DESIGN AND ANALYSIS ON BRAKE DISC SKIMMING MACHINE HOLDER WITH TRANSFER GEAR

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This thesis is submitted in partial fulfilment

of the requirement for the

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotation which have been accordingly acknowledge"

Signature :.....

Author :.....

Date :.....

APPROVAL

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of Bachelor of Mechanical Engineering (Design and Innovation) (Honours)"

Signature :.....

Name of Supervisor :.....

Date :.....

DEDICATION

I would like to dedicate my thesis to my beloved parents

Idris bin Adnan and Siti Sabariah bt Sulaiman

for their endless support.

ACKNOWLEDGEMENT

I am grateful and would like to express my sincere gratitude to my supervisor, Mr. Febrian bin Idral for giving guidance and encouragement to complete this report. I also sincerely thanks for time spend, constant support and guidance in making this report. Besides, I would like to acknowledge with much appreciation to the crucial role of the lecturer and assistant engineer of UTeM for giving full support and assistance in this project.

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ABSTRACT

Skimming is the process to resurface brake disc to make sure the effectiveness of the brake system nevertheless it is also one of safety factor in transportation. Hence, part of the brake disc skimming machine that emphasized in this project is brake disc holder with transfer gear. As the skimming machine become one of the important in car's maintenance it is essential to considered how the machine are implement to the customer. The objective of this thesis is to design the holder and simulate the brake disc skimming machine holder also to analyze the performance of the skimming machine holder using CATIA software. The thesis describe the importance of the brake disc skimming and the consequence for neglecting the skimming process. Transfer gear will act as regulator depends on required shaft rotation whereas the holder will tighten the grip of brake disc so the brake disc will rotate without any interruption. Furthermore, the holder will prevent the brake disc from uneven rotation and avoid rough surface after skimming. Despite all that, the holder are being test whether the performance of the skimming process could have undergo for better performance than previously. It is important to study of both, holder and transfer gear, as it will give an impact to the skimming process. Finally the acquired result from CATIA analysis and simulation can be help on the skimming process. The result show how brake disc holder with transfer gear work together in order to make the machine works perfectly and better in result.

ABSTRAK

Penyiringan adalah proses untuk mengembalikan permukaan brek cakera supaya keberkesanan sistem brek, dalam pada masa yang sama ia adalah salah satu faktor keselamatan dalam pengangkutan. Sebahagian daripada mesin penyiring brek cakera yang akan dibentangkan di dalam tesis ini adalah pemegang brek cakera bersama gear pemindahan. Mesin penyiring telah menjadi antara mesin yang penting dalam industri pengangkutan dan penyelenggaraan kereta, oleh demikian operasi mesin penyiring terhadap pelanggan harus diperincikan. Objektif tesis ini adalah mereka bentuk dan melakukan simulasi pemegang brek cakera mesin penyiring serta menganalisa keberkesanannya menggunakan perisian kejuruteraan bantuan komputer CATIA. Selain itu, tesis ini juga menekankan kepentigan dan akibat kepada pengguna jika mengabaikan penyelenggaraan brek cakera. Gear pemindahan yang digunakan berfungsi sebagai penyelaras kelajuan namun bergantung kepada putaran aci yang mana pemegang akan diadaptasi supaya brek cakera berputar tanpa gangguan. Tambahan pula, pemegang berfungsi mengelakkan brek cakera daripada mengalami ketidakstabilan dan menghasilkan permukaan kasar selepas proses penyiringan. Namun demikian, pemegang brek cakera mesin penyiring akan dinilai dari setiap aspek untuk perjalanan yang lebih sempurna dari sebelumnya. Kedua – dua pemegang dan juga gear pemindahan perlu dikaji kerana memberi impak yang besar kepada operasi penyiringan. Akhir sekali, keputusan analisa dan simulasi yang diperoleh dari perisian kejuruteraan komputer terbantu CATIA membantu dalam proses penyiringan. Hasilnya menunjukkan pemegang brek cakera bersama gear pemindahan untuk keputusan mesin yang berfugsi dengan lebih baik.

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LIST OF ABBREVIATIONS

CATIA	Computer Aided Three - Dimensional Interactive Application
CEA	Complex Eigenvalue Analysis
DMU	Digital Mock-Up
FE	Finite Element
FEA	Finite Element Analysis
HOQ	House of Quality
PDS	Product Design Specification
RSM	Response Surface Methodology
V5R20	Version 5 Release date 2010
VAC	Voltage Alternating Current
VDC	Voltage Direct Current

LIST OF SYMBOL

SYMBOL		DESCRIPTION
σ_{all}	=	Stress Allowable / Yield strength
σ_{max}	=	Stress Maximum / Von Misses Stress
π	=	Pi
F	=	Applied force
F.S	=	Factor of Safety
f	=	Frequency
hp	=	Horse power
N	=	Rotational speed
P	=	Power
r	=	Radius
T	=	Torque
D	=	Diameter
E	=	Modulus elasticity
L	=	Length
δ	=	Deflection
θ	=	Angular deflection
ω	=	Angular velocity

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Brake disc skimming machine are machine that perform a skimming process to resurface the brake disc. Mostly brake disc were being skim when braking system leads to poor braking performance or imbalance. Brake disc will have a friction problem such as excessive wear and surface damage of the brake components which leads to brake noise (Wang et al, 2016). Skimming machine are beneficial in prevent the brake pedal from pulsation, juddering, and noise. In addition, it will improve braking system performance on your vehicles and increase safety while driving.

Brake pedal pulsation results from uneven wear of brake disc. Wear process take place when there are two surface contact between brake disc and brake pad (Verma et al, 2014). Groove are one of the major problem that always occur if neglecting the expected service. The groove will occur when the brake pad are completely wear until make contact to brake disc surface. The damages to brake drum do a lot of harm to the braking performance and even the safety of automobiles (Zhou et al, 2008)

Nowadays, all the machine equipment are up to date and tally with the urban era. By that purpose, the skimming machine also need to be equipped with modern technologies and appealing design. In other words, new design that need to be develop are more profitable and beneficial.

As a result, mostly this project will focus on holder of brake disc skimming machine. The holder need to have a firm grasp to hold the brake disc. So, the brake disc thickness removed are more accurate and smooth. The thickness of brake disc will not really affect as the skimming machine remove the thinnest surface of the brake disc.

1.2 Problem Statement

Brake disc skimming machine has become one of the important technology in automotive industry. However, skimming machine have a several problem regarding brake disc where the thickness remove at the surface are not accurate during skimming process. This problem mostly because of the holder is not attach tightly enough throughout the skimming process. Brake disc rotation will become unbalance due to the improper set up of the holder and could lead to disc thickness variation which mean the brake disc is not uniformly thick. In addition due to the loose installation of skimming machine holder, brake disc tend to vibrate and cause surface roughness. Hence, the design and analysis of the skimming machine holder need to be consider for a better result in skimming process.

1.3 Objectives

1.3.1 To design the holder for brake disc in skimming machine.

1.3.2 To analyze the performance of skimming machine holder application compare to previous design using finite element analysis in CATIA software.

1.4 Scope of Project

1.4.1 Designing a brake disc holder for skimming machine using CATIA software.

1.4.2 Optimize the lathe skimming machine for brake disc to more compatible skimming machine.

1.4.3 Analyze the structure and simulation of Brake disc Skimming Machine Holder using CATIA software.

1.4.4 Modify the attachment of brake disc machine holder to the motor.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Automobile manufacturer considering that brake disc is an important aspect in safety while driving. It is dangerous if the customer not paying attention to brake disc services. In order to have proper brake system, the brake disc only need to be resurface also could prevent passenger from danger. Brake disc surface will form a groove or slot that will lead to poor brake system. All of this mostly occur because the brake pad are too thin until make contact with the brake disc. Then, the problem such as noise and unbalance disc thickness will occur.

2.2 Brake Disc

The brake disc actually are being analyze thoroughly before setup to the vehicle. During the analysis, there is several information that could explain the effect of brake disc. The brake pads often to have contact with brake pad however in a very long term it will make the brake pad run out. So, the brake pad will start rubbing off the disc and create an excessive temperature when braking. The brake disc shall have high and constant coefficient of friction because it is major influence for appropriate braking system. However depends material and considering sliding velocity, contact pressure and temperature (Yevtushenko et al, 2014).

Another experimental that has been studies is the design optimization of brake disc. Purpose of this optimization is to deal with noise problem that existing while braking. By that, there are several test run on each brake disc in order to optimize into the desire design.

Figure 2.1: The simplified model of a brake system after gone through an optimization. (Lu et al, 2016).

Improvement that have been involved to deal with the uncertainties the response surface methodology (RSM) to replace the time consuming finite element (FE) simulation. The optimization is obtain based on reliability and confidence interval. Both are construct by using RSM, complex eigenvalue analysis (CEA) and hybrid uncertain analysis (Lu et al, 2016). Different parameters are present for optimization method and being reviewed and compared to optimize the design.

2.3 Brake Pad

Part that mostly influence brake disc in braking system is brake pad. Brake pad will produce heat during braking and will dissipated to the surrounding atmosphere. Though for long term use, the brake pad will worn out and lead to brake disc surface cracking and vibration. In addition high temperature applied will cause the overheating of other components. The brake pad will lose the grasp if consequently used under extreme condition. Hence, there is need for a better selection in geometrical design variable and improve the thermal performance. (Bagda et al, 2014).

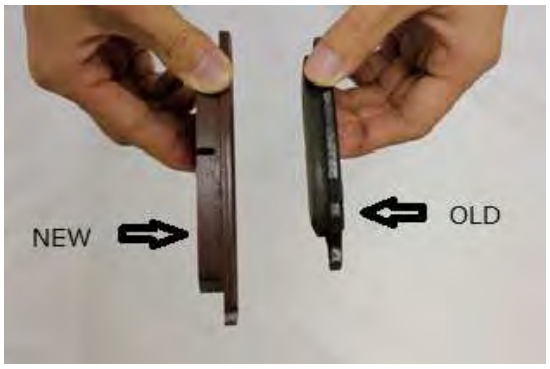


Figure 2.2: The difference of new and old brake bad that start to wear. (Source from Beforward, 2015).

The life time of brake pad can last up to 16000 to 80,000 kilometers depends on the quality of brake pads vehicle weight and driving condition (Beforward, 2015). Material of brake pad is made for ease on converting the kinetic energy of the vehicle into thermal energy by friction. However brake pad may lead to wear mechanism and formation. Braking condition should suitable with their type, morphology and hardness of brake disc (Verma et al, 2014). Thus the thickness of brake pad decreases also vehicle stopping power. Eventually the wear brake pad will rub off the surface of brake disc and cause groove or uneven surface.

2.3.1 Groove Mark

The important factor that could lead to the groove mark is that the thickness of the brake starts to wear off. This is because the friction generated by the brake pad rubbing against the brake disc and creates a lot of heat (Carley, 2011). The brake pad tends to become thinner and will be left with only the caliper with the backing plate.

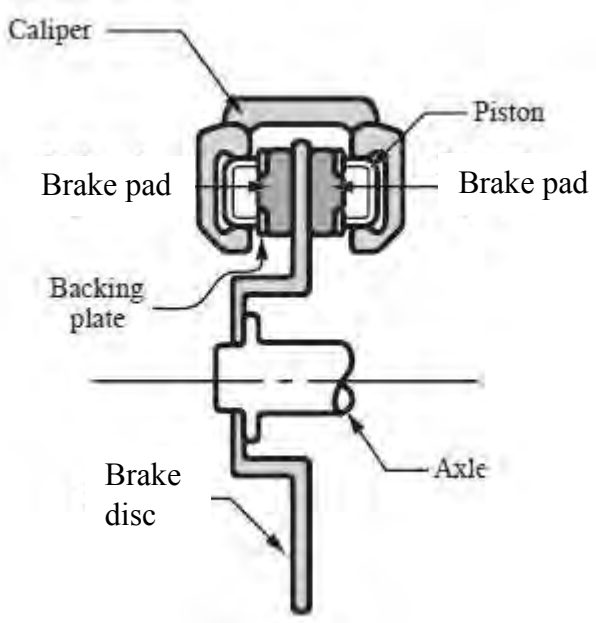


Figure 2.3: The cross-section of brake disc and brake pad (Kinkaid et al, 2003).

Analysis on the thermodynamics behavior of the dry contact between brake disc and brake pad during braking phase shows that ventilation system plays great role in cooling disc. The analysis result that temperature field and stress field in the process was fully coupled. The temperature, Von Misses stress and total deformation of the disc and contact pressure of brake pad increase the thermal stresses additional to mechanical stresses which cause the crack propagation and fracture of the brake pad and brake disc (Ali et.al, 2013).

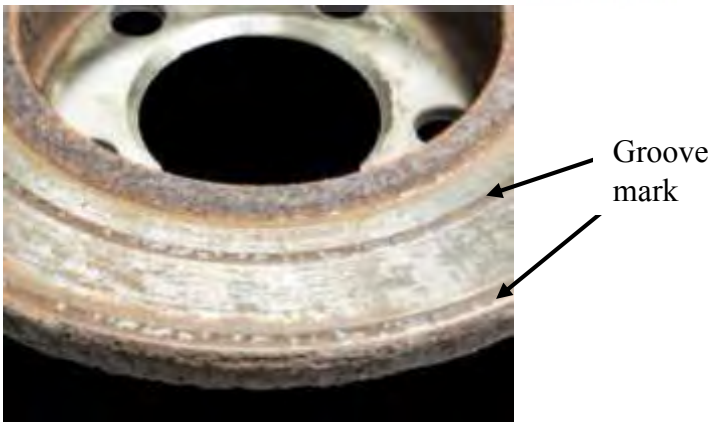


Figure 2.4: Groove marks that occur on brake disc. (Source from Meyle Product)

The figure above shows the grove mark cause by brake pad caliper. So when the metal contact with other metal it will leave a mark, lead to groove or also known scarring the brake disc surface and reduce the performance of the rotor (Knight, 2016). Solution to the problem is the brake disc can be resurface by using skimming machine. Instead of safety while driving the skimming brake disc also affect overall driving course.

2.3.2 Noise

Damage of brake component is the main reason why the noise during braking could occur. Usually the brake noise often associated with various friction such as excessive wear (Wang et al, 2016). The main factor that brake produce noise is because of the contact surface between wear brake pad and brake disc that result in the increase of the probability of squeal (Choe et al, 2012). The occurrence of brake disc noise influences in the characterization of pad vibration modes and on its natural frequencies (Triches Jr et al., 2002).

The noise strongly influence by the vibration where the system effect the optimal value of the two modes. In this case the complex phenomenon and various parameter affecting the friction have been develop. The excellence review of the friction can be divided into static and dynamic to determine the level of friction in velocity and acceleration (Choe et al, 2012).

2.4 Brake Disc Skimming Machine

Machine that resurface the face of brake disc, that result the brake disc look good as new. The brake disc are being skim because of several cause mostly involve the lifetime of brake pad and brake disc. Skimming process is often neglected and most of the user not pay any attention to the brake pad and brake disc maintenance. Nevertheless there is some customer that might aware of this phenomena but instead of skimming they purchase a new one. To them skimming will remove the surface unevenly and make it more badly. Major reason of this issue is an uneven brake disc while skimming. Uneven surface may cause entire car to vibrate and the brake apply will be not as efficient as it would be (Miller, n. d.).

To overcome this problem the skimming machine considering the brake disc holder with transfer gear.

2.4.1 Brake Disc Skimming Machine Holder

For a better grip during skimming machine the holder need to be attach tightly to the brake disc. The holder is a form of shaft that include with adapter that could tighten the brake disc. The main purpose of a holder is to locate and hold brake disc during skimming process (Kumara 2014). Skimming machine holder need to have better grasp because brake disc tend to rotate erratically and could lead to disc thickness variation.

The requirements of the brake disc holder emphasize clamping and fix brake disc for better rotation (Maniar et al, 2013). A better holder will guides the position correctly and support the brake disc firmly. In addition, operations of the brake disc skimming demand a fast and easy for positioning the brake disc for accurate result. Skimming process of brake disc can implement good result because of the holder could support and locates the brake disc securely (Kumara 2014).

