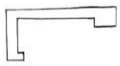
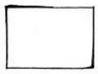
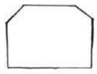
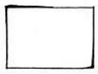
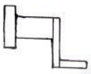
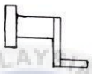
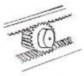
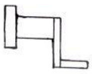
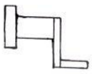
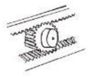
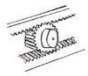
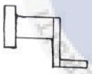
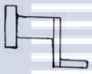
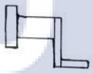
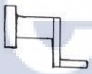
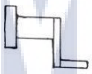
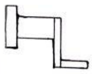
3.4 Conceptual Design

3.4.1 Conceptual design table

This design process is started and create numbers of any possible solutions into best concepts. It is a phase that need a high creativity that requires the coordination of many functions (Dieter & Schmidt, 2009). For conceptual design, solution is created. In the conceptual design concept, it is initiated with the examination of the specifications and design of problem statement. The step is followed by function decomposition and producing solutions. Solutions is a sub-function that are combined and identified in order to produce a conceptual design or working arrangement. The designs will be evaluated and solution is made (Summers & Mocko, 2006).

From the table below, eight concepts are able to generate through the morphological chart made at the previous subtopic. The combinations of the designs of each of the criteria is done through mix and matching and manage to come up with possible solutions and tabulated according to categories and concepts.

Table 3.5 : Conceptual design table

Criteria	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	Concept 7	Concept 8
Body								
Lock	With lock	With lock	Without lock	Without lock	With lock	With lock	With lock	With lock
Motion system (cutting tool)								
Motion system (jig)			None					None
Cutting tool	Twin	Twin	Twin	Twin	Single	Twin	Twin	Twin

Each of the eight concepts will be describe in the next section specifically by criteria and its functions or how or how it works.

3.4.2 Concept description

3.4.2.1 Datum

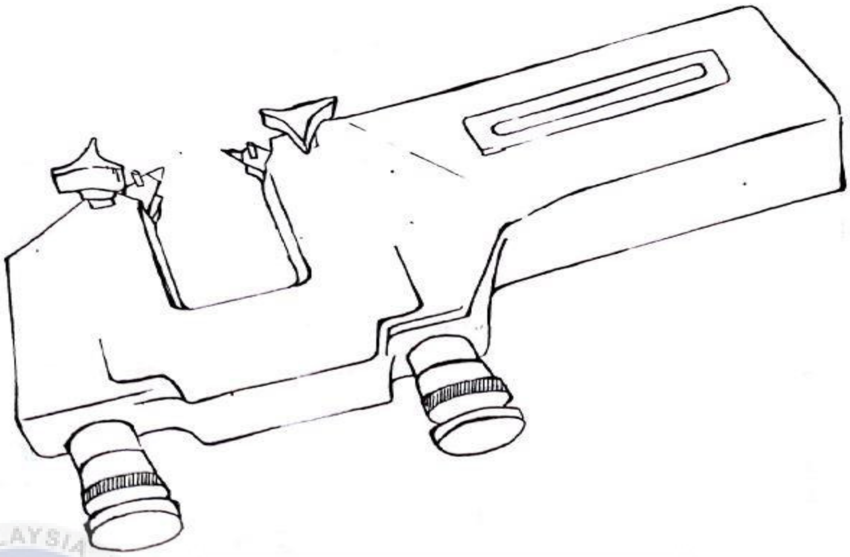


Figure 3.3 : Datum

In datum, there is a unique jig body shape used to hold compartment into places properly. There are twin cutter used in this concept to make the work faster and easier. Both twin cutter are set with lock placed on the above of the cutting tool. These lock enables the cutting tool to be fix in position and does not move. The datum also fix with adjustment knob to adjust the position of the cutting tool. The adjustment knob is set with inch and millimetre unit so that a more accurate result can be obtained.

3.4.2.2 Concept 1

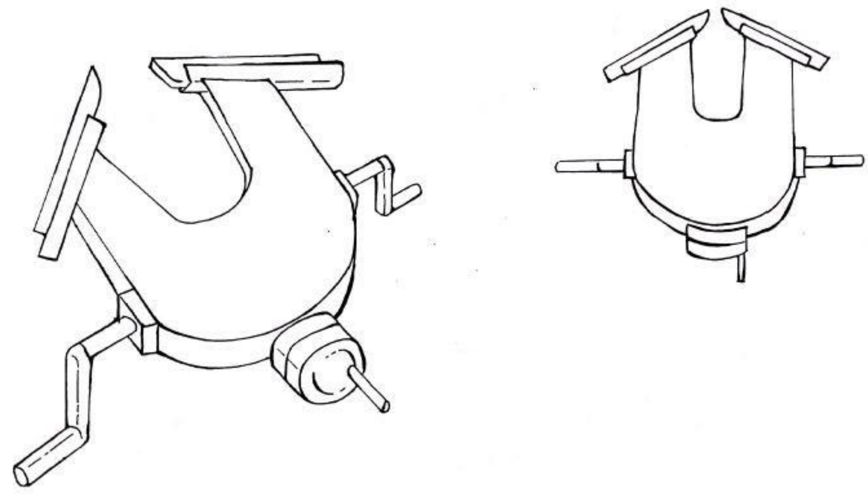
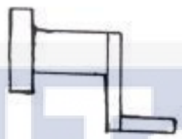
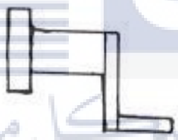


Figure 3.4 **:** Concept 1



Body : Option 1   Motion system (cutting tool) : Option 2



Lock : Option 1

Motion system (jig) : Option 1   Cutting tool : Option 2

In concept 1, the body chosen is option 1, with the presence of locking system, motion system of cutting tool is option 2, motion of jig is option 1 and uses twin type cutting tool. Concept 1 has a u-shape jig body. Two cutting tool are installed outside the body and is connected with clamp system for adjustment. The clamp system is a simple that applies full manually hand operation to set the distance of the tool to the brake disc. This concept is design with the presence of locking system to make the tool fixed and do not move when the machine is operating. The jig use cross slide or clamping system too for the movement of the jig body. Two cutting tool is used in order to make the work runs faster.

3.4.2.3 Concept 2

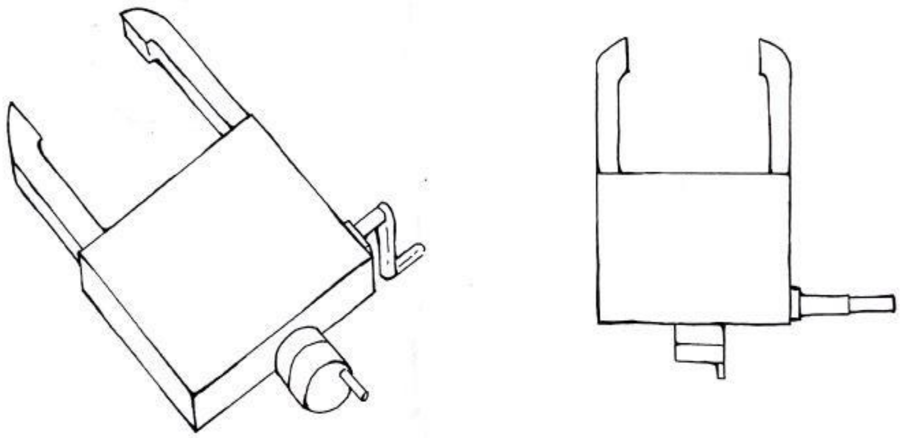
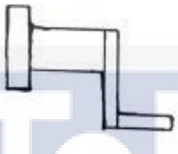
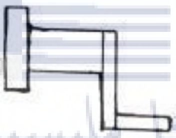


Figure 3.5 : Concept 2

Body : Option 4



Motion system (cutting tool) : Option 2



Motion system (jig) : Option 1

Lock : Option 1

Cutting tool : Option 2

Concept 2 uses option 4 as the body shape, with the presence of locking system, the motion of system of cutting tool uses option 2, the motion system of jig body is option 1 and applies twin type cutting tool. This concept uses a very simple square shape for the appearance of the jig body. It uses two cutting tools where the cutting tool on the left is fixed or does not move and only the cutting tool on the right can be adjusted. Therefore, the clamping system only applied on the right side of the jig for the right side cutting tool. The jig uses cross slide or clamping system for the jig body movement.

3.4.2.4 Concept 3

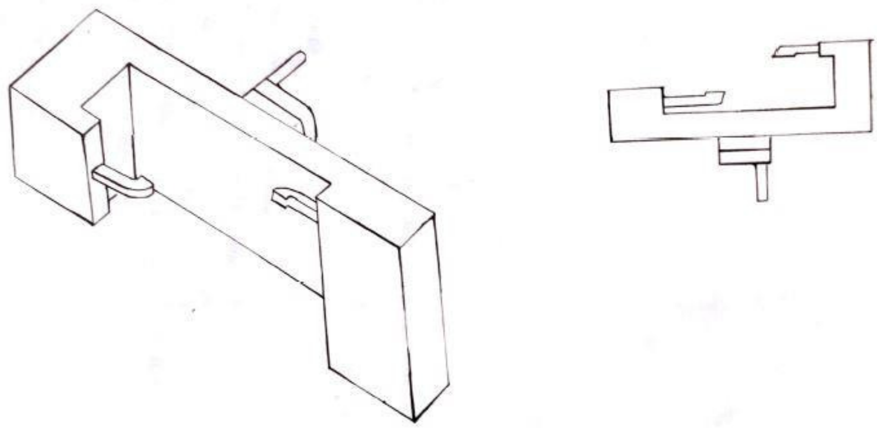
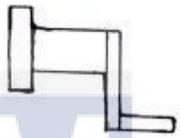


Figure 3.6 **:** Concept 3



Body : Option 2 Motion system (cutting tool) : Option 2

Motion system (jig) : Option 1 Lock : Option 2

Cutting tool : Option 2

Concept 3 uses option 2 as body shape, with the absent of locking system, using option 1 as motion system for cutting tool, option 2 for jig body motion system and twin type cutting tool. Concept 3 uses the double rack gear system to the cutting tool. The cutting tool moves horizontally and simultaneously when the first gear rotates. It does not have locking system. Once the brake disc is placed at the space provide, the rack gear will be turn and the cutting tools will move towards the jig follows the gear motion. When the machine is turn on, the rack gear will be slowly turn to perform skimming process. The brake disc will be skimmed simultaneously on both side.

3.4.2.5 Concept 4

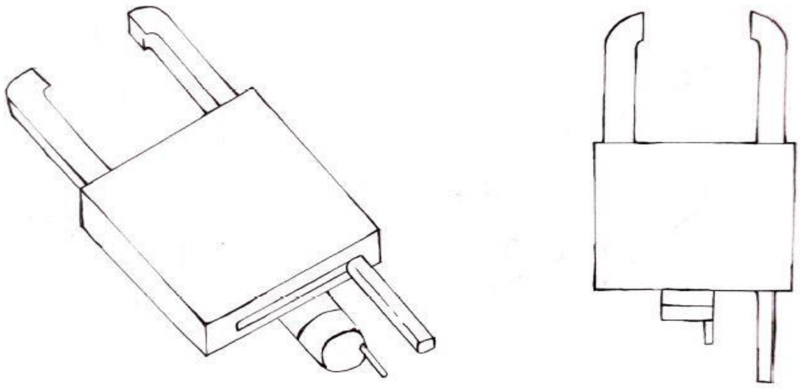
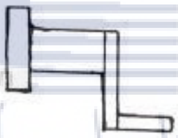


Figure 3.7 **:** Concept 4

Body : Option 4

Motion system (cutting tool : Option 3



Lock : Option 2

Motion system (jig) : Option 1

Cutting tool : Option 2

Concept 4 uses option 4 as the jig body, with the absence of locking system, using option 3 as the motion system of the cutting tool, option 1 for motion system of jig body, and using twin type cutting tool. This concept uses manual movement in positioning the cutting tool but only one cutting tool can be adjusted as the other one is in fixed position. It uses a very simple option of jig body shape which is a square shape and a simple clamping system for the movement of jig body. One side of the cutting tool will be pulled towards the brake disc before skimming and then turn the cross slide to make the jig move forward or backward.