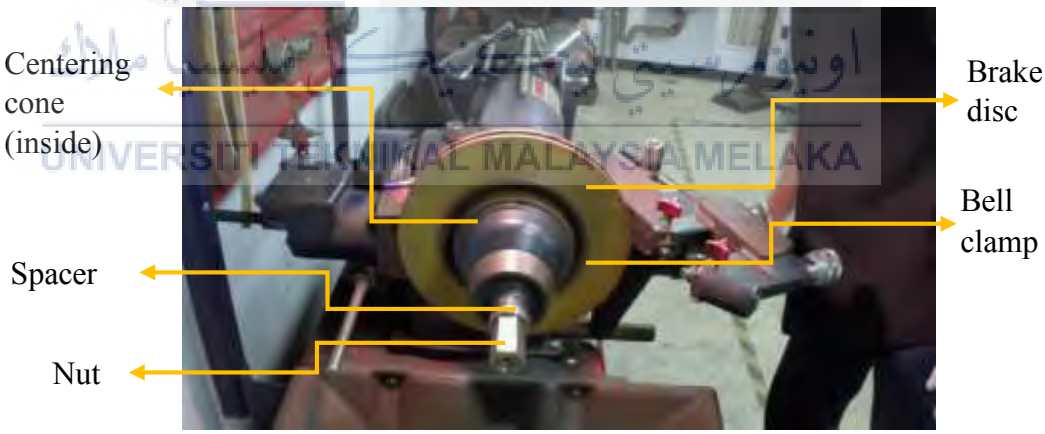


Figure 2.5: The example of brake disc skimming machine holder.

The figure above shows the labelled of every skimming machine holder part. Attachment of the shaft to the motor then the 3 finger cup are attach together with spring as then put in a cone that fits into the center hole of brake disc from the inside to center the brake disc on the shaft. The 3 finger cup adapter fit in the shaft, making contact with near

the brake disc surface, where possible rather than near the edge. Various adapter and spacer may be used to fill out the shaft according to the parameter of the brake disc.

Spring will aid the brake disc position from dropping, where it hold the center cone and 3 finger cup. Then put another 3 finger cup facing the brake disc complete with spacer. Lastly spacer, acts as adapter that fill out the shaft to prevent damage to the machine surface.

The self-aligning spacer prevents diagonal thrust on the adapters. The self-aligning spacer should always be used adjacent to nut. The nut should be not over tight due to that, the nut should be wrench counterclockwise until the brake disc and adapters begin to turn the shaft.

2.4.2 Wobble Effect

Holder is very important part in skimming machine, due to the thickness variation driving condition will accompany with improper noise. The surface become rough and leads to vibration and noise.

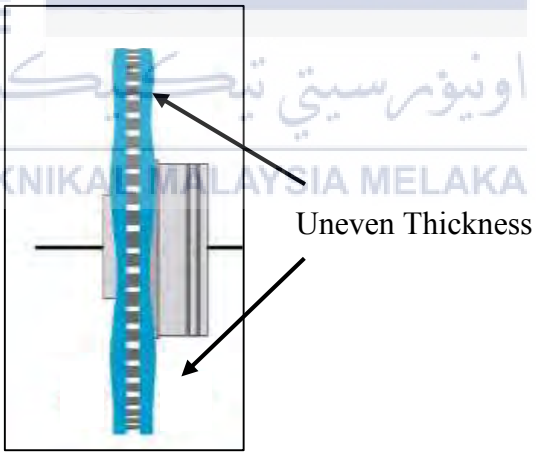


Figure 2.6: The rough and uneven surface of brake disc.

Others possible wobble effect occur during the operation is cause by the brake disc condition. The scratch cut of the brake disc before the brake disc being resurface will

experience wobble during skimming process. The brake this tend to tilt because of the uneven surface.

Inaccurate setups play a major role in creating uneven brake disc surface (Goms, 2005). Brake disc will wobble if the holder of brake not tightly enough. This result to the thickness variation and produce vibration while braking (Carley, 2011). Eventually, the brake disc surface worn off which ruins the parallelism of brake disc surface. That is why the holder needs to have firm grip to hold the brake disc tightly.

2.4.3 Vibration

The cause of unstable attachment of brake disc during skimming are juddering and roughness. Brake disc surface will cause noise during braking which also create vibration. The experimental and analytical approach seems to be influence by frictionally induces dynamics instabilities in the brake. Vibration appear when the brake disc start to have roughness surface due to the heavy wear and overheating because exceed the usage of brake pad more than brake disc can handle (Parker, n.d.). Hence, the vibration influence the surface of brake disc, by tighten the installation during skimming the brake disc surface it could prevent the vibration as the brake disc being resurface to smooth surface.

2.5 Deflection

For some applications, the shafts have to be designed on the basis of lateral rigidity or the deflection of shafts. The shaft will tend to have deflection if there is load applied however depend on the strength of shaft material. In order to define whether bending occur on shaft the calculation below were perform. The lateral deflection of a shaft depends on the dimensions of shaft (length and diameter), the important methods for determining the lateral deflection is Castigliano's theorem for complex structures using:

i. Strain energy principle.
ii. Graphical integration method
iii. Area moment method
iv. Double integration method

Lateral deflection can also be calculated by simple formula from strength of materials. The cases pertaining to

(a) Simply supported shaft subjected to central load;
(b) Simply supported shaft subjected to intermediate load;
(c) Simply supported shaft subjected to uniform load are given below

As for this shaft all the details will be display in the table below together with the calculation of deflection.

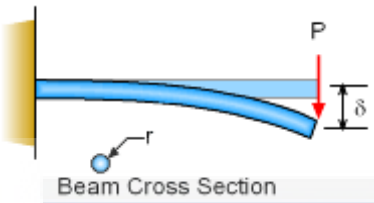


Figure 2.7: Illustration of deflection of the shaft.

The calculation of deflection of shaft involve several parameter which are force (P), deflection (δ), modulus of elasticity (E), shaft radius (r), and shaft length (l). In conclusion there are 5 parameter, n involve in this calculation.

Table 2.1: Quantity and symbol that involve in order to solve for deflection value.

Quantity	Symbol	Dimensional formula
Mass	-	M
Applied force	F	M
Deflection	δ	FL
Modulus of elasticity	E	FL-2
Length	L	L
Diameter	D	L

The above table shows that the parameter have 3 basic dimension which are M, F, and L. So the value of basic dimension equal to 3 (m=3). According to Buckingham pi theorem, the number of pi terms for this calculation is 3 where the formula is (n-m =6-3=3).

Then determine the form of pi terms, as for repeating parameter are modulus elasticity (E) and beam radius (r). The pi terms (r) are then given by

$$\pi_1 = FE^{a1}r^{b1} \tag{2.1}$$

$$\pi_2 = \delta E^{a2}r^{b2} \tag{2.2}$$

$$\pi_3 = IE^{a3}r^{b3} \tag{2.3}$$

From equation (2.1) the exponents are identified as followed equation (2.4)

$$\pi_1 = PE^{a1}r^{b1} = (F)(FL^{-2})^{a1}(L)^{b1} \tag{2.4}$$

When simplifies considering both side

$$M^0L^0T^0 = (M)(FL^{-2})(L) \tag{2.5}$$

$$\pi_1 = F^{(1+a1)}L^{(-2a1-b1)} \tag{2.6}$$

In order for π_1 , equation (2.6) to be dimensionless the equation (2.7) and (2.8) are define as followed. Equate powers of primary dimension. Since M only mass independent so the value is equal to zero.

Equating exponent

$$\begin{aligned} F: \quad & 1 + a1 = 0 \\ & a1 = -1 \end{aligned} \tag{2.7}$$

$$\begin{aligned} L: \quad & -2a1 + b1 = 0 \\ & b1 = -2 \end{aligned} \tag{2.8}$$

π_1 Hence, is determined to

$$\frac{P}{Er^2} \tag{2.9}$$

By inspection, the second and third pi terms, equation (2.2) and (2.3) respectively are given by (a2 = 0, b2 = -1, a3 = 0 and b3 = -1) using the same method as equation (2.5):

$$\pi_2 = \frac{\delta}{r} \tag{2.10}$$

$$\pi_3 = \frac{L}{r} \tag{2.11}$$

Hence according to the dimensional analysis, the important parameters are

$$\frac{\delta}{r} = \text{function}\left(\frac{P}{Er^2}, \frac{L}{r}\right) \tag{2.12}$$

According to the bending theory, the deflection of a circular is given by equation (2.13)

$$\delta = \frac{4}{3\pi}\frac{PL^3}{Er^4} \tag{2.13}$$

Deflection also have another formula as in equation (2.14), however the if using the formula, need to find inertia as in equation (2.15)

$$\delta = \frac{PL^3}{3EI} \tag{2.14}$$

$$I = \frac{\pi D^4}{64} \tag{2.15}$$

Recast the equation (2.13) in terms of the dimensionless parameters to yield which is in agreement with the results obtained from dimensional analysis.

$$\frac{\delta}{r} = \frac{4}{3\pi}\left(\frac{P}{Er^2}\right)\left(\frac{L}{r}\right)^3 \tag{2.16}$$

2.6 Torque

In order to determine the stress in a shaft, it is necessary to calculate the value of torque in the parts of shaft. Torsion mostly are encountered in many engineering application which are used to transmit power from one point to another (Beer, 2006). The output power of a transfer gear at specific points that rotates the shaft to make movement will experience twist. Initially, torque formula given as equation (2.17)

$$P = T\omega \tag{2.17}$$

Where ω is the angular velocity of the body express in radians per second. Though, $\omega = 2\pi f$ where f is the frequency of the rotation. The unit of frequency is thus $1s^{-1}$ and is called hertz (Hz). Substituting for ω into equation (2.18),

$$P = 2\pi fT \tag{2.18}$$

With f express in Hz and T in Nm, the power will be express in Nm/s that is in watt (W). Solving the equation (2.18) for T, the torque exerted on a shaft transmitting the power P at a frequency of rotation f,

$$T = \frac{P}{2\pi f} \tag{2.19}$$

Where P, f and T are expressed in the units indicate above. After having determined the torque T that will be applied to the shaft and having selected the material to be used.

2.7 Software

2.7.1 CATIA (Computer Aided Three – Dimensional Interactive Application)

By using CATIA software the analysis and simulation can be perform to the skimming machine holder with transfer gear. The structure model in the CATIA as assembling mode can change the position conveniently without any reconstruction of the model when need to evaluate the exposure characteristics of different position (Li et al, 2013) First thing first the design of the holder will be determine first and proceed with assembly

process in CATIA software. From there, the simulation and analysis could take place. For simulation, using digital mock up, then decide for degree of freedom where supposed the holder need to have a movement. Then by using finite element analysis (FEA), the information gather will show how much an appropriate load applied, von misses stress, factor of safety and other information that would be found useful.

2.7.1.1 Digital mock-up (DMU).

The DMU concept covers overall the preliminary and details design as well as supporting all the modification phases of chosen concept design for skimming machine holder. Capabilities of the digital mock up should be able to meet accuracy requirement of application, display good performance and quality (Guoping, 2007).

Every assembly if there is any faulty the application can be automated detect the every part of the product whether occur any collision or assembly failure. In addition DMU prevent any mismatch and interferences during precision examination assembly. Then the design can be digitized by means of the whole simulation and virtual testing (Gaoming, 2011).

2.7.1.2 Finite Element Analysis.

Provide with the material for the structure, analysis can be run throughout the desired load or force. Significantly this analysis is consider because it aims to determine the critical point which have highest stress (A. Rahman, 2008). Generate report that provided in CATIA software shows several value such as von misses, maximum stress and others value are given. In addition, the value can impose the calculation for factor of safety which used to provide margin over the theoretical design capacity. FEA had been used for product development and even after manufacture. With the aid of FEA the result can be further improve the design and determine the actual structure capability (Mohd et al 2012).

The analyses compromise every pre-processing where it develops the geometry and applies material properties, boundary condition and loads. The application of FEA as mention before, can solves for the displacements, strains, stresses and make possible the detailed

meshing and analysis of various effect for individual parts (Ghergina, 2015). Forming this analysis can detect every deformed shapes and contour plots which help to check the validity of the solution. Beside stress analysis can be determine whether the design have high stress value, maximum deflection and structure (Mohd et al, 2012).

2.8 Design Method

Early stages of obtaining concept design, house of quality is the method to gain the perspective of customer and engineer. From the house of quality the product design specification can be done that would be included the parameter of each concept design. As for concept design, firstly the option of each function are sketch using method morphological chart. Following then, solve the sub-function into a concept design. Next the concept design will be evaluate using weighted decision matrix.

2.8.1 House of Quality

HOQ help in identifying and translating customer requirement in critical quality of engineering characteristics on top of that, it will determine the customer satisfaction. The listing of engineering characteristics must withstand inspection before carried forward as design variables are set. In determining the result from the HOQ, depends on the highest ranking engineering characteristics. The values of each ranking can be set according to priorities of the designer or approving authority. Once engineering characteristics, further the documentation in product design specification (PDS).

2.8.2 Product Design Specification

Information gather from HOQ are analyze and create design process by completing every parameter for the product. The goal of design process planning is to identify and assemble enough information to decide on project development. Resulting from the planning process the concept design tasks are compiled in the form of set of product design specification. PDS is the reference document of the design and manufacture of the product, its contain all of the facts related to outcome of the design concept. It should prevent the design towards an unconvincing design outcome and contain relevant constraint and relevant to design. Creating the PDS finalizes the process of establishing the customer needs and

wants, prioritizing them, and beginning to cast them into a technical framework so that design concepts can be established.

2.8.3 Morphology Concept

Morphological method assist in producing concept design and structure the problem with different component but same required functionality. Every components are separated and categorized accordingly. The arrangement will very useful in refining the concept, subset of the problem and satisfy the need described by the identified function (Dieter, 2009). So far, in compiling each options into concept design result into one structure of solution. Generation solution concept comes from sub problem, where the solution is combine into design concept. Concept designs are being compare and evaluate further for better selection of design.

2.8.4 Weighted Decision Matrix

Decision matrix is a method evaluating the design concept retrieved from morphological chart. The evaluation complete with design criteria and with weighting factors and scoring of each concept to meet the criterion. The concepts need to convert into the consistent set of values by using a point scale (Dieter, 2009).

Table 2.2: Evaluations scheme for design alternatives or objectives (Source from engineering design fourth edition, page 282).

11- point scale	Solution description	5- point scale	Description
0	Totally useless	1	Inadequate
1	Very inadequate		
2	Weak	2	Weak
3	Poor		
4	Tolerable	3	Satisfactory
5	Satisfactory solution		
6	Good with few disadvantages	4	Good

7	Good		
8	Very good		
9	Excellent	5	Excellent
10	Ideal solution		

In determining the factors for criteria, valid weighting need to be recognize where the factor should sum to 1. Whenever the criterion based on ratio scale changes its magnitude from design concept to another this does not affect the change from one concept design to another. The new score based on the assessment on the description on Table 2.2. The ratings for each concept obtain by multiplying the score by the weight factor. Thus the highest rating concept designs are chosen for the detail design (Dieter et al, 2009)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explain the process and methods for obtaining the information and designing the skimming machine holder. Method in obtaining the design start with house of quality then proceed with product design specification follow with idea generation using morphological chart. The morphological chart is where the overall design problem are divided into simpler sub problem. Next, the sub problem are combine into solution and evaluate all combinations using weightage selection matrix method to choose the final concept design.

3.2 House of Quality

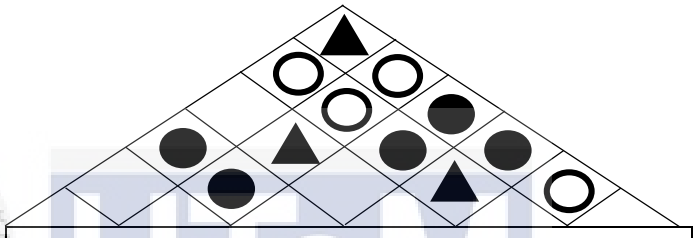
Table shown below are the information of engineering characteristics and customer requirement. Based on the table every important weight factor are being categorized from the important to the least important. The correlation of each engineering characteristics are relate accordingly.

Table 3.1: Indicator for house of quality description.

Description	**Indicator**
Importance weight factor – Importance rating	1 – 5 1 – least important 5 – most important
Engineering characteristics	1 -9

Customer requirements	9 – strong 3 – medium 1-weak
Improvement direction relationship	● Strong ○ Medium ▲ Weak Blank – none

Table 3.2: House of quality for configuration applied to skimming machine holder.



Customer Requirements	Importance weight factor	Toughness of material	Rotation speed	Stable installation	Service ability	Suitable required torque	Design consideration
Support various model	5	8	7	8		6	
Ease of control and installation	5			7	6		7
Safety operation and equipment	5			7			8
Good consistency	5		5	8		8	
Even skimming	5		7	7		8	
Reliable	4	8	6	8	5	6	

High quality production	4	8	6	7		7	
Low maintenance	3	7			8		
Long lasting	3	7			6		
Raw score		146	143	245	92	162	75
Relative weight %		16.92	16.57	28.39	10.66	18.77	8.69
Rank order		3	4	1	5	2	6

The HOQ for the skimming machine holder shows that the most important engineering characteristics are stable installation of the component, suitable torque requirement for a better rotation during operation, toughness of material, rotation speed, and service ability last but not least design consideration.

Stable installation ranked first among the engineering characteristics where it is strongly related to rotation of speed and toughness of material because the installation need to be free form vibration. Also the installation will become more reliable and have good consistency even various model are mounted.

Suitable required torque comes in second place, as for customer requirement that are related it must have a good consistency and even skimming during operation. In order to produce high quality production suitable torque will be able to support various model and reliable during the process.

Ranking third and fourth have a slightly difference regarding relative weight. However both toughness of material and rotation speed are important for customer requirement based on capable of various model support and on high quality production and reliable operation progress. Furthermore by considering toughness of material the machine experience a long lasting lifetime and low maintenance.

Service ability and design consideration are the low-ranking based on preference of engineering characteristics. The service ability that come at fifth order are least important, where the machine are more likely to withstand the break down. Also design consideration, of course safety is important however, complex design are undesirable because tend to having difficult control and installation.

Observation from this HOQ it was determine that customer need a stable installation and suitable torque in order to have a better result. A review of the ratings shows that customer require a very reliable and good outcome after skimming brake disc. Note that this conclusion can be read from the HOQ for other relation of the case that is not specifically included because of the least significant.

3.3 Product Design Specification (PDS)

In the design process, product design specification is a document created during the problem definition activity. It details the requirements that must be met in order for the product process to be successful. It is a basic control and reference document for the design and manufacture of the product. It also a document contains all the facts related to the outcome of the product development. As for the benchmark, Ammco brake lathe was set as datum of the detail specification. Therefore, the product design specifications for concept design of skimming machine holder with transfer gear are also provided below.

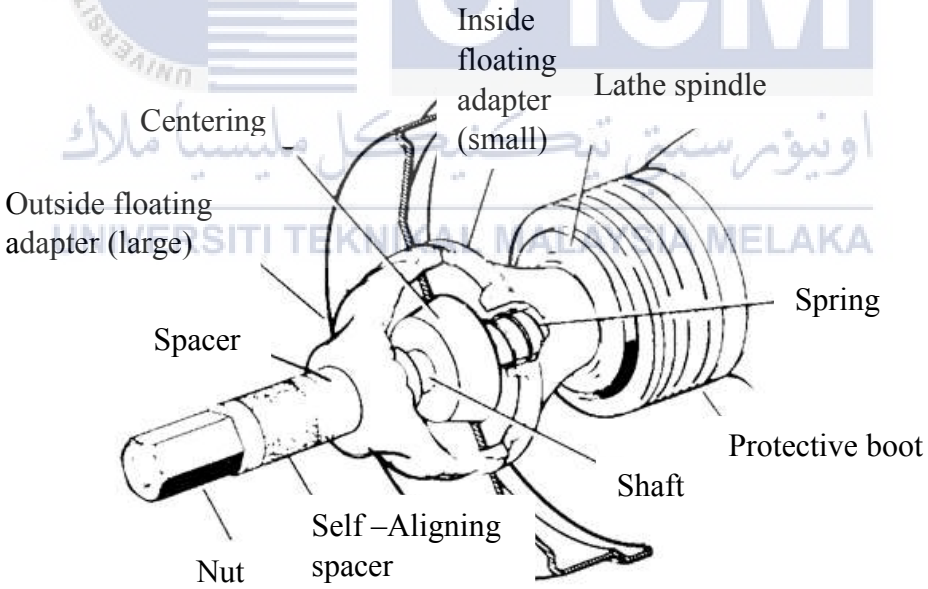


Figure 3.1: Parts of skimming machine holder. (Source from Ammco drum and brake lathes.)

Centering cone are mount on shaft so the brake disc were position at the center of shaft. The floating adapter will place both side of the brake disc to avoid vibration during skimming process. Fill out the shaft with spacers then tighten the assemblies. To avoid over tightening, wrench tight the nut counterclockwise until the brake disc and adapter begin to turn on the shaft, then continue to advance the wrench.

Table 3.3: The operating specification for Ammco brake lathe machine.

Operating specification	Description
Electrical requirements	115 VAC, 60HZ, single phase, fused at 15 amps
Output shaft diameter	28mm
Spindle travel	175mm
Brake disc diameter (max)	483 mm
Brake disc thickness (max)	175mm
Max load	25.4mm diameter shaft =(45.35kg) 47.63mm diameter shaft = (90.72kg)
Weight brake lathe loaded with tooling and adapter	160 kg

The operating specification for Ammco brake lathe machine consider all the main part of the brake pad holder involve. Consideration of the brake disc thickness and diameter both are important to verify the dimension for the adapter. The spindle also have different speed according to the diameter of brake disc. In order to reduce the speed feed, the modification of the brake lathe have been made.

3.3.1 Shaft Installation

Ammco product use a 1 inch of the shaft where it matched to the lathe during final assembly and testing. The witness mark have been fixed properly onto the shaft and spindle. The witness mark must be carefully aligned when installing the shaft because the result of the skimming depend on whether the shaft could rotate properly during skimming process.

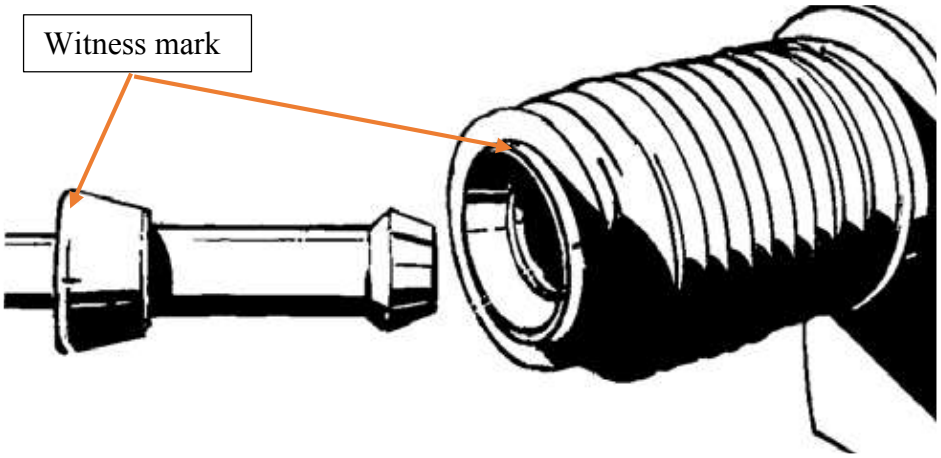


Figure 3.2: Align witness marks during shaft installation.

The attachment of the spindle and shaft are really crucial and need to consider whether the witness mark are align. Precise alignment of the witness mark could result an accurate while machining. Therefore, great care should be taken when handle or store the machine. Even the smallest scratch or loose chip on the machine can cause incorrect brake disc attachment.

3.4 Calculation for Datum

3.4.1 Calculation for Circular Shaft Deflection

Below will be the value of each parameter in order to calculate the deflection of beam. The value for this formula are obtain from the datum specification where the maximum force acting on the shaft is 889.96N. Another important value are the length and the diameter of the shaft which are $252.02\times10^{-3}\,\text{m}$ and $28\times10^{-3}\,\text{m}$ respectively. Given that the value of modulus elasticity for steel is $2\times10^{11}\,\text{Nm}^{-2}$. All the values are substitute to the circular shaft deflection. Calculate by using the formula from equation (2.11).

$$\delta = \frac{4}{3\pi}\left(\frac{(889.96)(252.02\times10^{-3})^3}{(2\times10^{11})(14\times10^{-3})^4}\right)$$

$$\delta = 0.7867\times10^{-3}\,\text{m}$$

$$\delta = 0.7867 \times 10^{-3}\,\text{m}$$

$$\delta = 0.7867\text{mm}$$

The deflection occur if there is force acting on the shaft is 889.69 N is $0.7867 \times 10^{-3}\,\text{m}$. However there is some tolerable deflection where for a transmission shaft with span length, L (distance between the two adjacent bearings), and the maximum deflection (δ) is in the range.

$$\delta = (0.001)\ \text{L to}\ (0.003)\ \text{L} \tag{3.1}$$

As for a sample calculation:

$$\delta = (0.001)\ 252.02 \times 10^{-3}\,\text{m}$$

$$\delta = 0.7561 \times 10^{-3}\,\text{m}$$

$$\delta = 0.7561\text{mm}$$

3.4.2 Calculation for Torque

Torque is a measure of how much a force acting on an object causes that object to rotate. Torque is define by the formula in (2.19) however, it is crucial to know the value for power and speed, ω. As for power the value can be obtain by convert the unit of horsepower HP to kW. One mechanical horsepower unit is approximately equal to 745.7 watts. As for speed, ω the formula are given as equation (2.17) the equation will be rearrange to find the value of ω. And for the rotation take the value of 150 RPM as it is for the fine cut for skimming.

$$\omega = \frac{2\pi N}{60}$$

$$\omega = \frac{2\pi(150\text{RPM})}{60}$$

$$\omega = 15.708\,\text{rad/s}$$

Substitute value P = 745.7W and value in equation (2.17) after rearrange the formula given by

$$T = \frac{P}{\omega}$$

$$T = \frac{745.7}{15.708}$$

$$T = 47.47\text{Nm}$$

Therefore the torque provided in when using the 1hp motor are 47.47 Nm.

3.5 Analysis of Datum Using Finite Element Analysis

3.5.1 Load Analysis using FEA

Von misses

Figure 3.3a: Value of von misses of datum shaft.

Translational Displacement

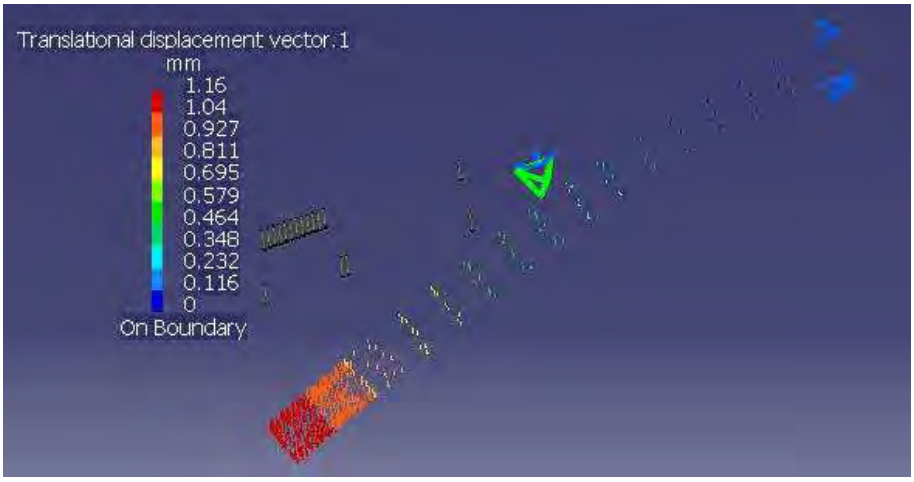


Figure 3.3b: Value of translational displacement of datum shaft.

Finite element analyses were perform for datum to determine the value of each von misses, displacement and stress principle. All the value then will be compare with analyze concept designs by using the same applied load and software. Datum analysis on von misses where it experience a greater value which make the factor of safety value become 2.6455 follow by translational displacement occur in datum is 1.16mm.

3.5.2 Torque Analysis using FEA

Von Misses Stress

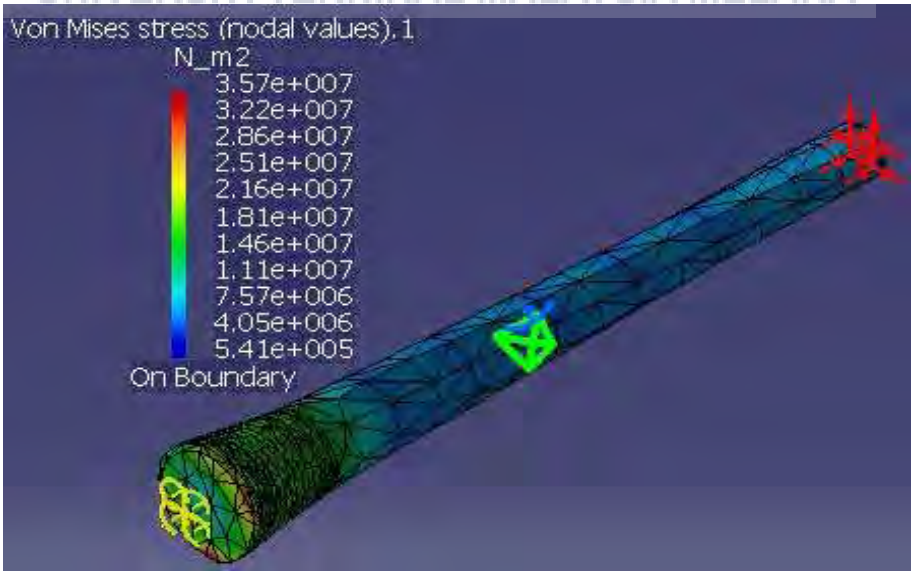


Figure 3.4a: Value of von misses for torque of datum shaft.

Translational Displacement

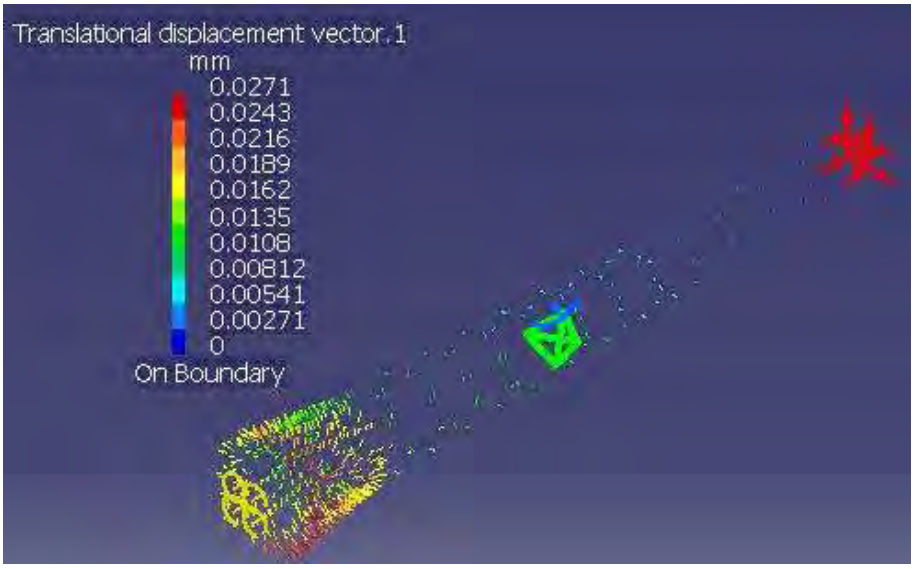


Figure 3.4b: Value of translational displacement for torque of datum shaft

Torque value, 47.47Nm that obtain from the previous calculation are applied to the torque analysis. Values obtain for torque applied for von misses, and translational displacement are $3.57\times10^{7}\,\mathrm{Nm}^{-2}$, 0.0271mm, respectively, the values are to compare with the chosen conceptual design and evaluate whether the chosen concept are much better than datum. Result from the torque analysis will tell the deformation and characteristics of shaft whenever applied torque. Frankly, the value obtain for datum are according to specification, however the concept design need to be more effective than the existence product.

3.6 Modified Brake Disc Machine Holder

Based on the datum specification, brake lathe or also known as brake disc skimming machine will modified the design accordingly. Instead of using spindle, the modified design will use a helical gear motor reducer. The helical gear as a regulator for the motor to adjust the shaft rotation.