3.4.2.6 Concept 5

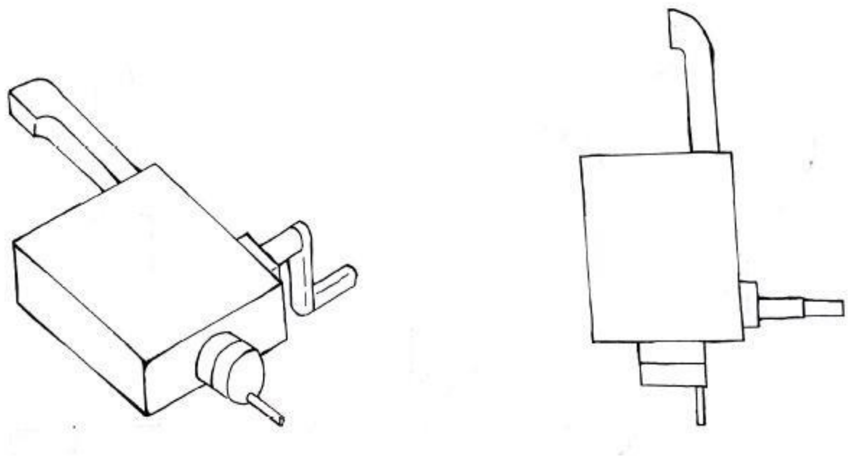
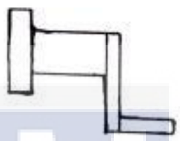
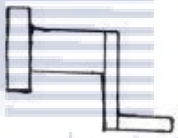


Figure 3.8 **:** Concept 5

Body : Option 4



Motion system (cutting tool) : Option 2



Motion system (jig) : Option 1

Lock : Option 1

Cutting tool : Option 1

Concept 5 uses option 4 as jig body, with locking system, option 2 for cutting tool motion system, option 1 for jig body motion system, and using single type cutting tool. As for concept 5, only one cutting tool is used. Due to that only one side of the brake disc can be skimmed at one time. The jig uses the clamping system to adjust the tool jig position and cross slide for the jig body to move towards or away from the brake disc. It uses a simple design that makes the jig look smaller than the datum or other design.

3.4.2.7 Concept 6

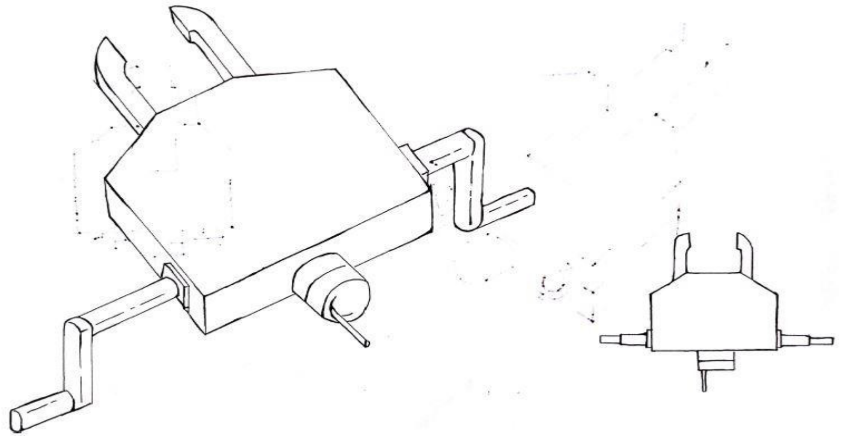
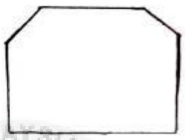
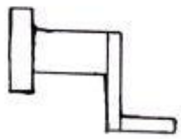
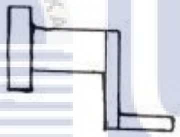


Figure 3.9 **:** Concept 7





Body : Option 4 Motion system (cutting tool) : Option 2



Lock : Option 1

Motion system (jig) : Option 1 Cutting tool : Option 1

Concept 6 applies option 6 for jig body, with locking system, option 2 for motion system of cutting tool, option 1 for jig, and using twin type cutting tool. This concept use two clamp system, one for the movement of cutting tool and the other one is for the movement of the jig body. The shape of the jig uses option 4 and locking system is installed in this type of jig. There are two cutting tools used for easier and faster job. Locking system is used after the cutting tools position is adjusted.

3.4.2.8 Concept 7

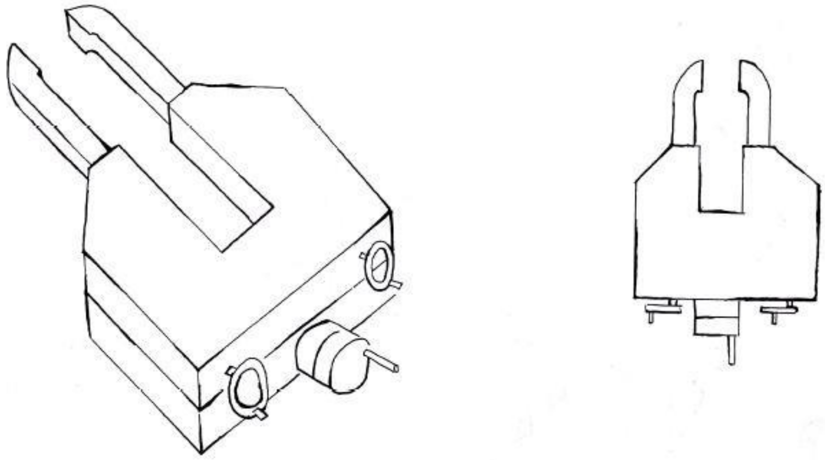
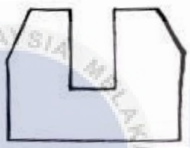
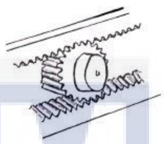


Figure 3.10 **:** Concept 7





Body : Option 5 Motion system (cutting tool) : Option 1

Lock : Option 1

Motion system (jig) : Option 1 Cutting tool : Option 2

As for concept 7, it uses option 5 for shape of body, with lock, option 1 for motion system of cutting tool and jig with twin cutting tool. In concept 7, rack gear system is applied to both jig. This type of gear enables both side of the brake disc surface to be skimmed at the same time. This type of jig is easier to use and save time. The movement of the jig body uses cross slide or clamping system and the body shape uses option 5.

3.4.2.9 Concept 8

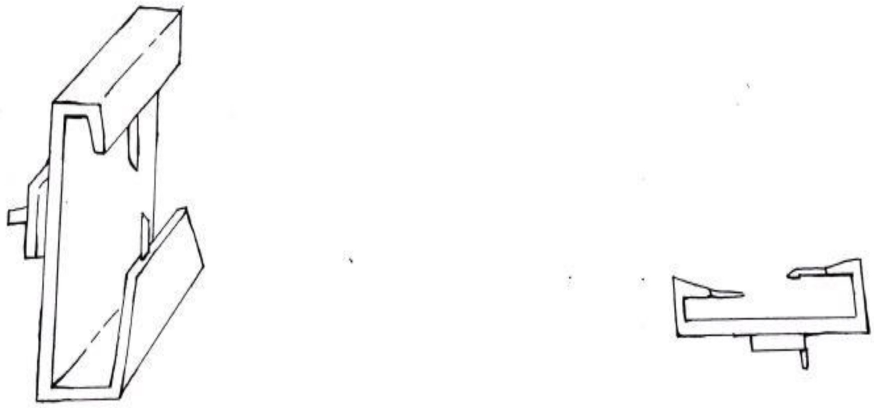
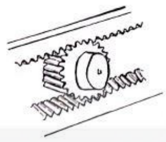


Figure 3.11 : Concept 8



Body : Option 6 Motion system (cutting tool) : Option 1

Motion system (jig) : Option 2 Cutting tool : Option 2

Lock : Option 1

Last concept uses option 6 for jig body shape, with lock, option 1 for motion system cutting tool, option 2 for jig movement and uses twin cutting tool. This concept is almost similar to concept 3 only the difference is in concept 3 the cutting tool move horizontally while on concept 8 it move vertically. The jig body shape is slightly the same as the concept 3. The jig is installed with two cutting tools and it is placed on both sides of brake disc. Double rack gear is applied in this design and two cutting tool is used where it will move simultaneously with different direction during skimming process. Therefore, the jig body movement is not needed.

3.5 Weight Decision Matrix

In weight decision matrix three best design will be chosen out of all the eight concept generated. Firstly, the criteria of the cutting tool jig is listed and decide the priority. The higher the priority the larger the number. In this project, the criteria listed are quality in service, operation and design & production. Below quality in service are smooth performance, safety and maintenance. For operation, ease of assembly, ease of use and adjustable and as for design & production are simplicity of design, size and difficulty of manufacturing. The weigh factor is determine and calculated from the criteria and sub-criteria obtained. Next, score the sub-criteria based on the evaluation scheme on table 2.2 in chapter 2. The table shows position of the sub-criteria based on its contribution or function to the cutting tool jig for skimming machine designed.

Figure 3.12 shows an objective tree for the design of cutting tool jig for skimming machine to determine the weight factor. The objective tree is broken down into three parts which are quality in service, operation and design& production. At the first level, quality in service is at 0.5, operation is 0.3 and design & production are 0.2. For the next level, it is easier to decide the weights as the chart is divided in to more parts than the first level.

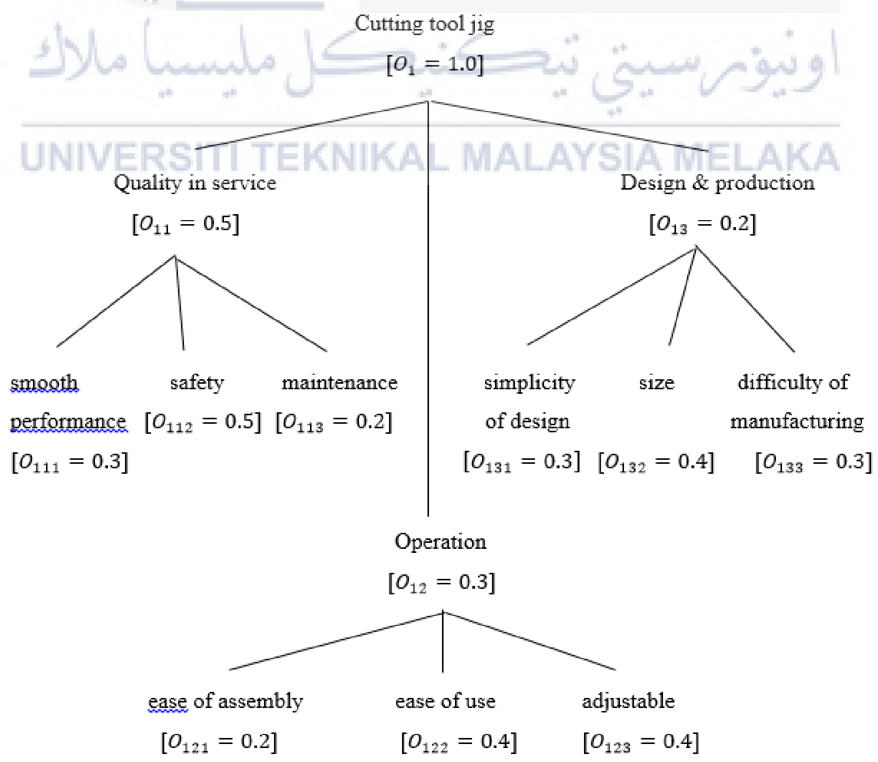


Figure 3.12 : Objective tree for the design of cutting tool jig for skimming machine

Table 3.6 : Weight decision matrix for cutting tool jig

Design criterion	Weight factor	Concept 1		Concept 2		Concept 3		Concept 4		Concept 5		Concept 6		Concept 7		Concept 8	
		Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating
Smooth performance	0.15	7	1.05	4	0.60	9	1.35	3	0.45	2	0.20	6	0.90	8	1.20	8	1.2
Safety	0.25	4	1.00	6	1.50	8	2.00	4	1.00	5	1.25	4	1.00	7	1.75	6	1.5
Maintenance	0.10	3	0.30	4	0.40	7	0.70	5	0.50	6	0.60	3	0.30	7	0.70	7	0.70
Ease of assembly	0.06	4	0.24	8	0.48	8	0.48	6	0.36	6	0.36	4	0.24	5	0.30	6	0.36
Ease of use	0.12	6	0.72	4	0.48	8	0.96	2	0.24	5	0.60	6	0.72	7	0.84	6	0.72
Adjustable	0.12	9	1.08	4	0.48	8	0.96	6	0.72	4	0.48	9	1.08	8	0.96	6	0.72
Simplicity of design	0.06	6	0.36	7	0.42	8	0.48	7	0.42	7	0.42	7	0.42	6	0.36	6	0.36
Size	0.08	6	0.48	6	0.48	4	0.32	6	0.48	7	0.56	6	0.48	5	0.40	4	0.32
Difficulty of manufacturing	0.08	6	0.36	4	0.24	5	0.30	7	0.42	6	0.36	5	0.30	7	0.56	8	0.48
Total			5.59		5.08		7.55		4.59		4.83		5.44		7.07		6.36

Based on the Weight decision matrix table, there are nine design criterion listed from the objective tree which includes smooth performance, safety, maintenance, ease of assembly, ease of use, adjustable, simplicity of design, size and difficulty of manufacturing. In order to obtain the weight factor listed in the table, the first level in the objective tree need to divide with the second level. The step is followed by setting the score of the design criterion for each concept. The rating is obtained by multiple the weight factor with the score and the total of the rating is calculated with all concept. Three highest value of the total ranking is selected as best three designs and the designs are concept 3, concept 7 and concept 8.

3.6 Calculations

The objective of the calculation is to determine the force applied to the jig by the cutting tool. The forces are from the rotating brake disc during the skimming process. Certain force are applied or received based on a few factors such as the horsepower of a motor, the speed of rotation etc. The calculation shown below describes how the forces applied is obtained.

Unit conversion used in this calculation,

1 lbs = 4.44822 N

1 cm = 0.394 inch

1 m = 100 cm

In chapter 2, derivation of the calculation has been stated where it starts from force that is obtained from power divide with velocity. After derivation, the cutting force will be as mention in Equation (2.10). Based on the table 2.2, the material used for brake disc is cast iron class 125 (standard), the $HP_c = 0.5\ in^3/min$. Since the diameter of brake disc is 0.25 m or 9.85 inch, the rpm should be referred at the table 2.3. Diameter of brake disc is between 8 inch to 15 inch, therefore the spindle rpm used will be 150 rpm.

Therefore, the calculation will be as below,

$$F_C = \frac{HP_C \times 33{,}000}{\frac{rpm \times D \times \pi}{12}}$$

$$F_C = \frac{0.5 \times 33{,}000}{\frac{150rpm \times 9.85'' \times \pi}{12}}$$

$$= 42.66lbs$$

$$= 189.75N$$

Based on the calculations, the cutting force applied to each cutting tool is 189.75 N.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Detail drawing

Detail drawing in engineering design are important. It is the final step in designing certain product. The drawing contains simple information regarding of the product design and the most important element need to be inserted is the dimensions. Dimensions are important as detail drawing also functioned as a guide for fabrication.

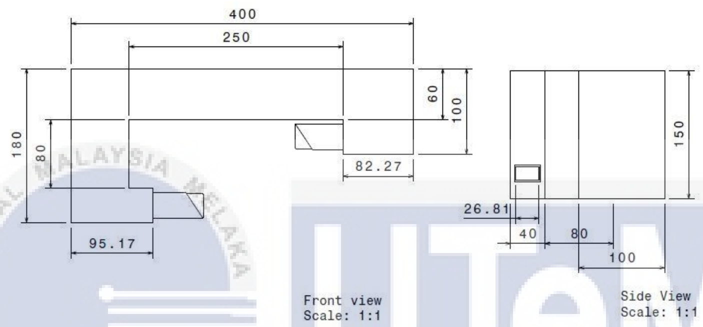


Figure 4.1 : Detail drawing for design 3

The basic dimension for design 3 is 180 mm × 400 mm and the cutting tool holder part is added. The part has one closer to the body and another is 80 mm further form the body. The width of the first cutting tool holder is about 40 mm while the other cutting tool holder is 180mm. As for the thickness the jig body is extended to 90 mm. The jig body is made in one part and assemble with the cutting tool jig.

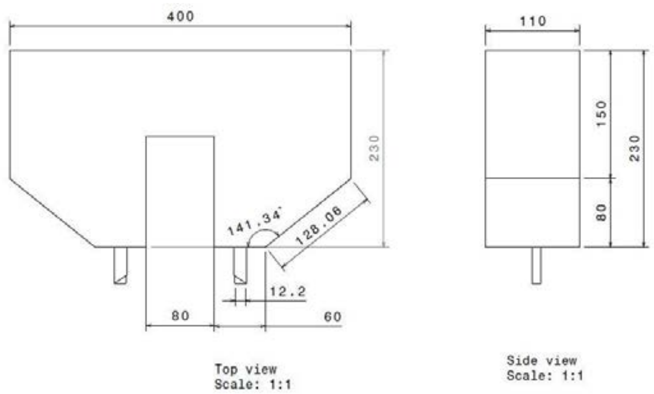


Figure 4.2 **:** Detail drawing for design 7

The basic dimension for this design is 400 mm × 230 mm. The cutting tool holder is made vertically for both side. The holders are 80 mm apart so that the brake disc can be inserted easily and the place for putting the cutting tool is 60 mm width. The thickness of the jig body is 110 mm thick and the side length is 230 mm. For this design, there are angle included as there are slope line with 128.06 mm in length and 38.66˚ or close to 39˚ from the outer horizontal line. It is the same with design 3 where the jig body is made in one part and assemble by using offset constraints of 0 mm with the cutting tool.

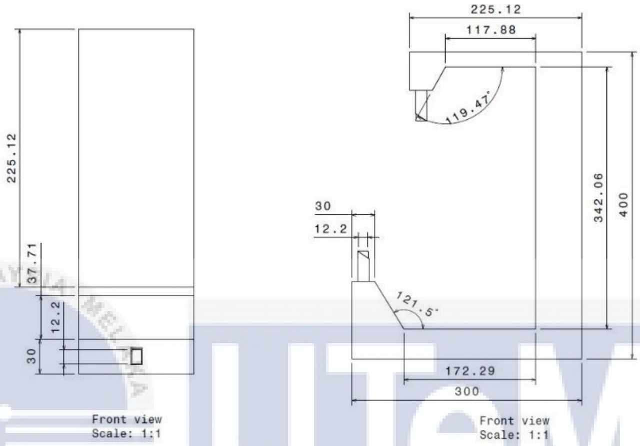


Figure 4.3 : Detail drawing for design 8

The design 8 is made up of 400 mm × 300 mm of outer dimension added with two vertically attached cutting tool holder. The first holder is 117.88 mm apart from the body while the second holder is 172.29 mm from the body with the same thickness as the first holder which is 30 mm. the uniqueness of the design is it is made vertically instead of horizontally.

4.2 Analysis of Conceptual Design

4.2.1 Finite Element Analysis

Based on the previous chapter, three best design have been chosen by the design method of weight selection matrix and as a result design 3, design 7 and design 8 are chosen. The next step is to find the force applied to the jig and do finite element analysis to determine the allowable stress. The reason to find the allowable stress is to search for the factor of safety of the design.

In this case, finite element analysis is done by using SolidWorks 2016 as it has more specific materials. The designs consists of two parts which are the jig body and cutting tool part. The material used for jig body is gray cast iron while for cutting tool is cast carbon steel. Firstly the drawings are done by using CATIA software V5R20 and converted to .igs format before it is transferred to SolidWorks 2016 for analysis.

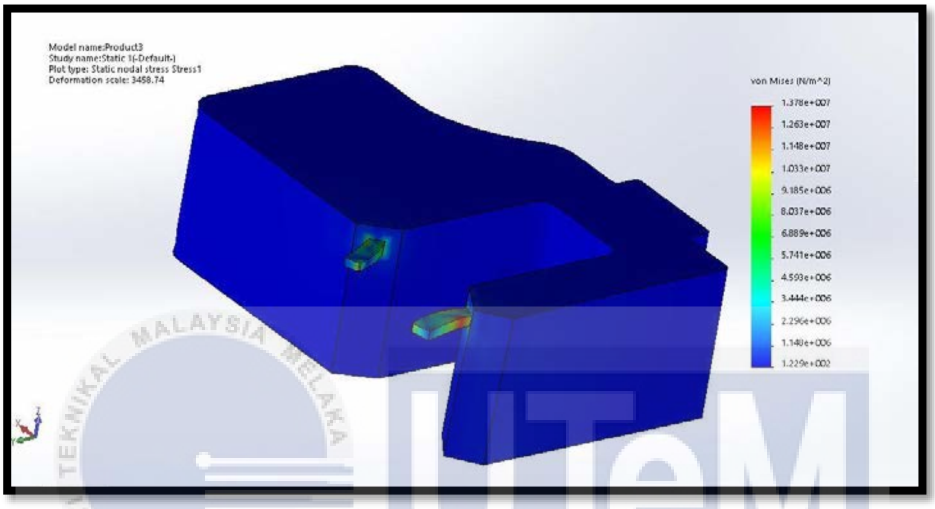


Figure 4.4 : Maximum Von Mises Stress on Datum

For each part of the drawing, one fixed part is selected and two force is applied at different direction based on the cutting tool. Before that, materials need to applied first to each part before any actions are taken. The force applied is the force calculated on chapter 3. When fixed part and applied force has been decided, the drawing can be mesh and run to obtain result. Figure 4.4, 4.5, 4.6 and 4.7 shows the Von Mises stress obtained by each design including datum. The Von Mises can be seen by colour orders where red colour indicates the highest Von Mises stress obtained and dark blue colour indicates the lowest Von Mises stress.