Table 3.4: The operating specification for modified brake disc skimming machine.

Operating specifications	Description
Electrical requirements	Horizontal type, foot mounted 220 VDC, Single phase, 0.75kW, 60Hz
Output shaft diameter	28mm
Gear ratio	12 : 60 60/12 = 5
Output rpm	344 rpm
Weight of helical gear reducer	17 kg
Dimension	Height = 180mm Width = 212mm Length =375mm

As for shaft for skimming machine, the shaft length have to consider the length of brake disc, adapter, and fastener. The diameter and length that suitable with the radius of brake disc and most importantly, compatible with any type of brake disc. Diameter of the shaft is 28mm whereas for the length is 180mm. The shaft complete with key way to accommodate with key and withstand the considerable shear and compressive stresses caused by the torque transmit.

Figure 3.5: The horizontal type foot mounted of helical gear reducer with 1hp motor.

The medium that provide the power to rotate the shaft is single phase motor with transfer gear. As shown in the Figure 3.5 the suitable motor is 1 horse power single phase motor with helical gear reducer which have an enough torque needed in order to run the machine. Therefore, torque power will distribute befittingly with the mass of the shaft, adapter and brake disc.

3.7 Concept Generation

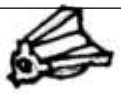
Creative thinking method and design process are needed to assist in the progression of the design concept to produce useful design concept. The ability to identify the concepts by using morphological chart as one of the creative thinking method. This method help to enhance the particular function required by the product. By using the morphological method the creativity and particular function are able to identify and develop an inspired concept.

Holder of the skimming machine are specified first then improved the design into parts and combine into design. There will be 5 design concept that are being retrieve from the morphological chart. Among the 6 concept out of 3 concept will be choose and analyze and simulate using CATIA software. One of the concept must have best design with the advantageous concept and satisfy the customer requirement.

3.7.1 Morphological Chart

Generating and representing all the relationship of every part of the skimming machine into sub function. There are many different combination of option that can satisfy the same functionality required in a concept design. The tabulated table below shows the arrangement of the sub function to merge with other generative method. Achievement develop in the table had approach an systematic design to create an accurate function structure for the product designed and seeks to generate of reasonable concept for further deliberation.

Table 3.5: The morphological chart of sub function of skimming machine holder.

Sub function	Option 1	Option 2	Option 3	Option 4	Option 5
Shaft					
Centering cone					
Clamp					
Fastener					
Key adapter					
Isolator					

The morphological chart are divided into five sub function and has another 5 option to be match and become one concept. From the option, 5 concept were develop by using different approach. Each consist of solution to compromise the skimming holder function. For first rows fill with different design of shaft. Second row is the main part for holder which centering cone, also have 5 design for each option. Next clamping of the brake disc that comes in five different option. For fastener used in this concept are bolt and nut as for adapter different type of key are also optional and lastly the isolator that commonly use.

3.7.2 Conceptual Design

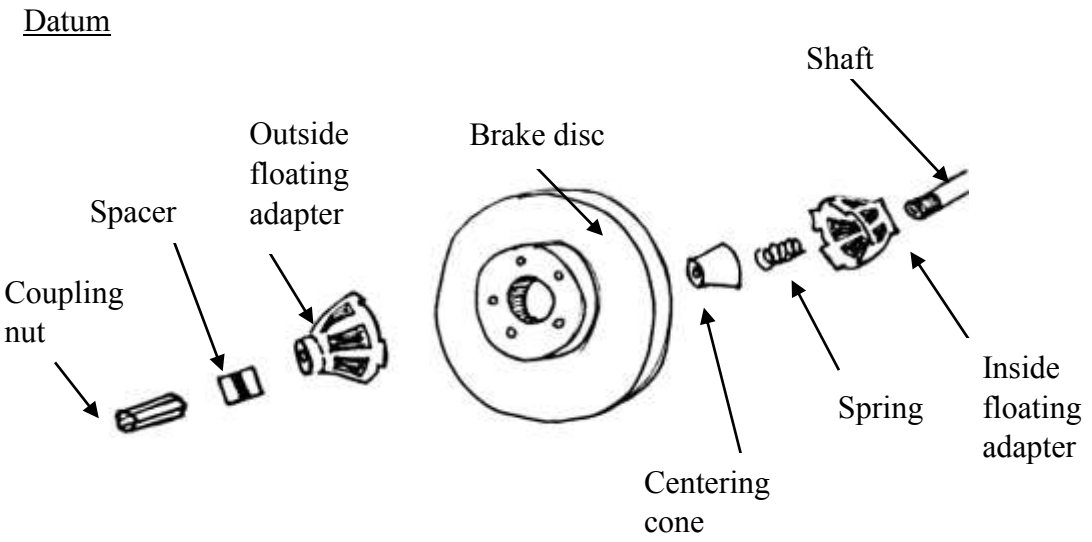


Figure 3.6: The exploded view with labeled part of datum.

The figure above shows the labelled of every skimming machine holder part. Attachment of the shaft to the spindle then the 3 finger cup are attach and spring act as then put in the taper centering cone to brake disc to position the brake disc at the center of shaft. Then put another 3 finger cup complete with spacer. Lastly secure the attachment with bolt.

The sketch of the datum act as guideline for the concept design. The concept design comes in 6 concept. Besides, the concept also implement several parts of the datum. Concept design then, will be evaluate based on the functionality whether the outcome are the same with datum or instead.

Design concept 1

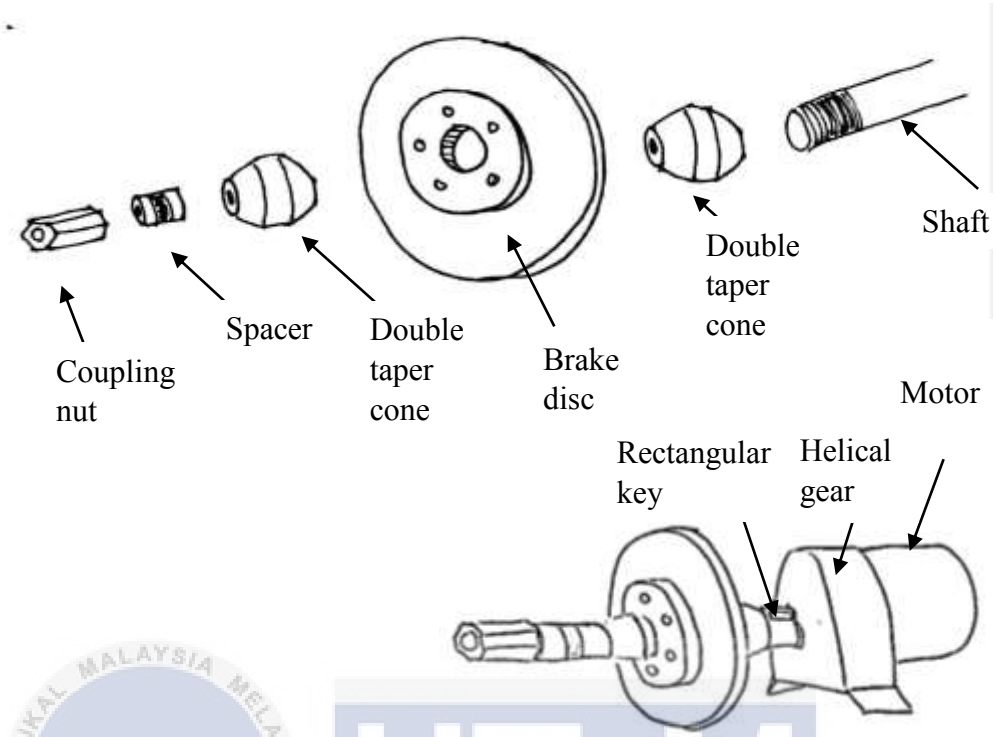


Figure 3.7: Exploded and assembly view of design concept 1.

Shaft	: Option 3
Centering cone	: Option 3
Clamp	: Option 4
Fastener	: Option 3
Key adapter	: Option 3
Isolator	: Option 1

Design concept 1 using a shaft that have threaded at the end of the shaft. As for the centering cone, this concept use double taper cone on both side of the rotor. The double taper cone will hold the brake disc also at the same time centering the position of brake disc on the shaft. This concept use vibration collar and coupling nut to fasten the mounting. Gib-head key was used in this concept as it suitable for heavy duty application.

Design concept 2

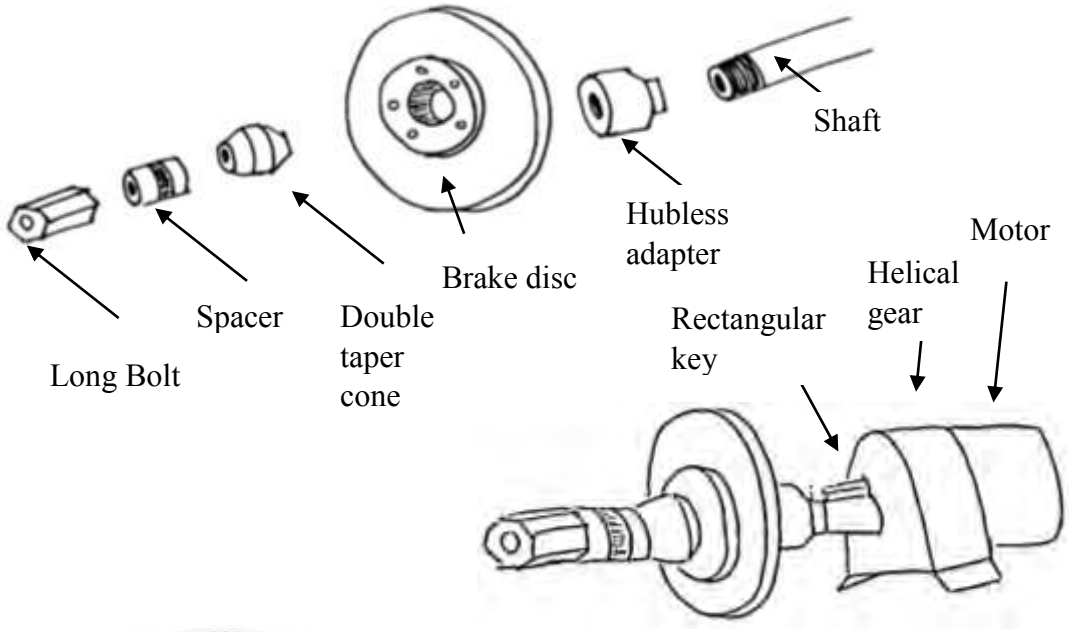


Figure 3.8: The exploded and assembly view of concept design 2.

Shaft : Option 5

Centering cone : Option 3

Clamp : Option 4

Fastener : Option 3

Key adapter : Option 3

Isolator : Option 1

The second concept use the same as concept 1, but slightly different where the clamping device use is hubless adapter and double taper centering cone. Both will clamp and center the position of the brake disc then will be tighten with vibration absorber and coupling nut. Key way of the shaft is provide with rectangular key to slide into the helical gear reducer. Furthermore rectangular key is suitable for heavy duty machining because of the chance to sliding are low.

Design concept 3

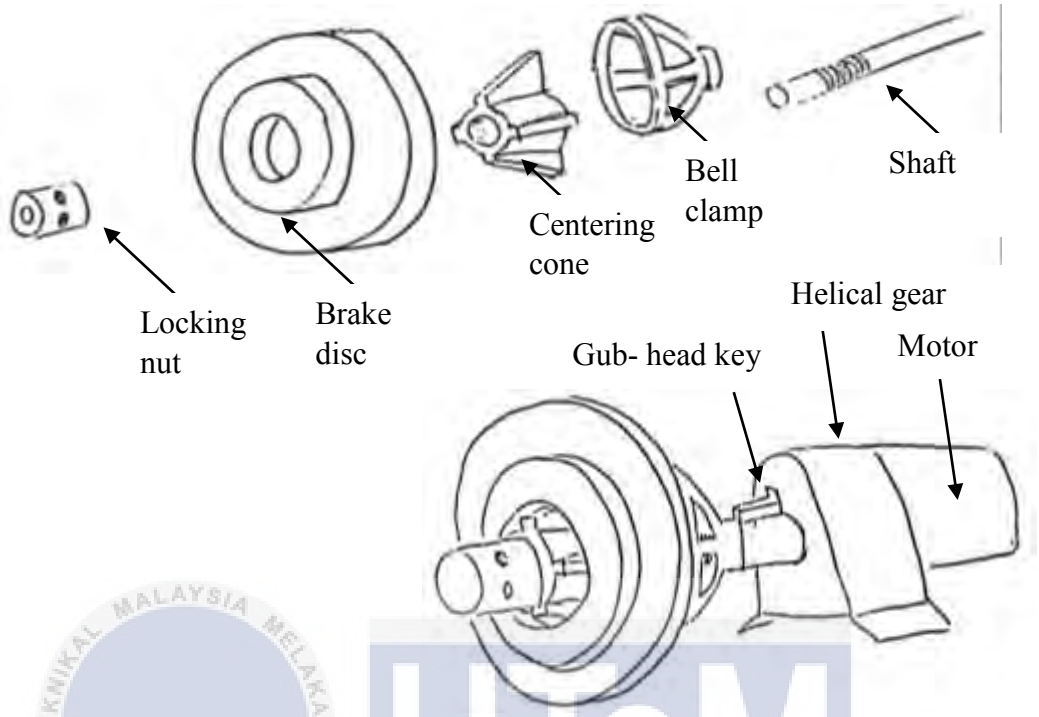


Figure 3.9: The exploded and assembly view of concept design 3.

Shaft	: Option 2
Centering cone	: Option 4
Clamp	: Option 1
Fastener	: Option 4
Key adapter	: Option 2
Isolator	: Option 2

This concept use less item because the fastener use in this concept are secure enough to tighten the brake disc. In addition the centering cone also help to locate the brake disc at the shaft. Nevertheless the brake disc are secured once again at the back side where the spring and clamp are attach together. Helical gear are slide a shaft with gub- head key. Threading at the middle of the shaft because use the locking nut.

Design concept 4

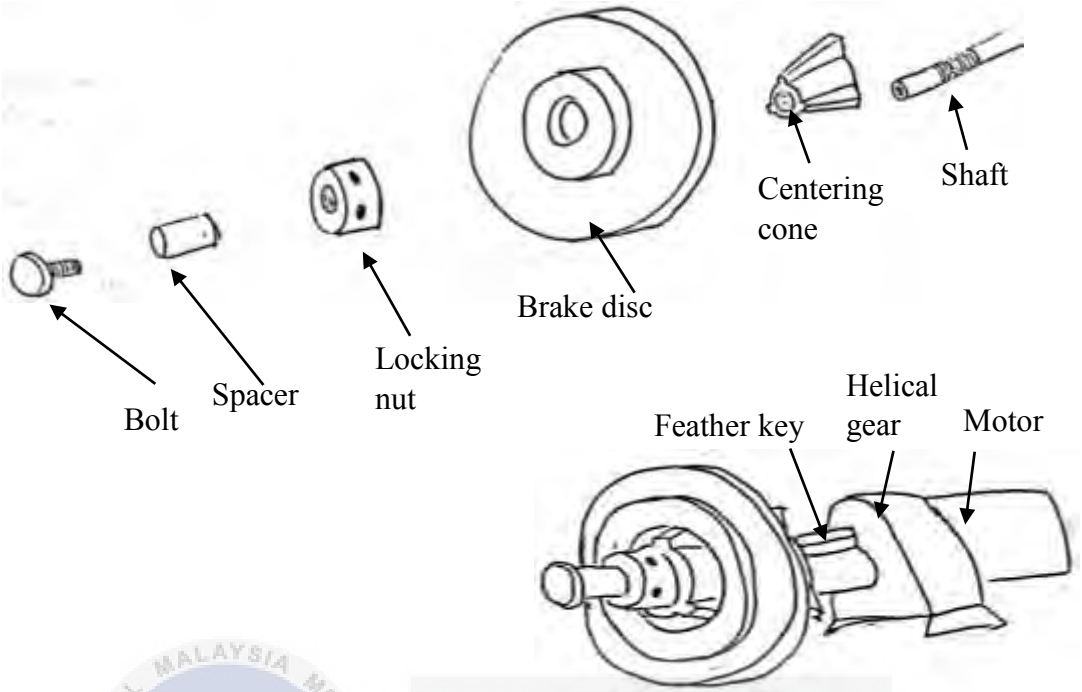


Figure 3.10: The exploded and assembly view of concept design 4.