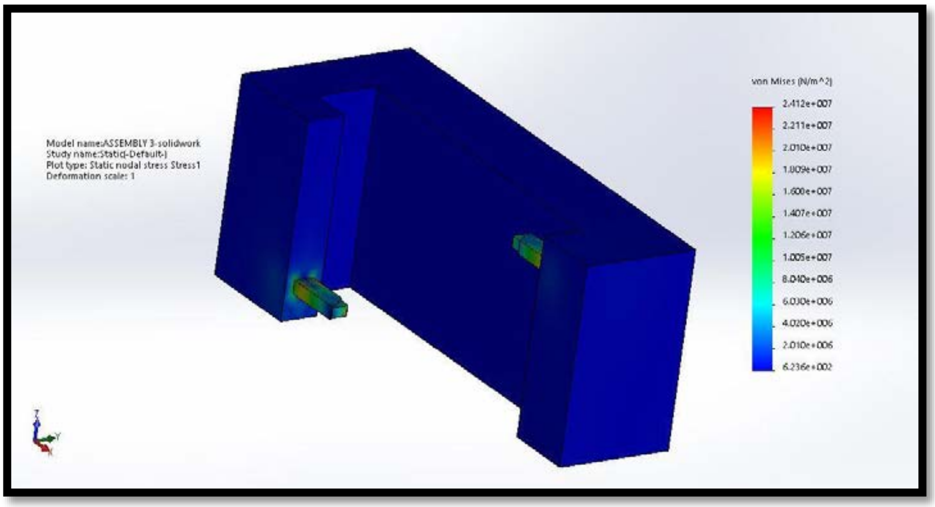


Figure 4.5 : Maximum Von Mises Stress on Design 3

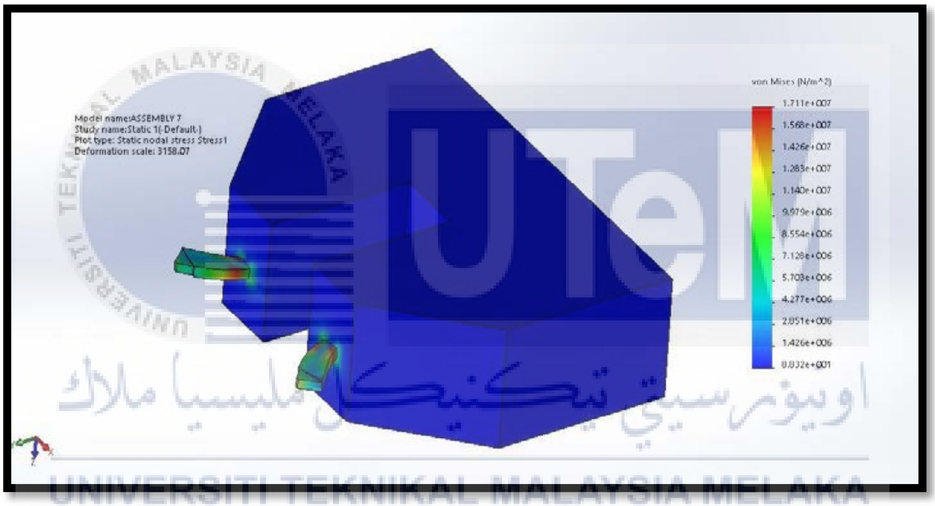


Figure 4.6 **:** Maximum Von Mises Stress on Design 7

Based on the figure shown, the design has different Von Mises stress based on the various designs.

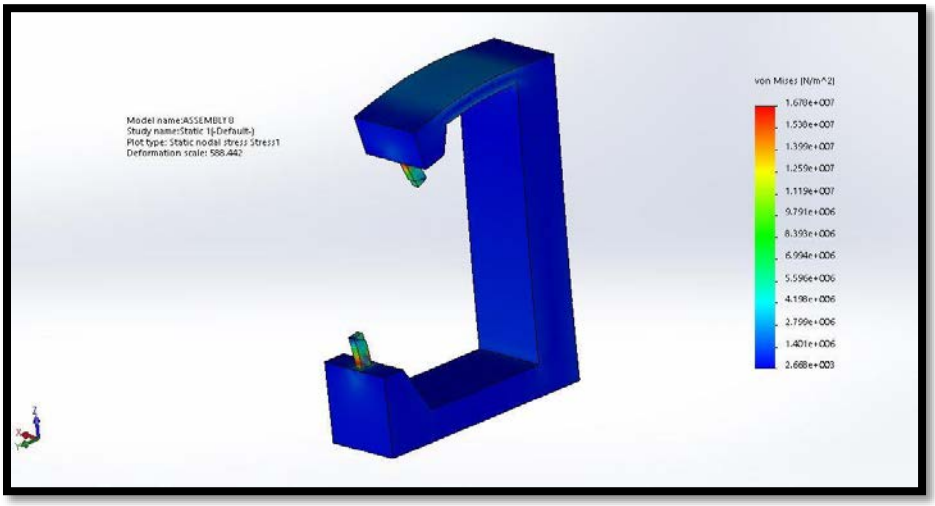


Figure 4.7 **:** Maximum Von Mises Stress on Design 8

4.3 Safety Factor

Safety factor of factor of safety (FOS) is the measure of a product sustain certain loads based on the different applications. Different applications shows different optimum safety factors obtained. Table below shows how the value of safety factor varies with the equipment.

Since cutting tool jig for skimming machine is a heavy duty equipment, the factor of safety range used is between 10–12 which is similar to heavy duty shafting.

$$Factor\ of\ Safety = \frac{Yield\ Stress, \sigma_y}{Allowable\ Stress, \sigma_{allow}} \tag{4.1}$$

The above equation is applied to each design to obtain factor of safety. The allowable stress is the maximum Von Mises stress applied to the design and the yield strength is based on the material used. The material used for jig design is gray cast iron and the yield strength is 248,618,000 Pa or 248 MPa. Table 4.1 shows the factor of safety obtain for datum, deign 3, design 7 and design 8.

Table 4.1 : Factor of Safety for each design

DESIGN	MAXIMUM VON MISES STRESS (MPa)	YIELD STRESS (MPa)	FACTOR OF SAFETY
Datum	13.78	248.168	18
Design 3	24.12	248.168	10.29
Design 7	17.11	248.168	14.5
Design 8	16.78	248.168	14.79

Based on the table, the datum has the highest safety factor of 18 which is above the safe limit or beyond 12. Therefore, we do not have to worry about its safety. Comparing the three best designs, design 3 has the lowest value which is 10.29. It is slightly above 10 which is close to the unsafe zone. Design 7 has the safety factor of 14.5 and design 8 is with 14.79 which both has a higher safety factor value than the range needed. This is considered safe.

Table 4.2 : Weight decision matrix table for design 7 and 8

Design Criterion	Weight factor	Design 7		Design 8	
		Score	Rating	Score	Rating
Safety	0.25	7	1.75	6	1.5
Ease of use	0.12	7	0.84	6	0.72
Adjustable	0.12	8	0.96	6	0.72
Total			3.55		1.8

Since design 7 and 8 has equal quality in terms of safety factor, another comparison is made based on the weight selection matrix that have been done in chapter 3. The comparison is made by using the three highest weight factor in the table which are safety, ease of use and adjustable. Compared to design 8, design 7 has a higher value for both score and rating. The same result for total rating, design has a higher value of 3.55 compared to design 8 with 1.8. Based on the criteria and reasons stated, design 7 is chosen as the best design for cutting tool jig for skimming machine.

4.4 Design Optimization

The function of design optimization is to improve a product design in terms of either performance, appearance, functions etc. Optimization can be done in many ways. In this case, the size and thickness of the jig is modified in order to obtain a more a safety factor within ten to twelve.

Table 4.3 : Difference in thickness and size for both original and modified design

Parts	Original (cm)	Modified (cm)
Side length	15	14
Upper side length	12	13
Cutting tool holder length	6	5
Thickness	5	6.4

Based on table 4.2 it can be shown that, dimensions and thickness of a design can affect the safety factor of a product. Figure below shows the change of the dimensions of the jig design 7.

Figure 4.8 **:** Dimension for original design of design 7

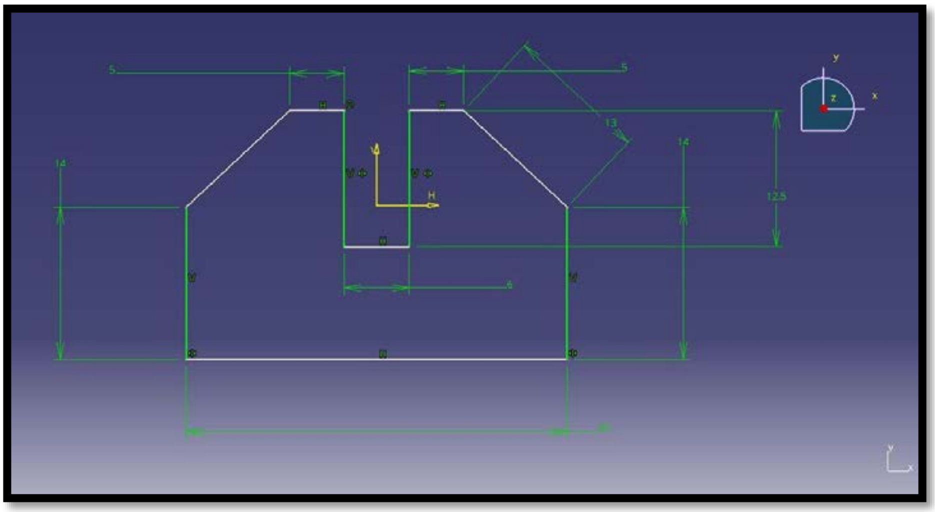


Figure 4.9 : Dimension for modified design of design 7

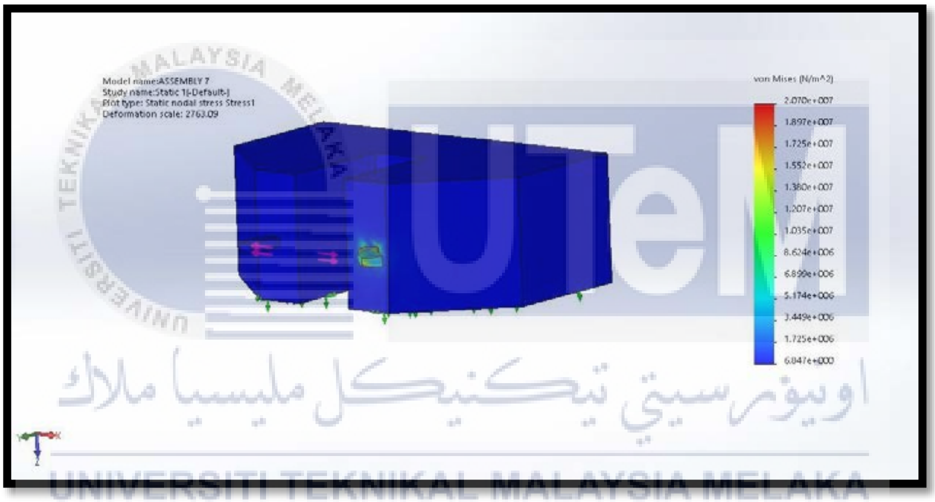


Figure 4.10 : Maximum Von Mises stress for modified design 7

The maximum Von Mises stress of modified design 7 is $2.07 \times 10^7 Pa$ or 20.7 MPa while the factor of safety obtained is 11.99 which is within the safety range for a heavy duty component.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the cutting tool jig for skimming machine is designed by using the engineering design method. Firstly, Product Design Specifications is made to state the standard design for the jig for example the average dimensions, weight and other specification required to design cutting tool jig. House of Quality (HOQ) is generated to know the customer needs and supports the Product Design Specifications (PDS). From HOQ and PDS, morphological chart is produced in order to generate ideas for each part of the jig. Next, conceptual design table is made from the mix and match of parts in morphological chart. Eight different designs obtained from the conceptual design table. In order to select three best design, Weight Selection Matrix method is done. Based on a few considerations and calculations, three highest ranks out of the eight design is obtained and go through to next step. Cutting force is calculated by using specific formulas and referring certain tables based on the application of the jig.

The cutting force obtained is 189.75 N and it is applied to each of the three best design to get its safety factor. The safety factor can be found by dividing the yield strength of a specific materials with the allowable stress or in this case is considered as the maximum Von Mises stress. The standard safety factor for cutting tool jig is between ten to twelve. Design 7 is the most suitable design to e select based on its safety factor of 14.5. Although the value of safety factor is beyond range, but it can be optimize to improve the design. The process is followed by the optimization of the selected final design. The optimization process is done by changing the dimensions and thickness of the product. Therefore, the factor safety of 14,5 can be optimize to 11.99 with the maximum Von Mises stress of 20.7 MPa. Lastly, detail drawing of the modified design 7 and the simulation is made. The detail drawing is made to show the dimensions and the figure of the final design clearly while the simulation is made to show the movement or reaction of the jig and the cutting tools.