Shaft	: Option 4
Centering cone	: Option 4
Clamp	: None
Fastener	: Option 4
Key adapter	: Option 1
Isolator	: Option 1

This concept use bolt to fasten the holder before that spacer are added to fill the space left when attaching the shaft bolt with center cone. The center cone have 3 fin that were design taper so mostly every disc brake can go through the centering cone. Usually the centering cone are design with solid structure, this could influence the power for load applied. The shaft use also have a hollow to reduce the load that complete with key way of feather key. The feather lightly fitted when slides along the shaft to lock with the power source by means it secure the shaft keyway assuredly.

Design concept 5

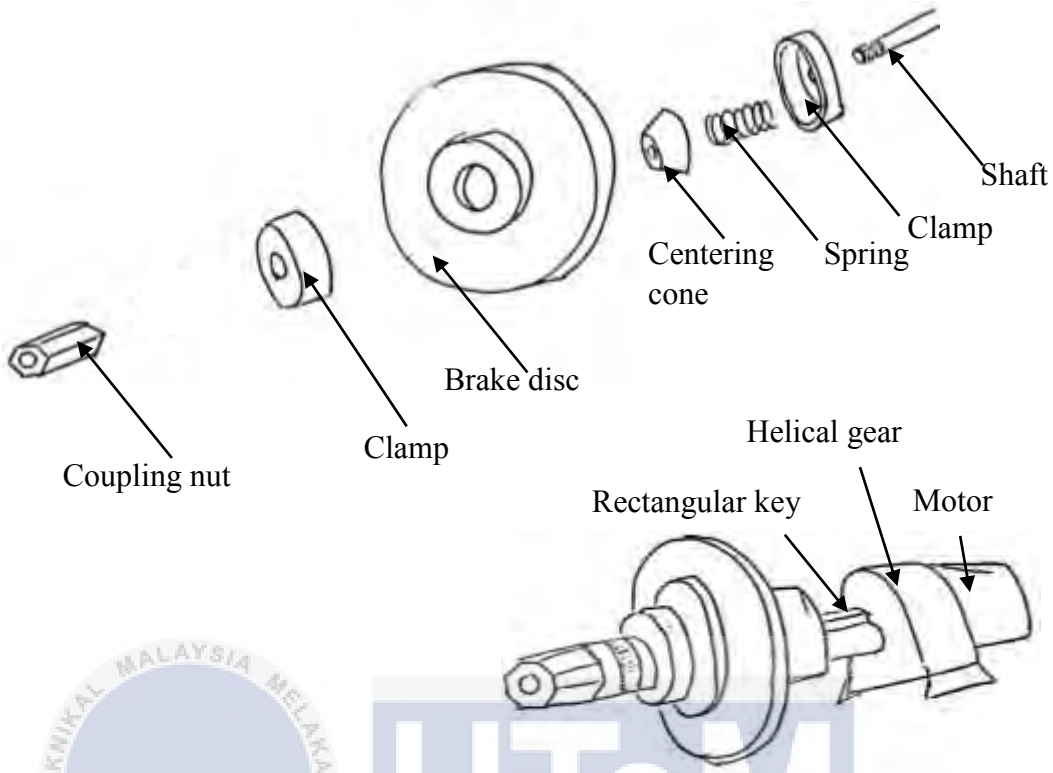


Figure 3.11: The exploded and assembly view of concept design 5.

Shaft	: Option 3
Centering cone	: Option 2
Clamp	: Option 3
Fastener	: Option 3
Key adapter	: Option 3
Isolator	: None

This concept, mostly similar as datum but the difference is the clamping device. Clamping device use are circular shape and applied on both side of the brake disc. This concept have a stable structure because the clamping are secure mostly with required with complete attachment. The centering cone also use a non-solid centering cone where it help to reduce the load applied. Helical gear are attach with rectangular key so there no sliding occur.

Design concept 6

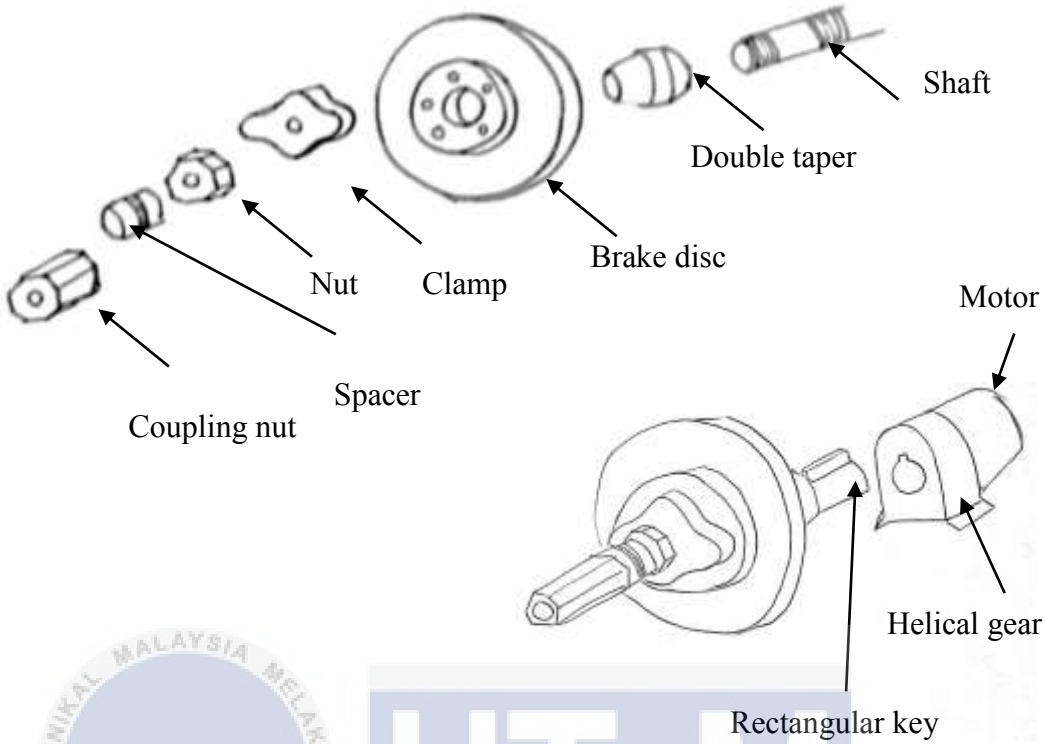


Figure 3.12: The exploded and assembly view of concept design 6

Shaft	: Option 3
Centering cone	: Option 3
Clamp	: Option 5
Fastener	: Option 2 and 3
Key adapter	: Option 3
Isolator	: Option 1

The clamping use for this design are design for better clamping and tightly secure by the small bolt. Brake disc as result will be position by double taper centering cone. The shaft use will left out for the longer bolt to tighten at the end of the shaft. By using the rectangular key that securely slide in the key way to attach to the helical gear reducer.

3.8 Decision Making and Concept Selection

All of the design concept from the morphological chart are being review attentively in decision making to select the best concept design. Around 3 concept design are being selected after using weighted selection matrix. Moreover, the decision making are decided based on the creativity, ability combination of physical and working concept that is critically important in making wise decision.

3.8.1 Weightage Decision Matrix

A skimming machine's holder that has been proposes by design concept need to be evaluate by using weight decision matrix. Firstly identify the design criteria by each of the concept accordingly. From product design specification there are several criteria need to be identify. Next, determine the weight of each categories. Below shows the weight that has been consider for the concept designs.

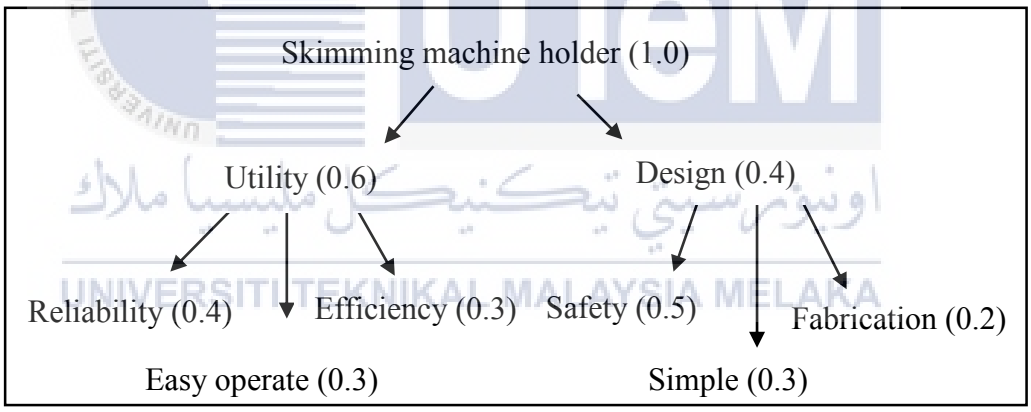


Figure 3.13: the objective tree for design skimming machine holder.

For the first level, the tree must be 1.0 and each level need to have 1.0 solution for each division total. The weight factor of the lower level under utility at 0.6 which are reliability, easy operate and efficiency are weight 0.4, 0.3 and 0.3 respectively. On the other hand, the design criteria are weight at 0.4 and for the lower level of design, the safety need the most rating which is 0.5 then, fabrication and simple style each have 0.3 and 0.2 rating. The weighting factor for overall are obtain. For evaluation in weightage the weights of each level are multiply to get the factor of weight. 11-point score is chosen to determine the best 3 concept design.

Table 3.6: The weight decision matrix with for skimming machine holder with transfer gear.

Design criterion	Weight factor	Design Concept											
		1		2		3		4		5		6	
		Score	Ratings	Score	Ratings	Score	Ratings	Score	Ratings	Score	Ratings	Score	Ratings
Reliability	0.24	7	1.68	6	1.44	8	1.92	6	1.44	9	2.16	9	2.16
Easy to operate	0.18	8	1.44	7	1.26	7	1.26	8	1.44	8	1.44	8	1.44
Efficiency	0.18	6	1.08	7	1.26	7	1.26	6	1.08	8	1.44	8	1.44
Safety	0.2	5	1	8	1.6	5	1	5	1	9	1.8	9	1.8
Simple	0.12	8	0.96	8	0.96	6	0.72	5	0.6	7	0.84	6	0.72
Fabrication	0.08	7	0.56	8	0.64	6	0.48	6	0.48	8	0.64	7	0.56
Total			6.72		7.16		6.64		6.04		8.32		8.12
Ranking		4		3		5		6		1		2	

Ranking of the design concept from 1 to 3 listed below are the chosen concept. The total score of those three design are higher than the other 3 concept. Design concept 5 are the highest score among all where it is capable in every aspect listed. Next, design concept 6 also almost applicable in every aspect especially in reliability and safety. Yet, design concept 2 that comes in third place was not as poor as it be, this concept obey the design consideration effortlessly. Therefore, the design concept 2, 5 and 6 are chosen for further study and analysis.

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This section provides the results that obtain from the three chosen design concept from the previous chapter. The three concept design will be analyze thoroughly using finite element analysis by using CATIA software. The result shown the value of von misses stress, and translational displacement for every design concept. Not to mention these concept design also have to analyze the torque applied within the capabilities of each concept design. The only selected concept design undergo DMU analysis to simulate the movement of the skimming machine holder.

4.2 Calculation Of Deflection For Design Concept

The three chosen drawing are drawn by using CATIA complete with the dimension of each concept. The purpose of this drawing is to ease on analysis and simulation process. In this case the three concept of each component are draw separately then assemble to become one product. In the assemble state the part are constraint regarding which part that need to be simulation. Mostly there are three type of constraint use which is contact, offset and coincidence. Contact constraint are use if the component are surface met with another surface, as for offset there will be certain dimension between edge whereas for coincidence is for allign axis symmetry especially for circle part.

4.2.1 Deflection of Second Design Concept

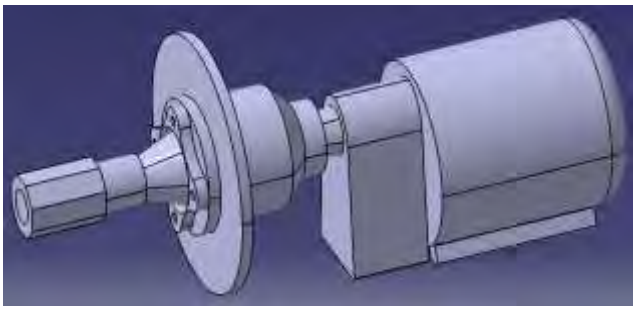


Figure 4.1: The second concept design of skimming machine holder.

The second concept design does not use a clamp however in this concept use double taper cone and hubless adapter as clamping. Then the deflection of this attachment are calculated as below.

Table 4.1: Detail on the parameter for design concept 2.

Quantity	Symbol and value
Applied force	$F = 889.96N$
Deflection	δ
Modulus of elasticity	$E = 2 \times 10^{11} Nm^{-2}$
Length	$L = 275.606 \times 10^{-3} m$
Outer diameter	$D_o = 0.03m$
Inner diameter	$D_i = 0.025m$

For the bending moment of this shaft the formula (4.1), the product of force and distance is use to determine the value

$$M = F \bullet L \tag{4.1}$$

$$M = (889.96N)(275.606 \times 10^{-3} m)$$

$$M = 245.28Nm$$

The formula of deflection (2.14), where the parameter needed is force (F), length (L), modulus of elasticity (E), and moment of inertia (I). In order to find the value of I, firstly need to identify the shape that will be use for the calculation. As for this case the shaft use is hollow round shaft therefore the equation in (2.15) need to be rearrange as equation (4.2).

$$I = \frac{\pi\left(D_0^4 - D_i^4\right)}{64} \tag{4.2}$$

$$I = \frac{\pi\left(0.03^4 - 0.025^4\right)}{64}$$

$$I = 2.0586\times10^{-8}\,\mathrm{m}$$

The deflection of shaft can be calculated after obtain the moment of inertia value. Then subtitute the value required by using the formula (2.14).

$$\delta = \frac{(889.96\mathrm{N})\left(275.606\times10^{-3}\right)^3}{3\times\left(200\times10^{9}\,\mathrm{Nm^{-2}}\right)\times\left(2.0586\times10^{-8}\,\mathrm{m^4}\right)}$$

$$\delta = 1.5084\times10^{-3}\,\mathrm{m}$$

$$\delta = 1.5084\mathrm{mm}$$

Deflection for design 2 is, 1.5084mm the result obtain exceed the deflection for datum which it is not really compatible for this case. This is because the hollow shaft had been the main contribution because the inner layer especially similar to solid shaft because it have a better strenght even the failure points are better. A hollow shaft will catastrophically buckle, a solid shaft will bend under compression. Under tension, a solid shaft will result in a gradual cup and cone type of failure while hollow shaft will fail relatively catastrophically.

4.2.2 Deflection of Fifth Design Concept

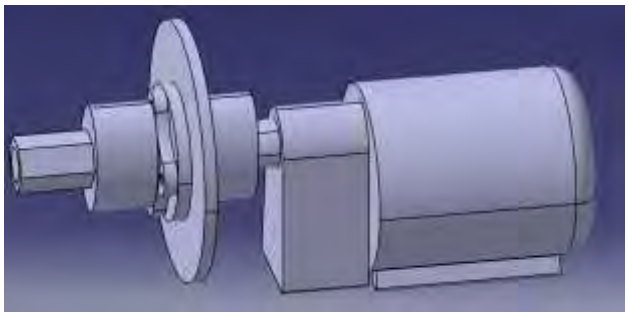


Figure 4.2: The fifth concept design of skimming machine holder.

Fifth design concept has a different attachment design where the clamp at both side an oval shape design. The oval shape is more lightly have a higher strength for grip the brake disc.

Table 4.2: Detail on the parameter for design concept 5.

Quantity	Symbol and value
Applied force	$F = 889.96N$
Deflection	δ
Modulus of elasticity	$E = 2 \times 10^{11} Nm^{-2}$
Length	$L = 202.081 \times 10^{-3} m$
Diameter	$D = 0.03m$

For the bending moment of this shaft the formula (4.1) is use to determine the value.

$$M = (889.96N)(202.081 \times 10^{-3} m)$$

$$M = 179.84Nm$$

The formula of deflection at equation (2.14), where the parameter needed is force (P), length (L), modulus of elasticity (E), and moment of inertia (I). In order to find the value of I, firstly need to identify the shape that will be use for the calculation. As for this case the formula is at equation (2.15) where the I indicate the moment of inertia for a solid round shaft.

$$I = \frac{\pi\left(0.03^4\right)}{64}$$

$$I = 3.9761\times10^{-8}\,\mathrm{m}^4$$

The deflection of shaft can be calculated after obtain the moment of inertia value which is $3.9761\times10^{-8}\,\mathrm{m}^4$. Then subtitute the value required by using the formula (2.14).

$$\delta = \frac{(889.96\mathrm{N})(202.081\times10^{-3}\,\mathrm{m})^3}{3\times(200\times10^9\,\mathrm{Nm}^{-2})\times(3.9761\times10^{-8}\,\mathrm{m}^4)}$$

$$\delta = 0.3078\times10^{-3}\,\mathrm{m}$$

$$\delta = 0.3078\mathrm{mm}$$

Deflection occur in this concept design are much better than previously, this show the deflection occur within the shaft are tolerable.

4.2.3 Deflection of Sixth Design Concept

Figure 4.3: The sixth concept design for skimming machine holder.

Table 4.3: Detail on the parameter of design concept 6.

Quantity	Symbol and value
Applied force	$F = 889.96\mathrm{N}$
Deflection	δ
Modulus of elasticity	$E = 2\times10^{11}\,\mathrm{Nm}^{-2}$
Length	$L = 270.382\times10^{-3}\,\mathrm{m}$
Diameter	$D = 0.03\mathrm{m}$

For the bending moment of this shaft the formula (4.1) is use to determine the value

$$M = (889.96N)(270.382 \times 10^{-3} m)$$

$$M = 240.63Nm$$

The formula of deflection at equation (2.13), where the parameter needed is force (P), length (L), modulus of elasticity (E), and moment of inertia (I). In order to find the value of I, firstly need to identify the shape that will be use for the calculation. As for this case the formula is at equation (2.14) where the I indicate the moment of inertia for a solid round shaft.

$$I = \frac{\pi(0.03^4)}{64}$$

$$I = 3.9761 \times 10^{-8} m^4$$

The deflection of shaft can be calculated after obtain the moment of inertia value. Then subtitute the value required by using the formula (2.13).

$$\delta = \frac{(889.96N)(270.382 \times 10^{-3})^3}{3 \times (200 \times 10^9 Nm^{-2}) \times (3.9761 \times 10^{-8} m^4)}$$

$$\delta = 0.7374 \times 10^{-3} m$$

$$\delta = 0.7374mm$$

Lastly the deflection occur in design concept 6 is as mention in equation is 0.7374mm it is quite higher from the previous value. As for this design it is quite structural because the attachment is steadier than the other two. However the value deflection is quite higher instead of design concept 5.

4.2.4 Range Of Deflection

From the design above the only calculation that favorable is the fifth concept, the second calculation, where the deflection is 0.3078 mm. Compare to the datum deflection this concept are way much better. Then for the permissible deflection are calculated to prove whether the deflection occur for the shaft. Recall from equation (3.1) same goes to this calculation where need to be applied the same method as below.

As for a sample calculation of deflection for fifth concept design will be compare by using equation (3.1) to estimate the range:

$$\delta = (0.001)\ 202.081\times10^{-3}\,\mathrm{m}$$
$$\delta = 0.2021\times10^{-3}\,\mathrm{m}$$
$$\delta = 0.2021\mathrm{mm}$$

Using the next equation for range determination

$$\delta = (0.003)\,202.081\times10^{-3}\,\mathrm{m}$$
$$\delta = 0.6062\times10^{-3}\,\mathrm{m}$$
$$\delta = 0.6062\mathrm{mm}$$

The rest of the calculations for fifth and sixth design concept are calculated the same as above, the value obtain are preview in the Table 4.4.

Table 4.4: The result for deflection range of the chosen design concept.

Design concept	Length (mm)	Deflection range (mm)	Deflection (mm)
2	275.606	0.2756 ~ 0.8268	1.5084
5	202.081	0.2021 ~ 0.6062	0.3078
6	270.382	0.2704 ~ 0.8111	0.7374

Therefore the deflection for fifth design is tolerable since the value is in the range between 0.2021mm to 0.6062mm. Moreover the concept designs will be further evaluate as by using CATIA software. The CATIA software will be doing two proven test which is analysis using finite element analysis and simulation using digital mock up.

4.3 Analysis Conceptual Design

This section including finite element analysis on load and torque. Each shaft will be applied 889.96N for load and 47.47Nm for torque value.

4.3.1 Finite Element Analysis

By using FEA the design undergo the possible applied force at the shaft. This analysis will be determine the strength of the shaft with a generative specification-driven approach. The specific force will be applied to the shaft, then to acknowledge the result will preview the outcome in report generate. Especially for the shaft of the holder where include every information for the material usage and value of analysis result as shown in table and figure below.

Table 4.5: Properties of shaft that made of steel.

Material	Steel
Young's modulus	$2\times10^{11}\,\mathrm{Nm}^{-2}$
Poisson's ratio	0.266
Density	$7860\mathrm{kgm}^{-3}$
Coefficient of thermal expansion	$1.17\times10^{-5}\,\mathrm{K}^{-1}$
Yield strength	$2.5\times10^{8}\,\mathrm{Nm}^{-2}$

By this table we can get an information for the steel use for shaft. This table are obtain from finite element whereby its shows the commonly properties for steel which are Young's modulus, Poisson's ratio, density, coefficient of thermal expansion and yield strength. This properties information helps in various way especially in factor of safety, whereby using the value of yield strength also known as maximum stress that can be applied along the shaft, thereby the factor of safety can be obtain by the ratio of von misses and yield strength.

Young modulus is a measure of the ability of a material to withstand changes in length when under lengthwise tension or compression. Furthermore, young's modulus can be used to predict the elongation and compression of an object. As for Poisson's ratio is a

dimensionless parameter that provide a good deal for material. It will be noted that the most brittle materials have lowest Poisson's ratio, and that the material appear to become generally more flexible as the Poisson's ratio increases. Nature of steel depends on the density of steel whereby the denser the steel the harder it is. On behalf of coefficient of thermal expansion is a material property that is indicative of the extent to which a material expands upon heating also often defined as the fractional increase in length per unit rise in temperature.

Von Misses Stress

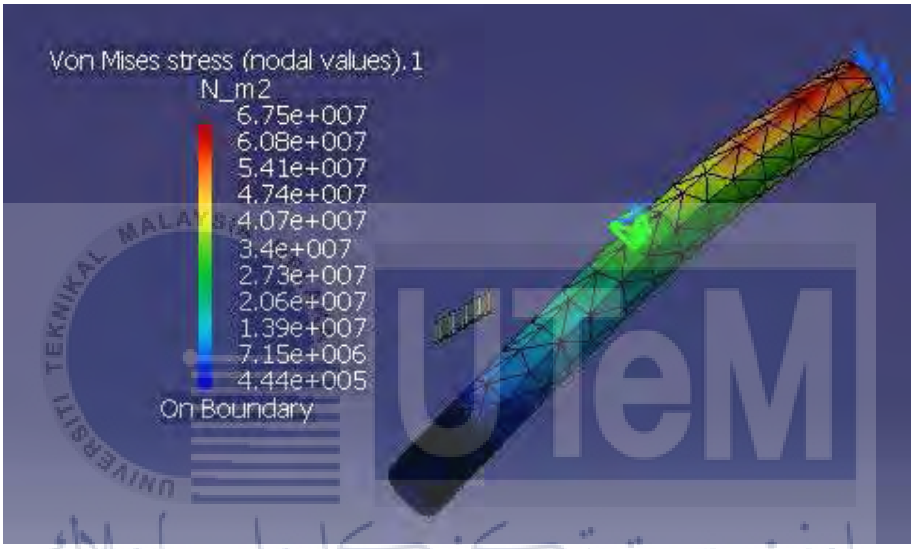


Figure 4.4a: The value of von misses stress for second shaft concept design.

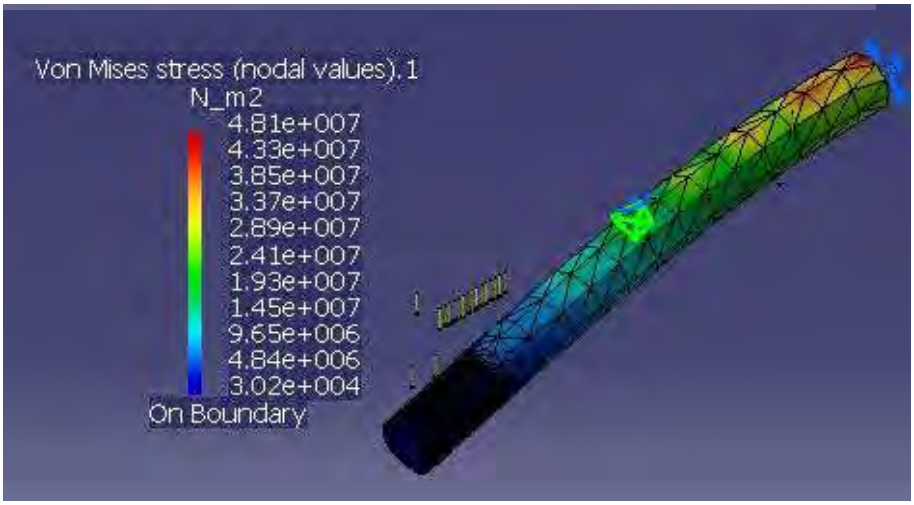


Figure 4.4b: The result from finite element analysis that shows the value of von misses stress

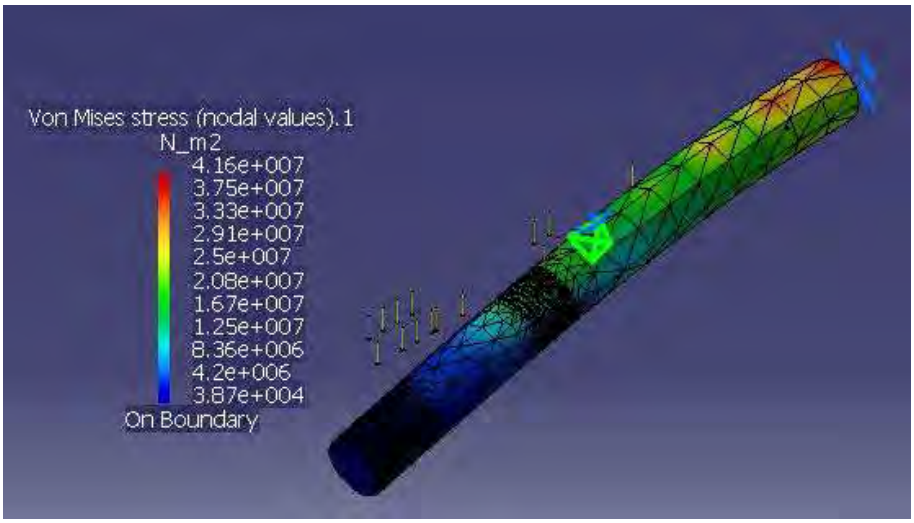


Figure 4.4c: The value of von misses stress for sixth shaft concept design.

At the left corner of each figure shows the value of von misses stress describe by eleven stress which vary from point to point according to the colour indicator. The red colour experience the highest stress whereas the blue colour indicate the lowest stress occurs while the force are acting all over the shaft. The von misses stress is commonly used to represent the total stress given region is experiencing therefore it is a reasonable indicator of where failure will occur.

By using the highest value of von misses, the safety factor could be obtain by formula shown in equation (4.3). The highest value factors of safety are being calculated below.

Calculation for figure 4.4a

$$F.S = \frac{\sigma_{all}}{\sigma_{max}} \tag{4.3}$$

$$F.S = \frac{2.5 \times 10^{8} Nm^{-2}}{6.75 \times 10^{7} Nm^{-2}}$$

$$F.S = 3.7037$$

The calculations are repeat for factor of safety for concept design 5 and 6 respectively. Below is the tabulated of factor of safety of each concept design.

Table 4.6: The value of factor of safety for each concept design.

Concept design	Yield strength	Von misses stress	Factor of safety
2	$2.5\times10^{8}\ \mathrm{Nm^{-2}}$	$6.75\times10^{7}\ \mathrm{Nm^{-2}}$	3.7037
5	$2.5\times10^{8}\ \mathrm{Nm^{-2}}$	$4.81\times10^{7}\ \mathrm{Nm^{-2}}$	5.1975
6	$2.5\times10^{8}\ \mathrm{Nm^{-2}}$	$4.16\times10^{7}\ \mathrm{Nm^{-2}}$	6.0096

All the objects have a stress limit depending on the material used, which are represented as material yield or ultimate strengths. As for safety factor it must be over 1 for the design to be acceptable, less than 1 means there is some permanent deformation. Based on the engineering edge article, most designer strives for a safety factor of between 5 or 6 especially the load is likely to be alternately put on and taken off. Load that applied to the shaft will be continuously applied therefore the factor of safety need to be consider whether the shaft can withstand the load instead.

Translational Displacement

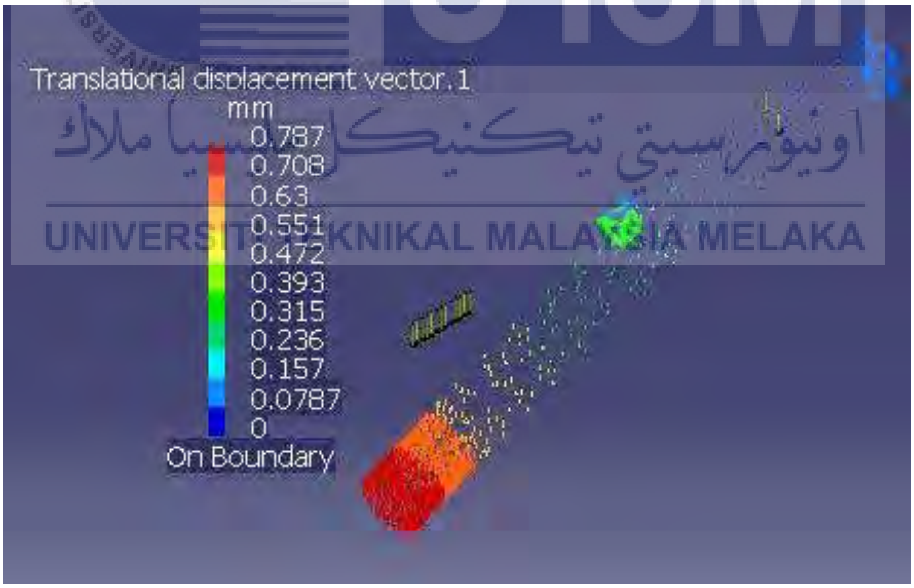


Figure 4.5a: The translational displacement vector of shaft concept 2.

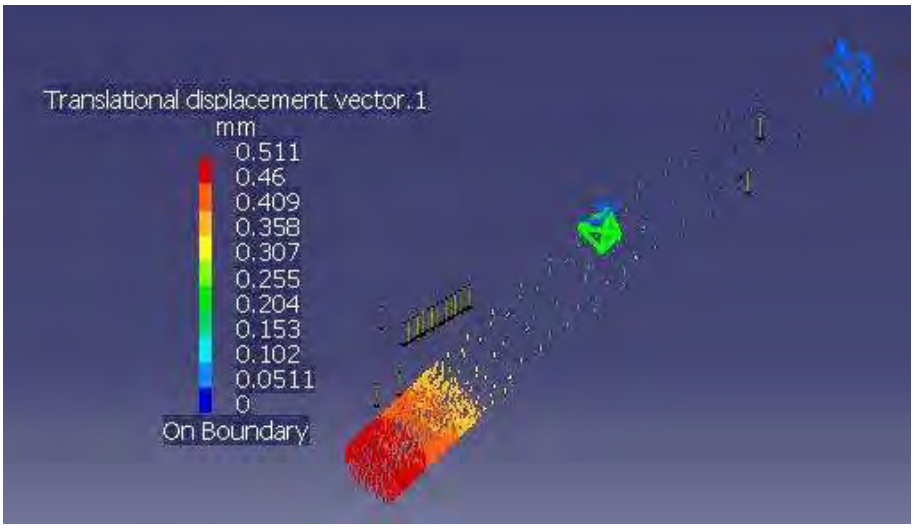


Figure 4.5b: The translational displacement vector of shaft concept 5.