5.2 Recommendations

There are a few recommendations that can be stated for future research in designing the cutting tool jig for skimming machine. In terms of design, future researchers can make a different design concept. Since, most of the jig design in this research are vertically designed, a horizontally design can be done. Furthermore, the specifications can be added more so that the design limit can be known clearly by the design engineers. Besides that, more specifications or parts of the cutting tool jig can be added so that the jig can be seen at a more innovative stage. In addition, the analysis can be made by other software to widen the knowledge of static analysis. The finite element analysis can may be applied in ANSYS software and as for the movement or reaction of the jig, SolidWorks can may be used. Moreover, for future studies, usage of material can be done following the sustainability development concept in order to safe the environment.

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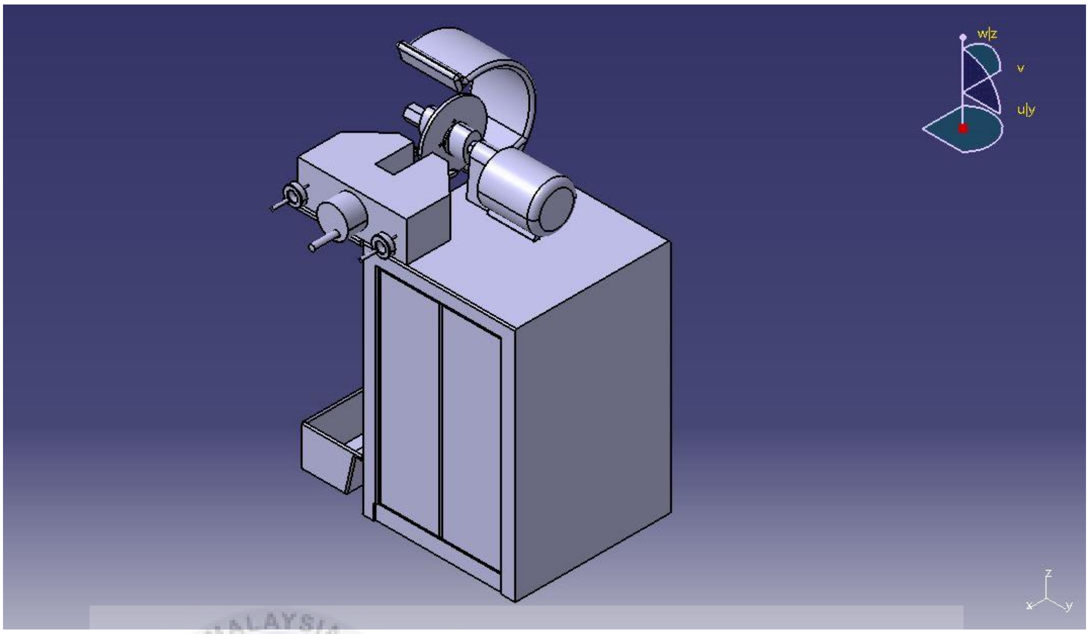
APPENDIX A

A Fully assembled skimming machine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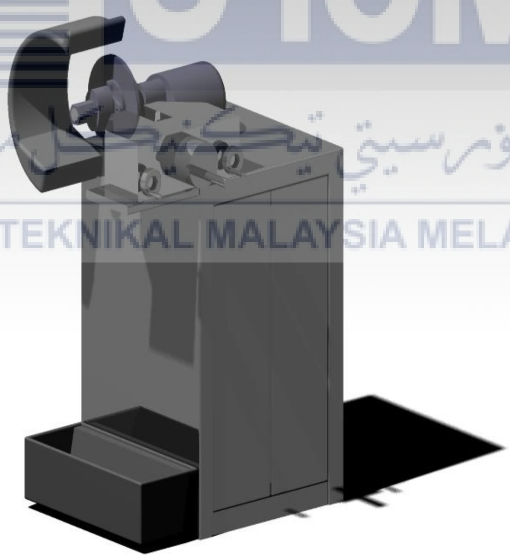
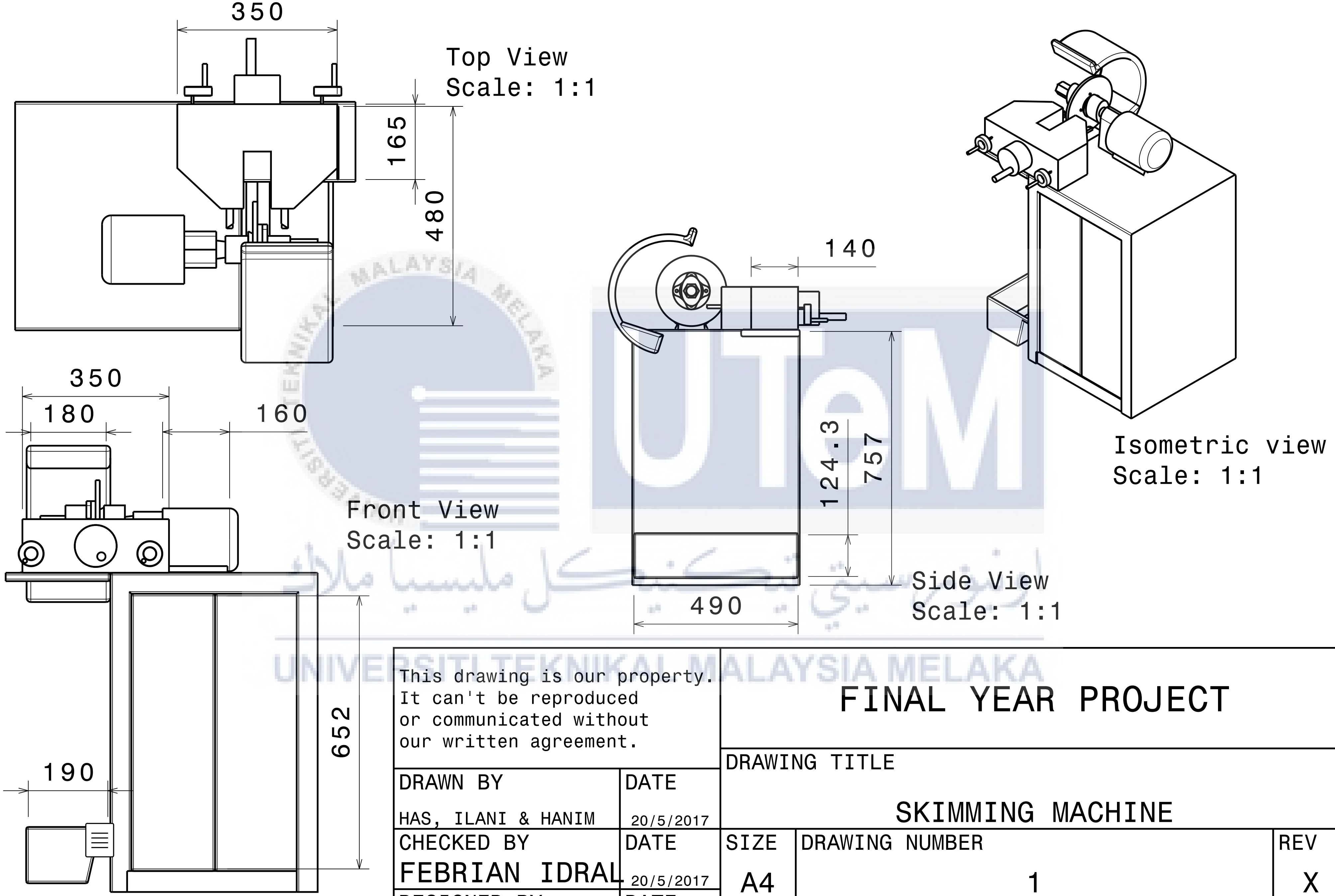


APPENDIX B

B1	Detail drawing of assembly skimming machine
B2	Detail drawing of design 3
B3	Detail drawing of design 7
B4	Detail drawing of design 8
B5	Detail drawing of datum
B6	Detail drawing of jig body for datum
B7	Detail drawing of cutting tool for datum
B8	Detail drawing of holder for datum
B9	Detail drawing of knob for datum
B10	Detail drawing of screw lock for datum