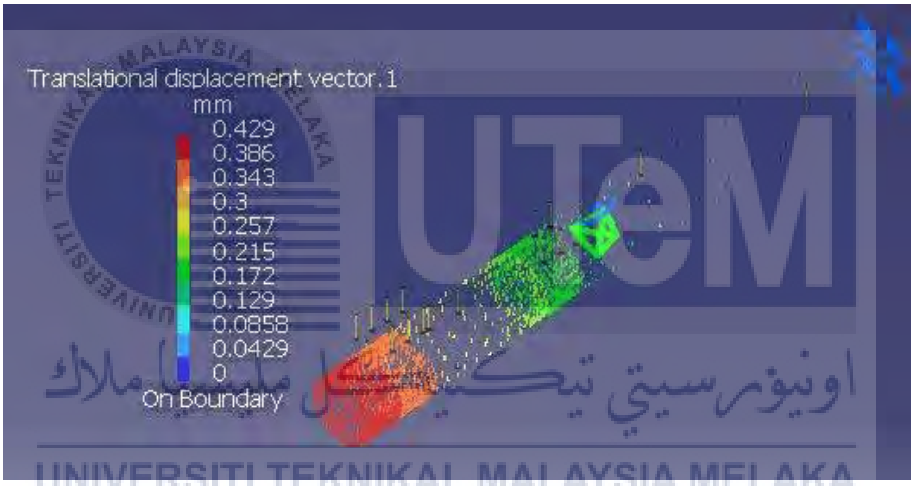


Figure 4.5c: The translational displacement vector of shaft concept 6.

Displacement of the geometry gives insight how the model will behave under specific static loads during the finite element analysis (FEA). Calculated magnitude of displacement depends on the material properties. For this case, the colour palette shows from the highest displacement following with the lowest values going down the palette. Translational displacement vector for the shaft are 0.787mm, 0.734mm and 0.429mm respectively on each figure at the end of the shaft. The displacement that is tolerable is figure 4.5c it has the least value among others. However the value for others concepts design of the displacement did not have a severe translational.

Table 4.7: Different range value between deflection and translational displacement.

Design concept	Deflection	Translational displacement	Different range
2	1.5084mm	0.787mm	0.7214mm
5	0.3078mm	0.511mm	0.2035mm
6	0.7374mm	0.439mm	0.3084mm

Translational displacement apparently are the same as deflection, therefore the table show the percentage different of each concept design. The highest percentage different show imprecise deflection occur because too much different. For the least value are much more acceptable where it is only low percentage difference therefore the chances of deflection may be the same.

4.3.2 Torque Analysis

Shaft rotation each have the value of torque where for this case the torque value is 47.47Nm refer to the calculation of torque in sub topic 3.4. Every each of the conceptual design shaft are applied with the same torque to determine whether the value of von misses, principle stress and von misses exceed the limitation.

Von Misses

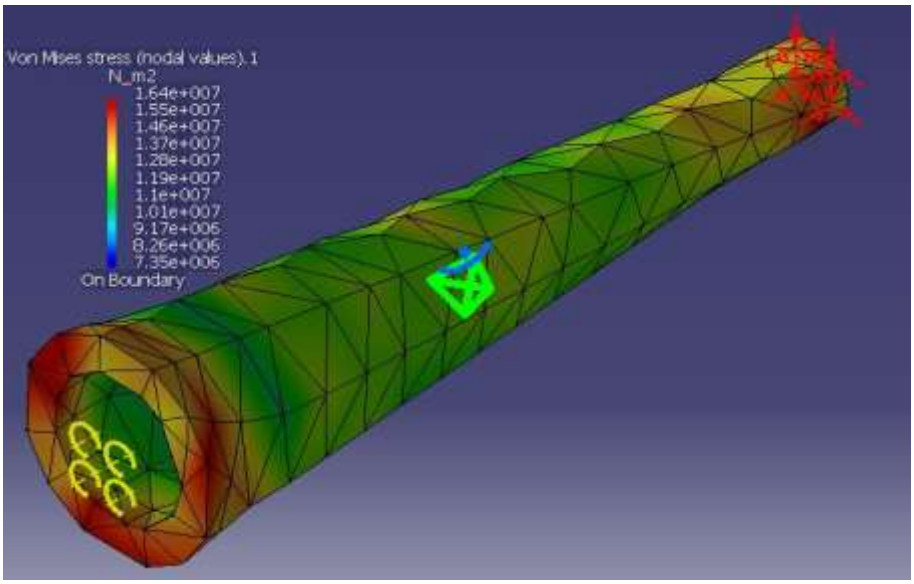


Figure 4.6a: Value of von misses stress for design concept 2.

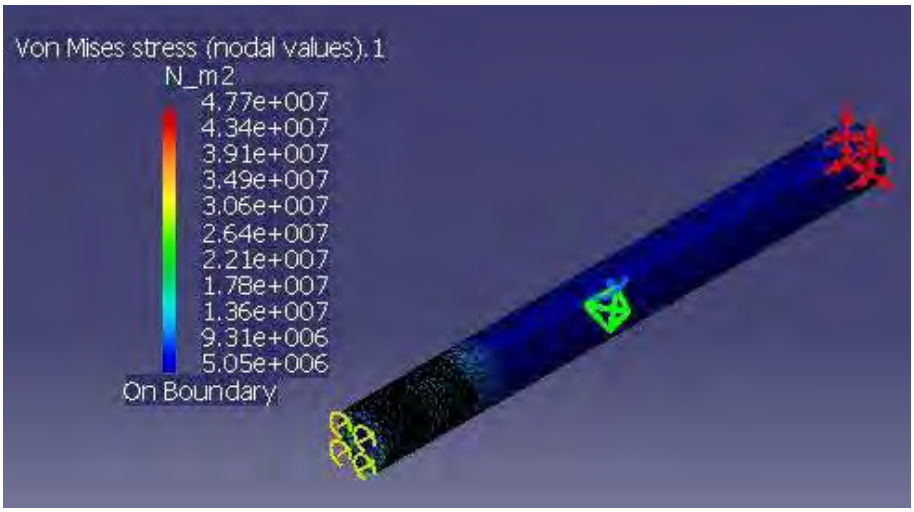


Figure 4.6b: Value of von misses stress for design concept 5.

Figure 4.6c: Value of von misses stress for design concept 6.

Each of the shaft concept design portray a result that not exceed the limitation for deflection. The value of von misses stress for this second, fifth and sixth conceptual design are $1.64\times10^{7}\,\mathrm{Nm}^{-2}$, $4.77\times10^{7}\,\mathrm{Nm}^{-2}$ and $1.04\times10^{7}\,\mathrm{Nm}^{-2}$ respectively. Therefore, the lowest value of von misses will acquire a good result for factor of safety.

Translational displacement

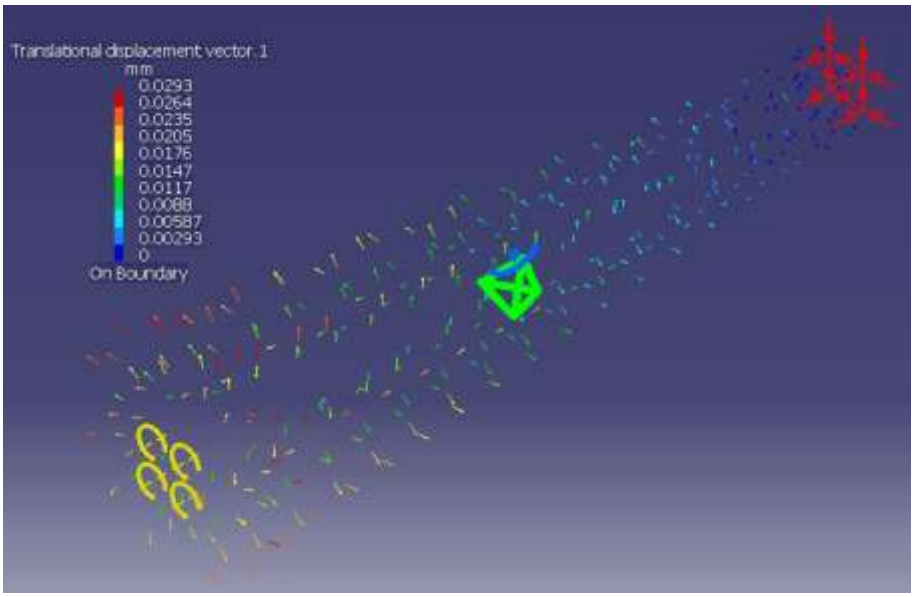


Figure 4.7a: Value of translational displacement for design concept 2.

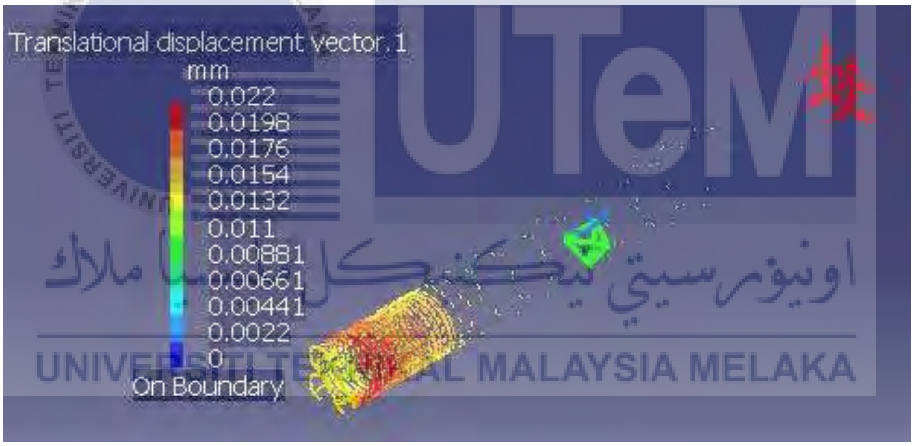


Figure 4.7b: Value of translational displacement for design concept 5.

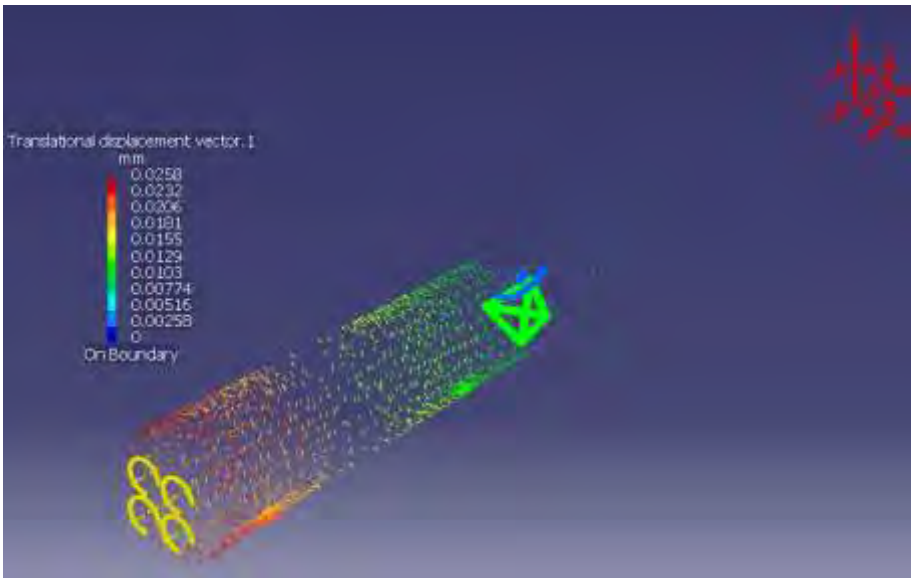


Figure 4.7c: Value of translational displacement for design concept 6.

Translational displacement shown by the applied torque analysis are mostly have a better result than applied load. Where each of the concept only deflect for 0.0293, 0.022 and 0.0258 for design concept 2, 5, and 6 respectively. Each of the deflection occur are mostly permissible and concept design 5 have a lowest displacement value among others concept design.

4.4 Final Design Concept

Once the analysis conducted, result from overall concept design only the chosen concept which is fifth concept will undergo digital mock-up. Fifth concept mostly comply with element that require in designing skimming machine holder. From the above simulation the chosen design were being compare first to select the most suitable design. Table 4.8 below shows the overall data of analysis for design concept 2, 5, and 6

Table 4.8: The result of finite element analysis

Design concept	**2**	**5**	**6**
Von misses stress	$6.75\times10^{7}\ \mathrm{Nm}^{-2}$	$4.81\times10^{7}\ \mathrm{Nm}^{-2}$	$4.16\times10^{7}\ \mathrm{Nm}^{-2}$
Translational displacement	0.787mm	0.511mm	0.439mm
Factor of safety	3.7037	5.1975	6.0096
Torque von misses	$1.64\times10^{7}\ \mathrm{Nm}^{-2}$	$4.77\times10^{7}\ \mathrm{Nm}^{-2}$	$1.04\times10^{7}\ \mathrm{Nm}^{-2}$
Torque translational displacement	0.0293mm	0.022mm	0.0258mm

Conceptual design firstly being compare to select the best result before compare to the datum. As shown in the Table 4.8 the result mostly shows that design concept 5 have a better potential among the others. Stress that fifth concept design can withstand are the highest value, $4.81\times10^{7}\ \mathrm{Nm}^{-2}$, nevertheless the factor of safety is 5.1975 which is within the range of required factor of safety. Value of deflection or also called translational displacement of all the concept design are least however, as mention previously the permissible range for deflection for design concept 5 is the most appropriate. On the other hand, the torque analysis applied for the shaft clearly shows the highest for von misses stress and the lowest deflection occur are fifth concept design.

Table 4.9: Result value comparison between datum and fifth design concept.

Description	**Datum**	**Fifth concept**
Deflection	0.7561mm	0.3078mm
Von misses	$9.45\times10^{7}\ \mathrm{Nm}^{-2}$	$4.81\times10^{7}\ \mathrm{Nm}^{-2}$
Translational displacement	1.16mm	0.511mm
Factor of safety	2.6455	5.1975
Torque von misses	$3.57\times10^{7}\ \mathrm{Nm}^{-2}$	$4.77\times10^{7}\ \mathrm{Nm}^{-2}$
Torque translational displacement	0.0271mm	0.022mm

Factor of safety of the fifth concept design is 5.1975 which is the suitable for this type of machine furthermore it much way better than datum. As for deflection and translational displacement occur are also in range between 0.2021 ~ 0.6062 where both of

the value are 0.3078mm and 0.511mm respectively. In place of that, for finalize the principle stress shows that the shaft could withstand 900N load where the only highest expectation are 889.96N applied load. The torque analysis clearly shows a better result than datum for both von misses and deflection. Hence, the fifth concept design are the most suitable for skimming machine.

4.5 Operation Description for Skimming Machine Holder

4.5.1 Operation Description Skimming Machine Holder by DMU

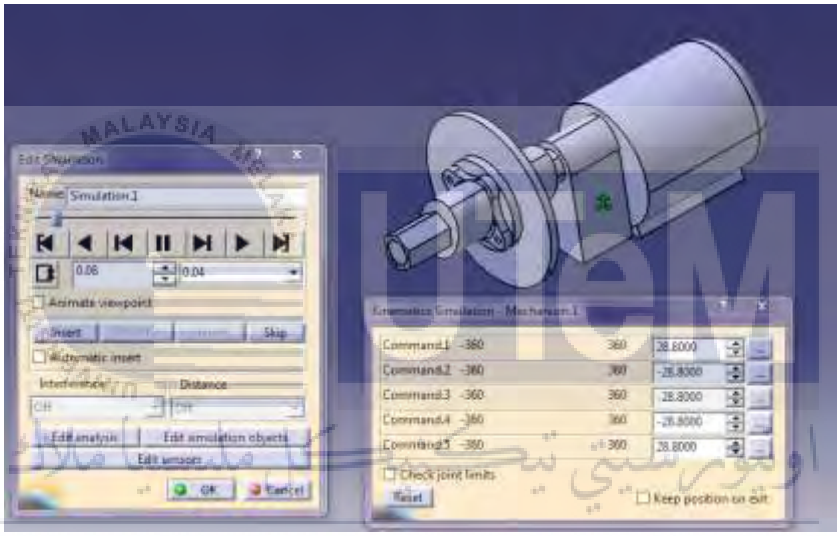


Figure 4.8: Simulation of fifth design concept of brake disc skimming machine holder.