FINAL YEAR PROJECT

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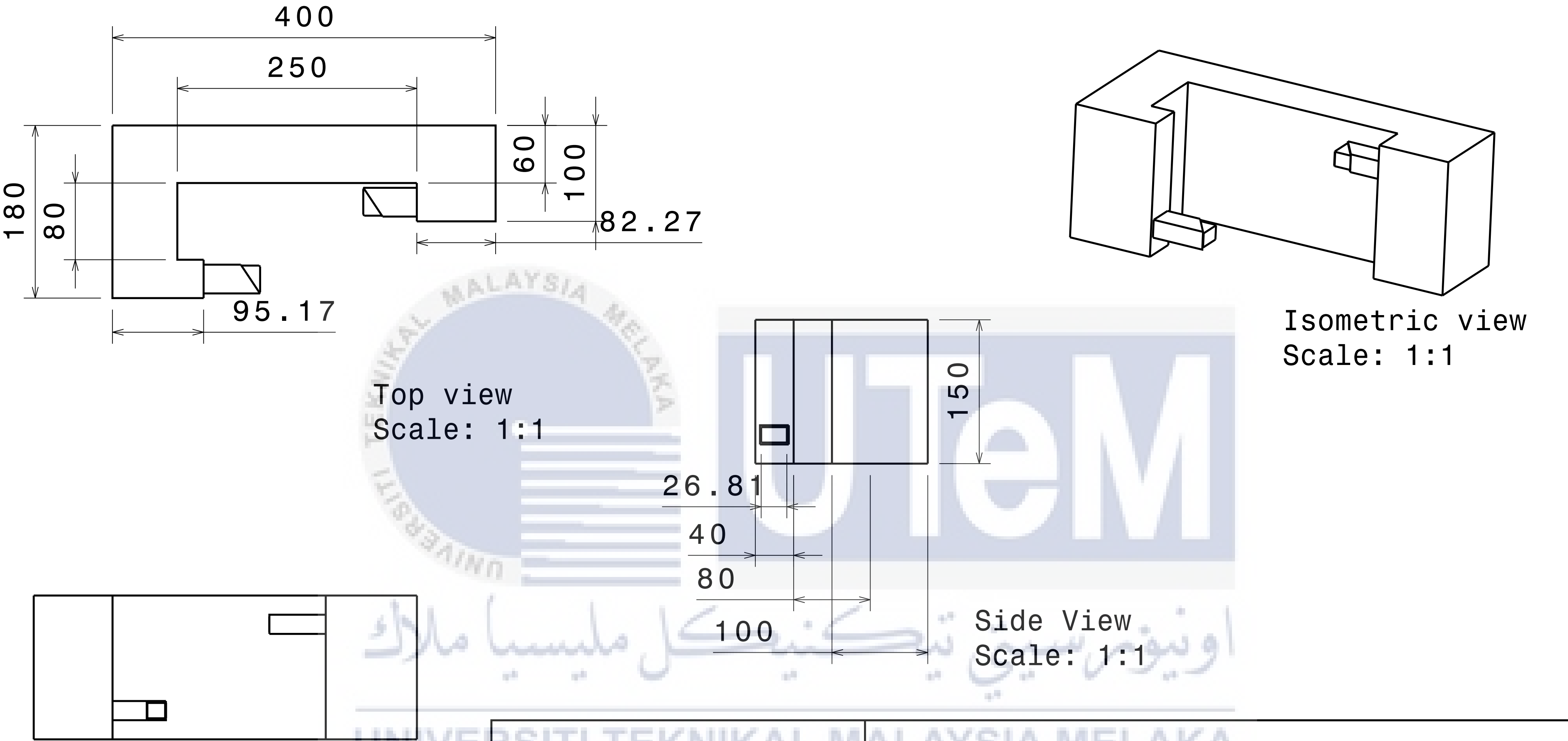
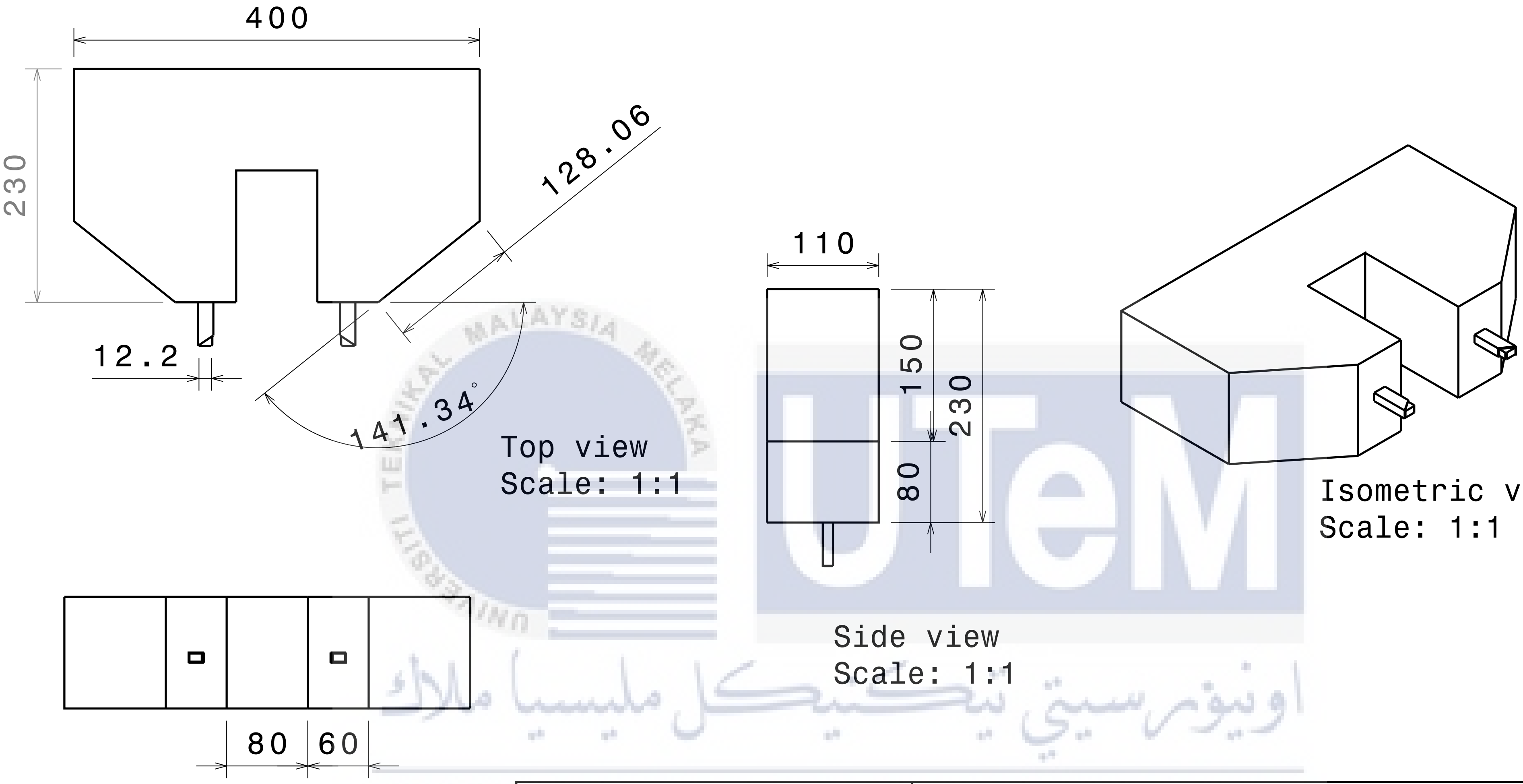
CHECKED BY: FEBRIAN IDRAL	DATE: 20/5/2017	SIZE: A4	DRAWING NUMBER: 1	REV: X
DESIGNED BY: HAS, ILANI & HANIM	DATE: 20/5/2017	SCALE 1:1	WEIGHT(kg) XXX	SHEET 1/1



FINAL YEAR PROJECT

DRAWN BY	HANIM	DATE	22/5/2017
CHECKED BY	FEBRIAN IDRAL	DATE	22/5/2017
DESIGNED BY	HANIM	DATE	22/5/2017

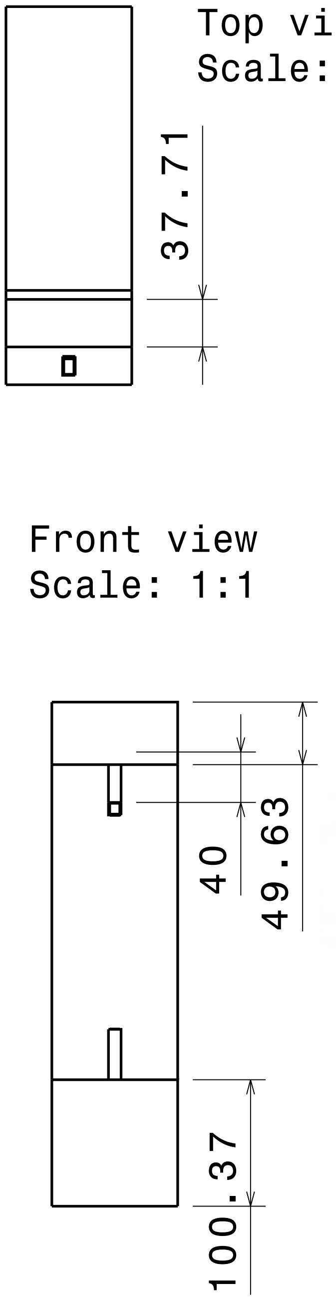
DRAWING TITLE	CUTTING TOOL JIG
SIZE	A4
DRAWING NUMBER	DESIGN 3
REV	X
SCALE	1:1
WEIGHT(kg)	0.00
SHEET	1/1

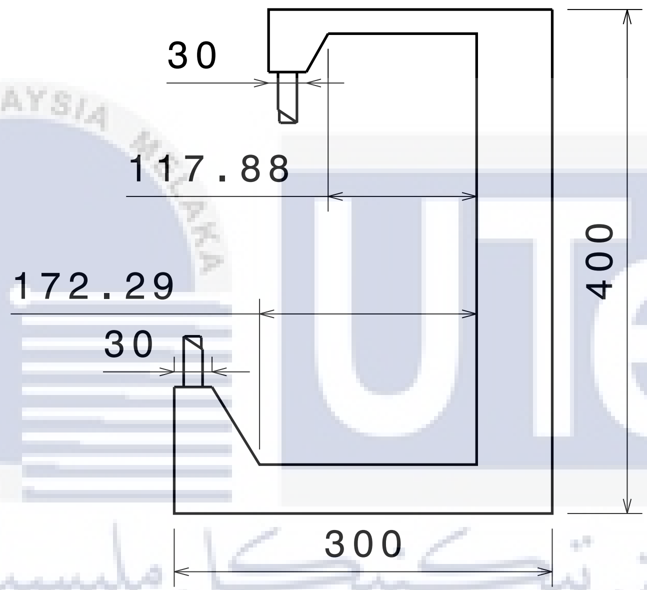


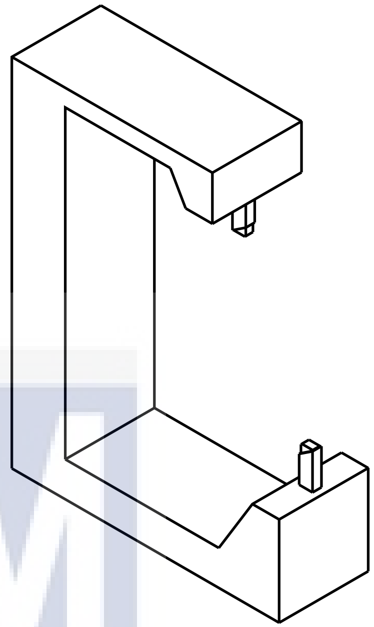
Front view
Scale: 1:1

FINAL YEAR PROJECT

DRAWN BY: HANIM	DATE: 22/5/2017	DRAWING TITLE: CUTTING TOOL JIG	
CHECKED BY: FEBRIAN IDRAL	DATE: 22/5/2017	SIZE: A4	DRAWING NUMBER: DESIGN 7 / REV: X
DESIGNED BY: HANIM	DATE: 22/5/2017	SCALE: 1:1 / WEIGHT(kg): 63.81	SHEET: 1/1







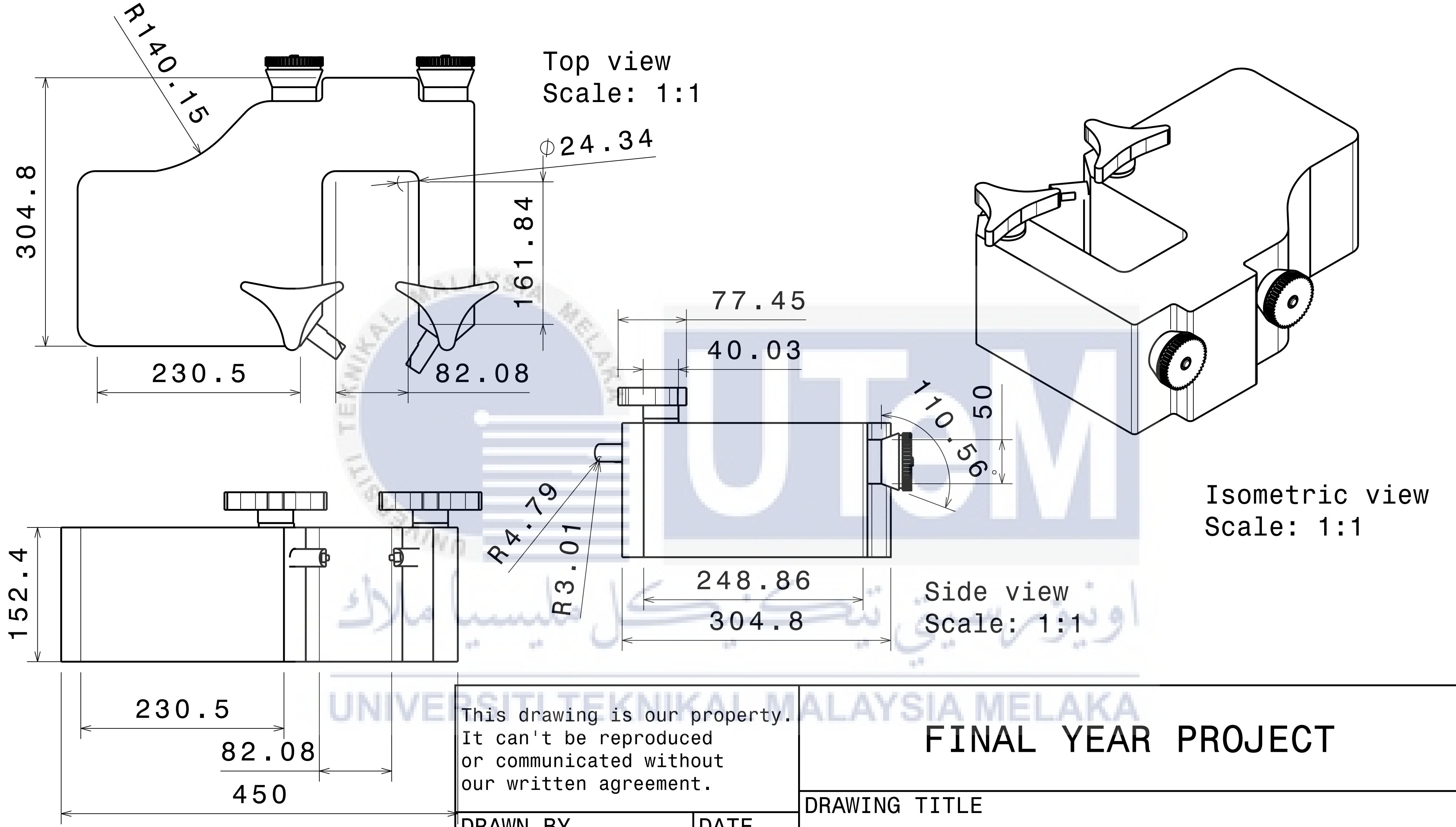
FINAL YEAR PROJECT

DRAWN BY: HANIM	DATE: 22/5/2017
CHECKED BY: FEBRIAN IDRAL	DATE: 22/5/2017
DESIGNED BY: HANIM	DATE: 22/5/2017

DRAWING TITLE: CUTTING TOOL JIG

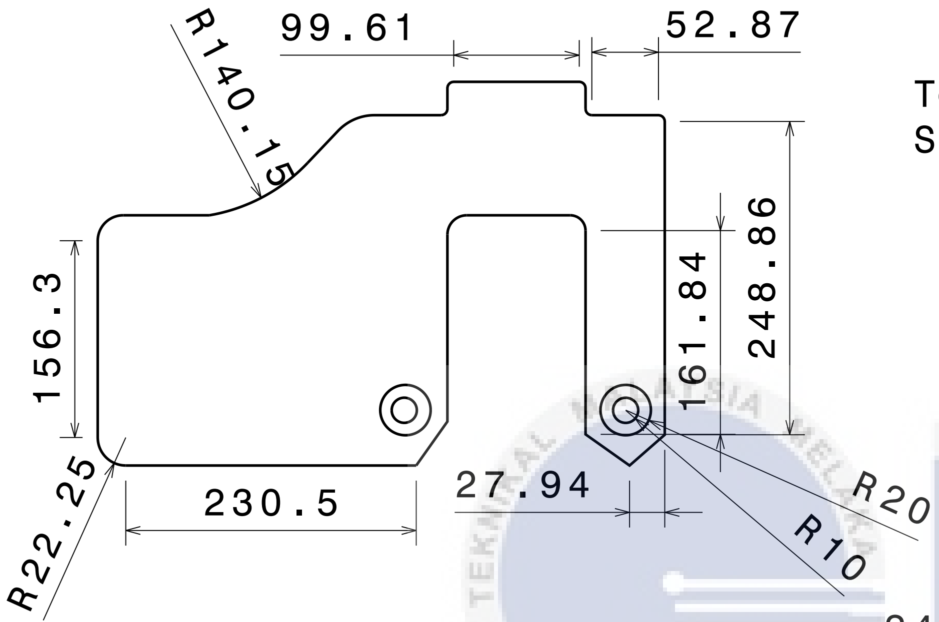
SIZE	DRAWING NUMBER	REV
A4	DESIGN 8	X

SCALE	WEIGHT(kg)	SHEET
1:1	XXX	1/1

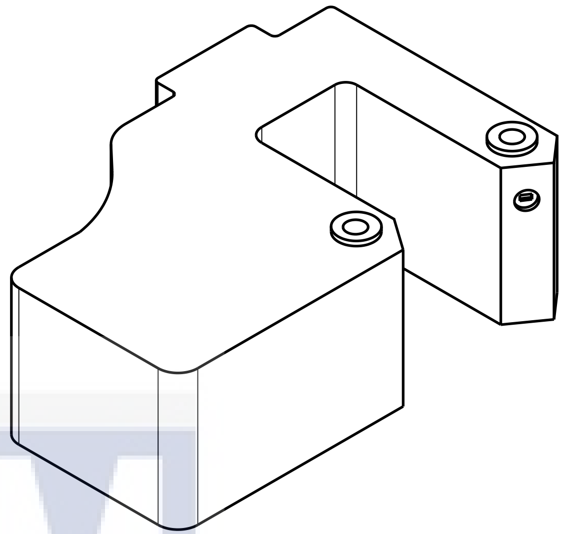


FINAL YEAR PROJECT

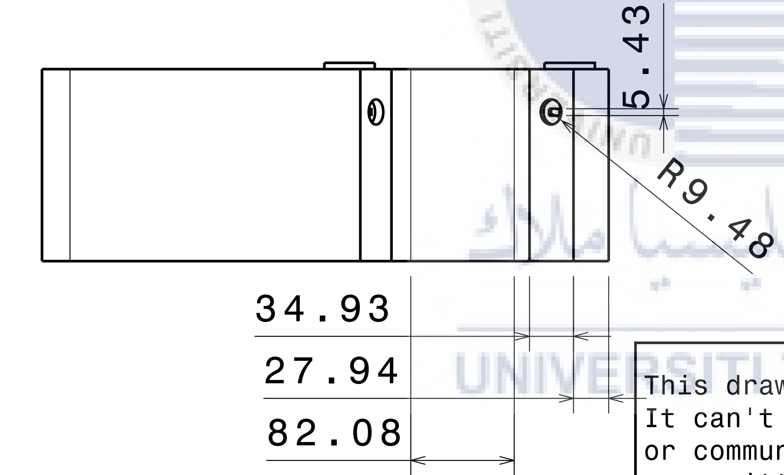
DRAWN BY HANIM	DATE 8/6/2017	DRAWING TITLE CUTTING TOOL JIG	
CHECKED BY FEBRIAN IDRAL	DATE 8/6/2017	SIZE A4	DRAWING NUMBER DATUM — REV X
DESIGNED BY HANIM	DATE 8/6/2017	SCALE 1:1	WEIGHT(kg) XXX — SHEET 1/1



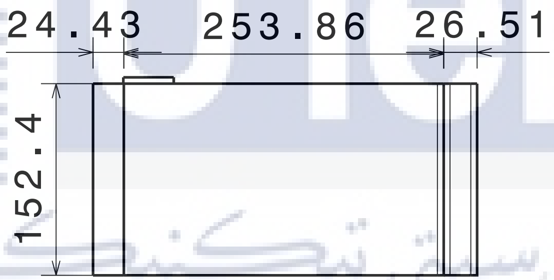
Top view
Scale: 1:1



Isometric view
Scale: 1:1



Front view
Scale: 1:1



Side view
Scale: 1:1

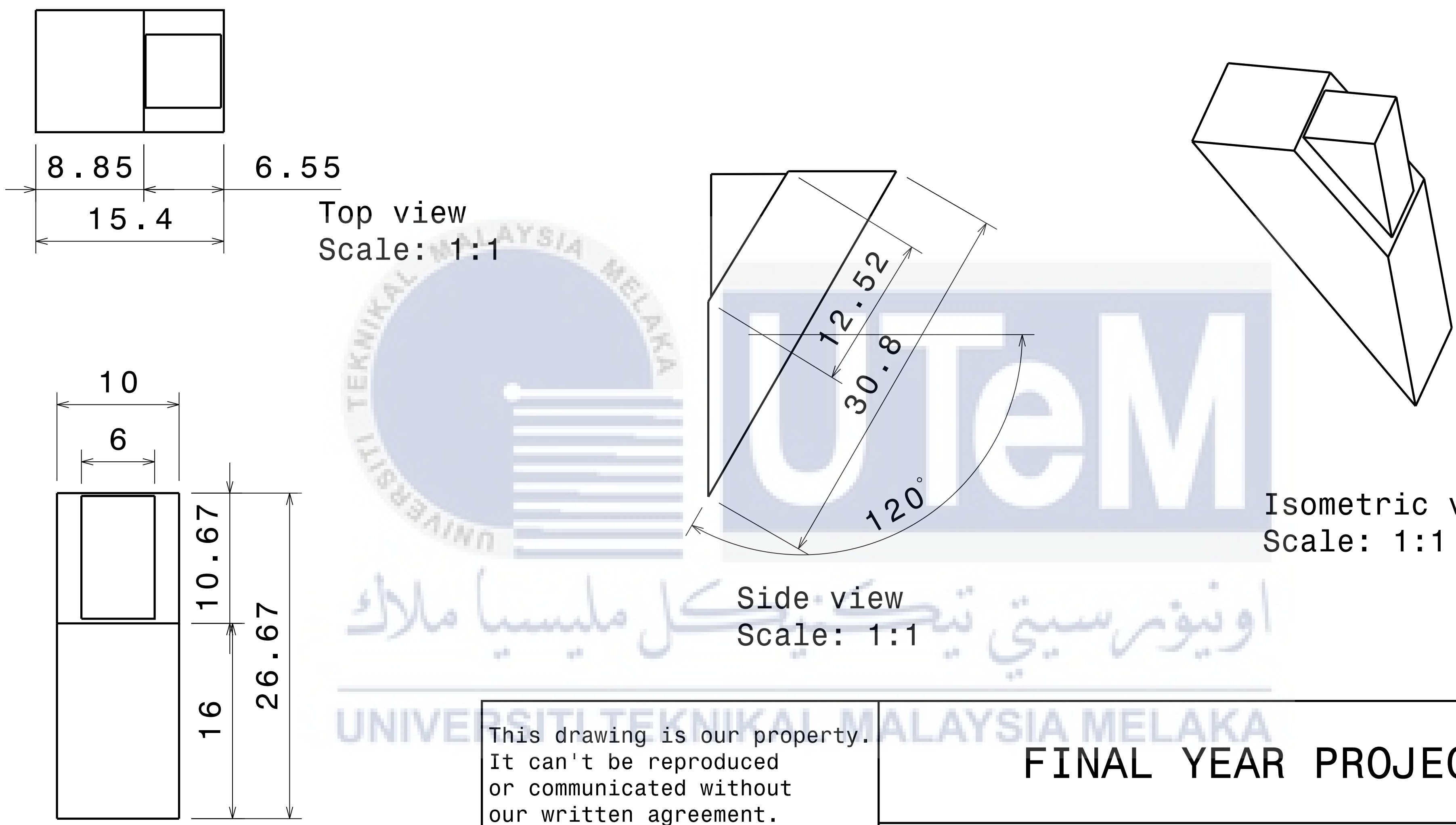
FINAL YEAR PROJECT

DRAWN BY	HANIM	DATE	9/6/2017
CHECKED BY	FEBRIAN IDRAL	DATE	9/6/2017
DESIGNED BY	HANIM	DATE	9/6/2017

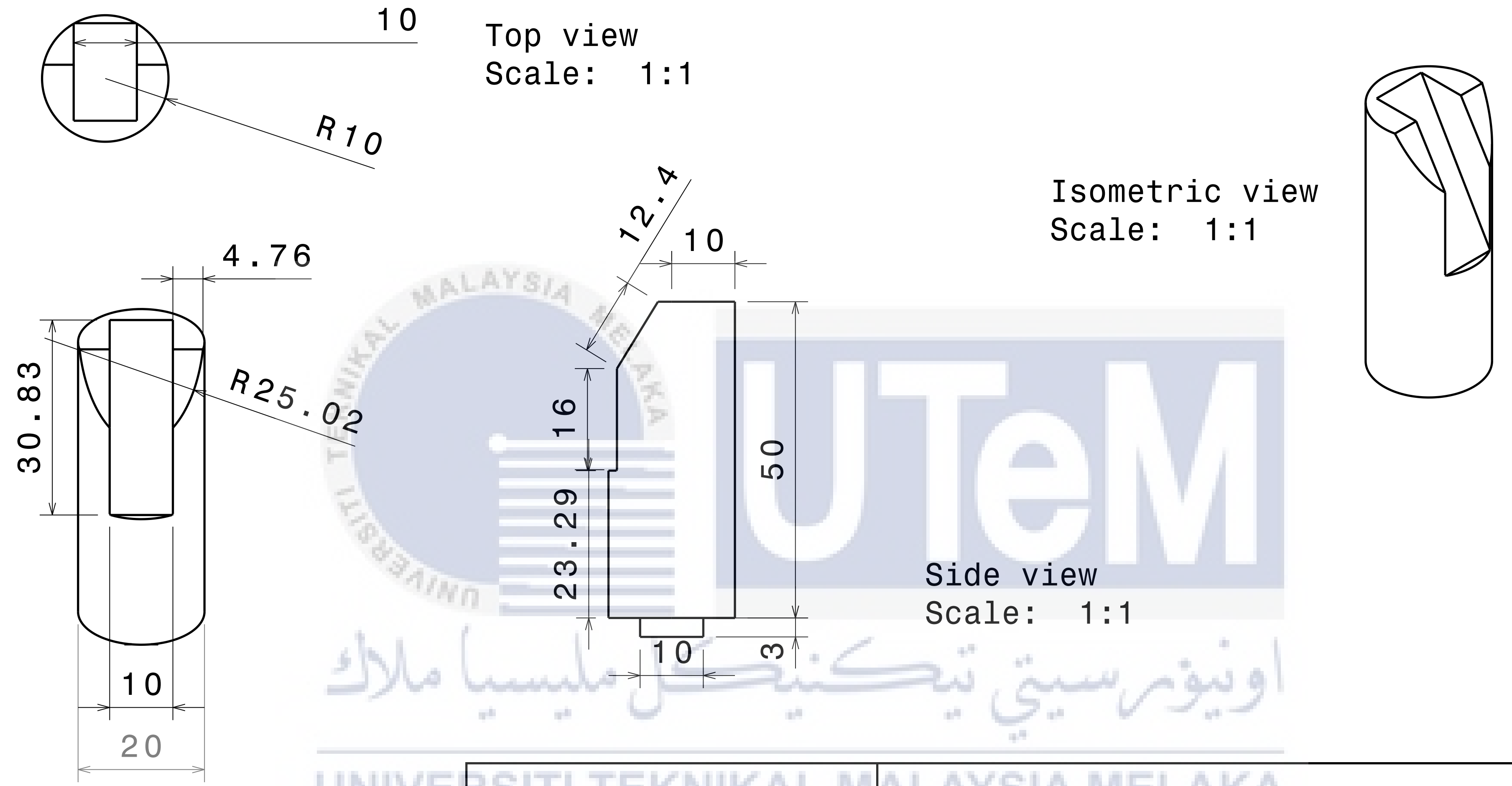
DRAWING TITLE: CUTTING TOOL JIG

SIZE	DRAWING PART	REV
A4	JIG BODY	X

SCALE	1:1	WEIGHT(kg)	XXX	SHEET	1/1

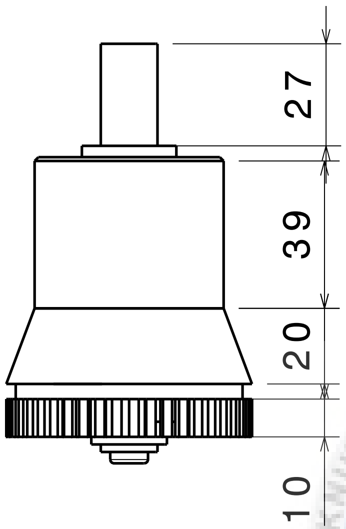


DRAWN BY HANIM	DATE 9/6/2017	FINAL YEAR PROJECT			
CHECKED BY FEBRIAN IDRAL	DATE 9/6/2017	DRAWING TITLE CUTTING TOOL JIG			
DESIGNED BY HANIM	DATE 9/6/2017	SIZE A4	DRAWING PART CUTTING TOOL		REV X
		SCALE 1:1	WEIGHT(kg) XXX		SHEET 1/1

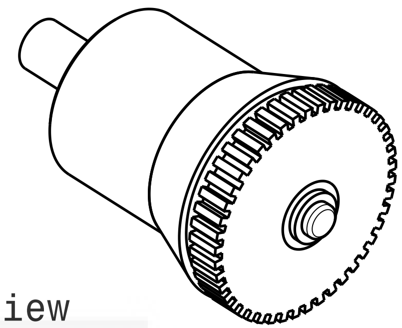


FINAL YEAR PROJECT

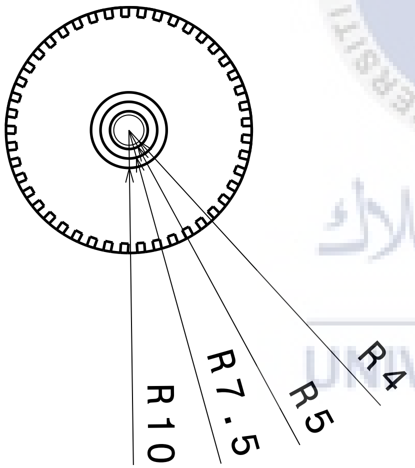
DRAWN BY: HANIM	DATE: 9/6/2017	DRAWING TITLE: CUTTING TOOL JIG		
CHECKED BY: FEBRIAN IDRAL	DATE: 9/6/2017	SIZE: A4	DRAWING PART: HOLDER	REV: X
DESIGNED BY: HANIM	DATE: 9/6/2017	SCALE: 1:1	WEIGHT(kg): XXX	SHEET: 1/1



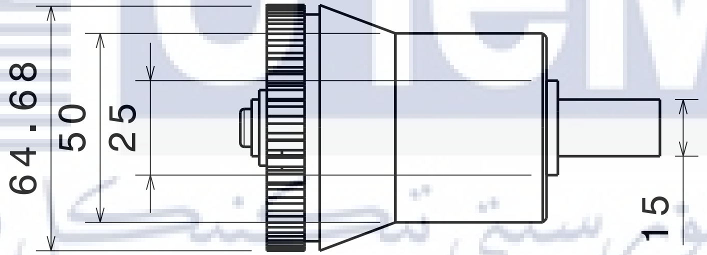
Top view
Scale: 1:1



Isometric view
Scale: 1:1



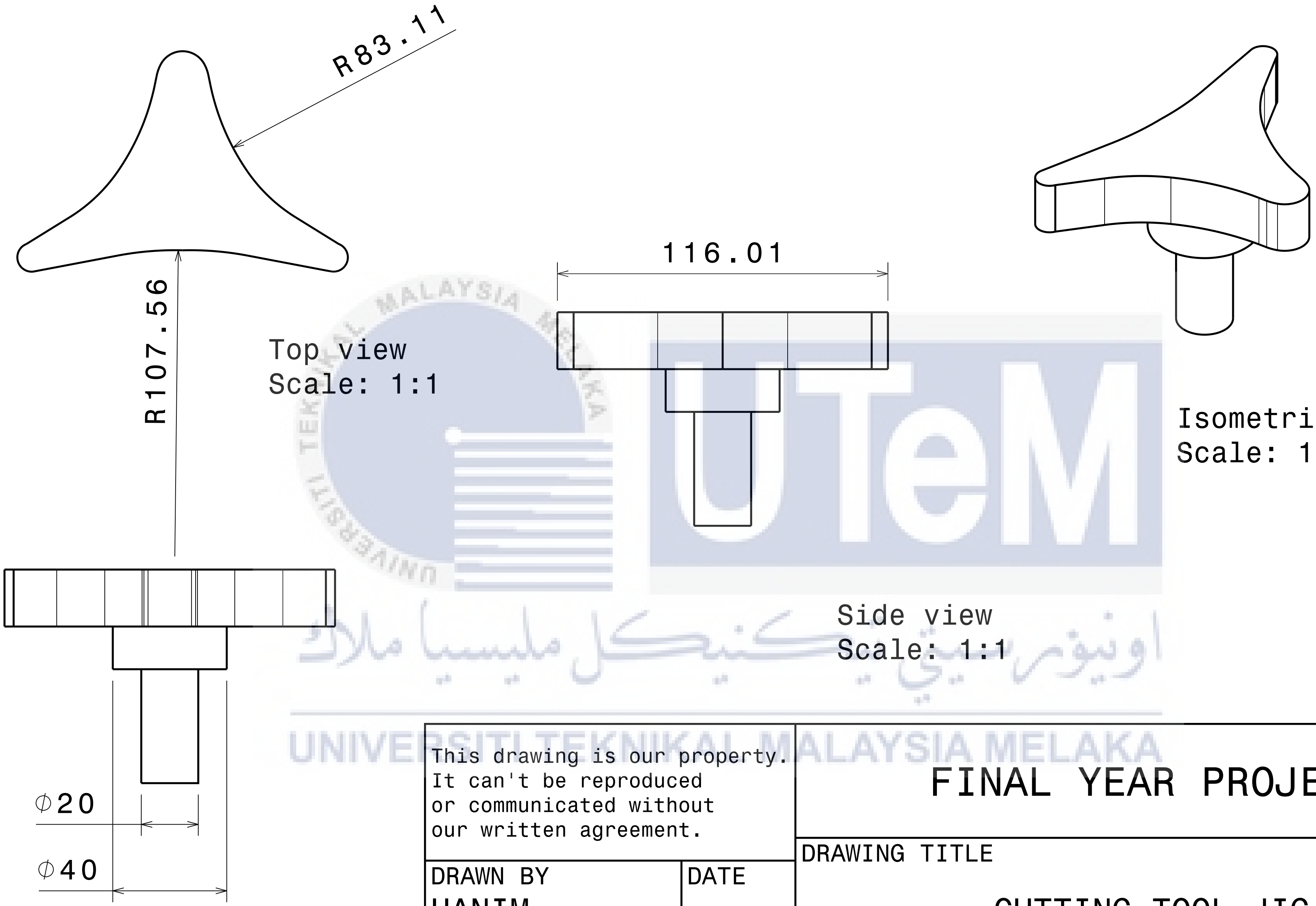
Front view
Scale: 1:1



Side view
Scale: 1:1

FINAL YEAR PROJECT

DRAWN BY: HANIM	DATE: 9/6/2017	DRAWING TITLE: CUTTING TOOL JIG			
CHECKED BY: FEBRIAN IDRAL	DATE: 9/6/2017	SIZE: A4	DRAWING PART: KNOB		REV: X
DESIGNED BY: HANIM	DATE: 9/6/2017	SCALE: 1:1	WEIGHT(kg): XXX		SHEET: 1/1



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DRAWN BY HANIM	DATE 9/6/2017	DRAWING TITLE CUTTING TOOL JIG			
CHECKED BY FEBRIAN IDRAL	DATE 9/6/2017	SIZE A4	DRAWING PART SCREW LOCK		REV X
DESIGNED BY HANIM	DATE 9/6/2017	SCALE 1:1	WEIGHT(kg) XXX		SHEET 1/1

APPENDIX C

C Gantt Chart

WEEK / TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DEFINE PROBLEM														
i. Problem Statement														
BACKGROUND RESEARCH														
i. Identify objective & scope														
ii. Search journals & books														
iii. Literature review														
SPECIFICATION & NEEDS IDENTIFICATION														
i. Product Design Specifications (PDS)														
ii. House of Quality (HOQ)														
CONCEPTUAL DESIGN														
i. Brainstorming														
ii. Morphological Chart														
SELECTION DESIGN														
i. Weighted Selection Matrix														
DETAIL DESIGN														
i. Detail drawing														

WEEK / TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ANALYSIS														
i. Analyse & Modify – Generative Structural Analysis (Solidwork)														
ii. Select best design														
REPORT WRITING														