The operation of the skimming machine holder can be more digitalize by using CATIA V5R20, digital mock up. The attachment of the component must be assemble accordingly so the software can identify the degree of freedom (DOF). Degree of freedom is where the joint may have experience planar, cylindrical revolute or rigid movement depends on how the constraint applied.

Simulation of skimming machine holder mostly cylindrical, because of the movement of every part will turn according to shaft rotation. By using digital mock up DMU, adjustment of the movement is control by the kinematics simulation title bar. Then after adjust the setting position are insert to edit simulation title bar. The play button will illustrate the movement of the skimming machine. All the parts are rotate simultaneously with the rotation of shaft.

4.5.2 Assembly of Skimming Machine

As stated at earlier, this thesis are separated into 3 part which is structure, tool jig and holder. Thus the final of the result is the assembly of the product. All three part are combined together and are confirm to be match each other from dimension and portion.

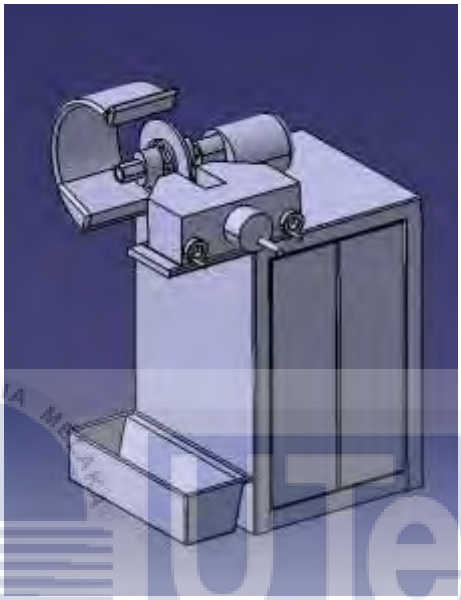


Figure 4.9: Assembly of brake disc skimming machine.

Assembly of the complete product by using CATIA software are as shown in figure 4.9. For the structure part, consist of part where there is a sideboard. Sideboard is suitable for store every adapter since the skimming machine uses a lot of adapter according to sizes. Then the structure also equipped with safety shield and fragment of resurface brake disc container. Both act as safety consideration where the shield will prevent from the chips and debris splatter all around, same goes for container that gather all the metal chip and dust and into one place.

As for tool jig, the setup will according to the thickness of brake disc where adjust the cross slider position accordingly. Tool jig are attach with carbide as tool bits, where it will feed the thickness of brake disc around 0.05mm with each increment. However, the feed rate thickness of brake disc need to be consider as long as it is obey the tolerance for disc brake thickness.

Lastly, the function of holder with transfer gear is to match the rotor size and provide speed according to the load of brake disc. As the calculation previously, the maximum torque that given by the skimming machine is 47.47Nm. Nevertheless the brake disc rotation affect more on the speed of rotation. Feed speed refers to the rate of movement that the cutting tools move per revolution of the spindle. The cross feed is variable, depends on how the process being operates. This is because the cross feed have rough cut and fine cut.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Brake Disc skimming machine is actually separated into three other part which is structure, tool jig and holder however for this thesis overall will be more focus on design and analysis on brake disc skimming machine holder with transfer gear. Apart from that, this thesis had been cultivate by complying with the engineering design and requirement perception. To begin with, finding from the current research about brake disc skimming machine then proceed with the six conceptual design. Evaluation continues with the conceptual design to choose the best three concept design for further analysis. The chosen concept design are being evaluate based on weight decision matrix where also been considering house of quality concept. Next the top three concept undergoes manual calculation and finite element analysis to acknowledge the value of deflection, maximum stress and appropriate factor of safety. As the result the design concept 5 are chosen as the best design because comply with the element needed especially objective and scope. Turns out the objective of this thesis are successful where the design, analysis of the skimming machine is improve by using CATIA V5R20. Furthermore, the operational of the machine are successfully simulate. Lastly, still the concept of this design could be more improvise and innovate. Brake disc skimming machine act as an eye opener for the vehicle industry for a better solution to the customer.

5.2 Recommendation

For future researcher, look forward on how the design can be more innovative. The design for brake disc holder not only can be design horizontally, instead vertically design will gave an advance look for skimming machine. The parameters of the conceptual design are costly design because of material, so the new researcher might have investigate on composite material because there is some material that would be more likely suitable. Also for the installation of shaft to the helical gear need to be consider for a better grip solution. Further investigation on brake disc resurface need to be emphasize since it is not really popular regarding their usage. In addition the attachment of component needs to be analyses in order to obtain the safety and strength during operation. Improvements for this design are mostly based on the design configuration to be more automated, furthermore to realize the publics that skimming machine for brake disc could save an amount of money instead of spending to buy a new one.

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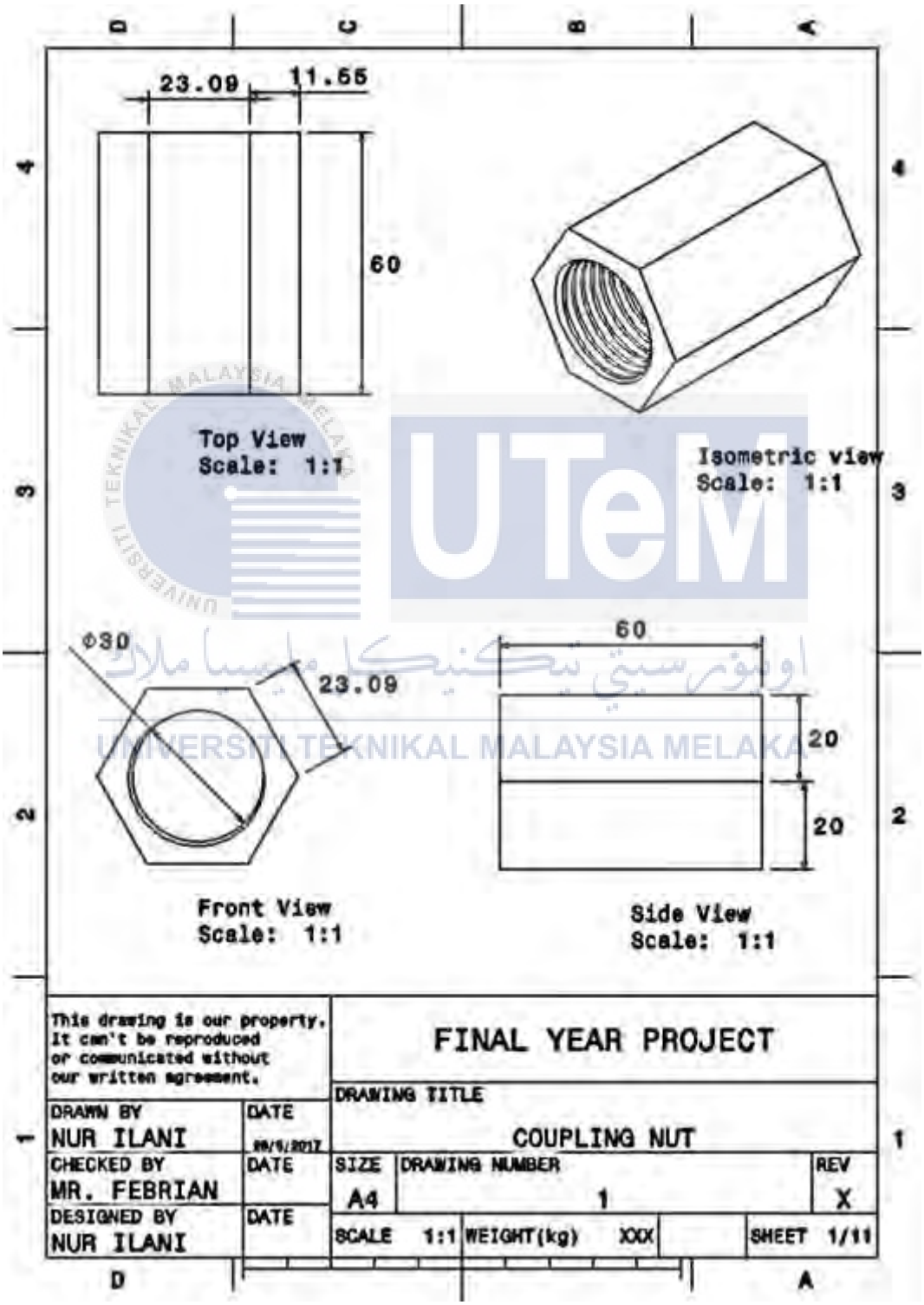
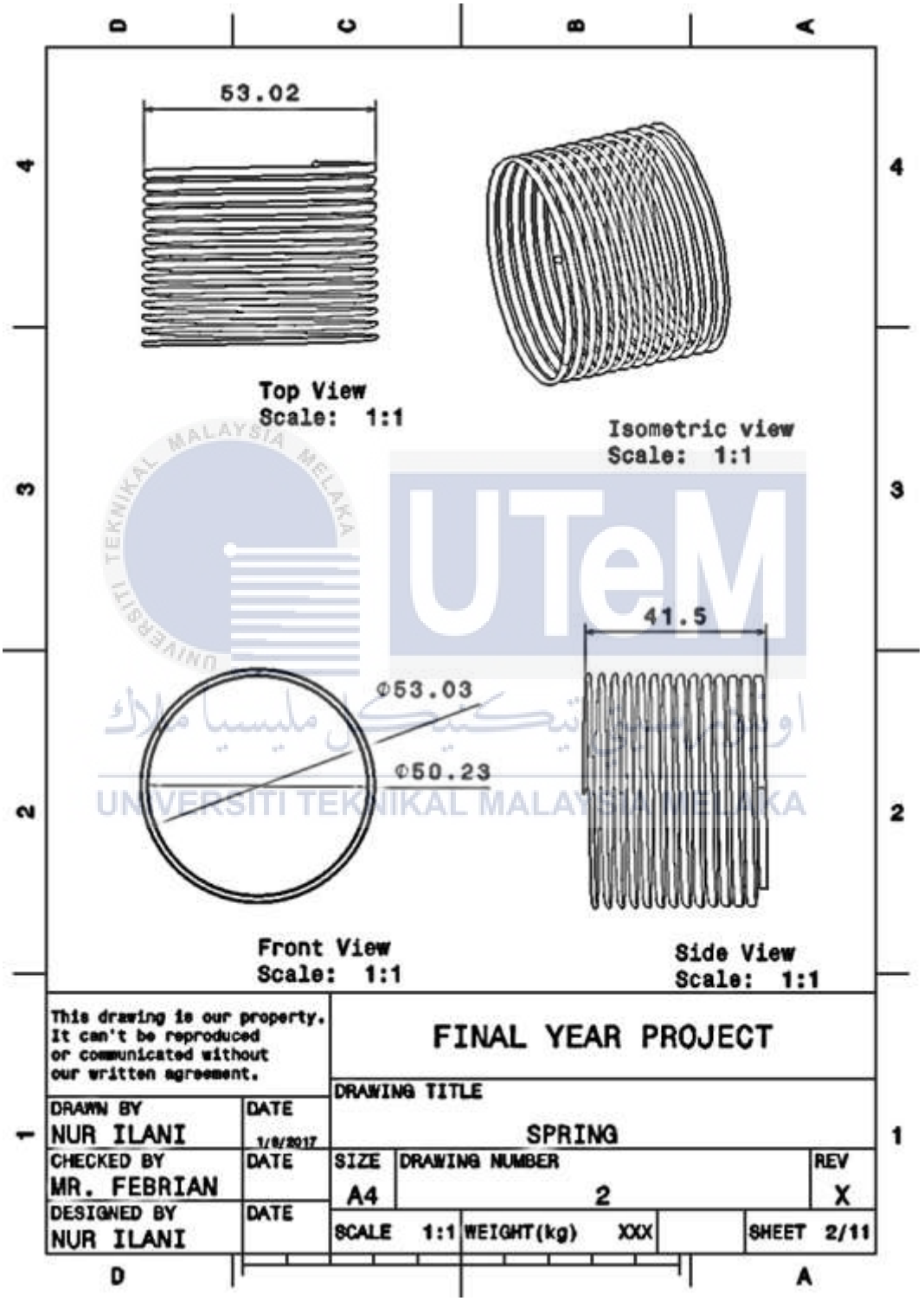
APPENDIX A1

Detail Drawing of Coupling Nut



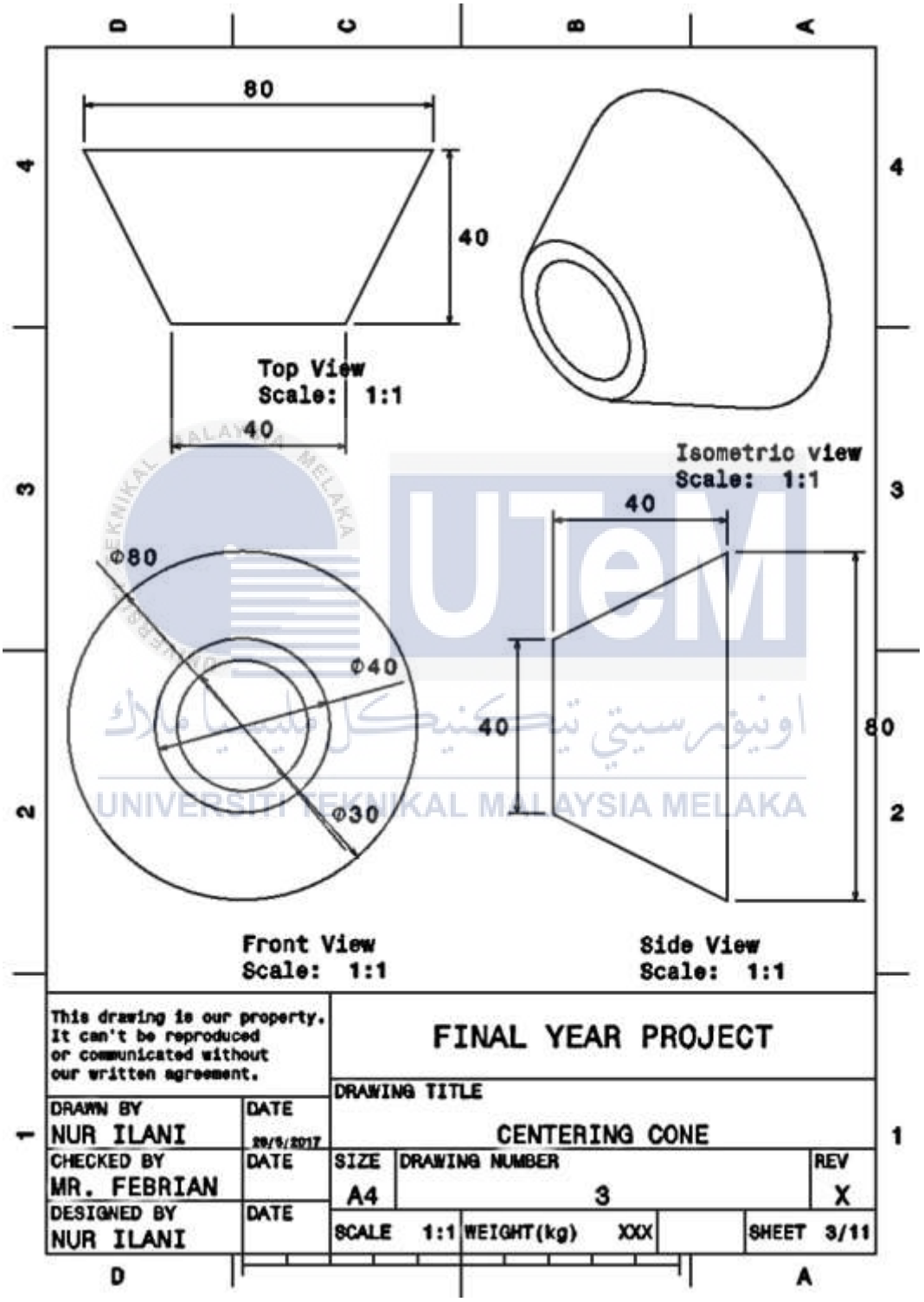
APPENDIX A2

Detail Drawing of Spring



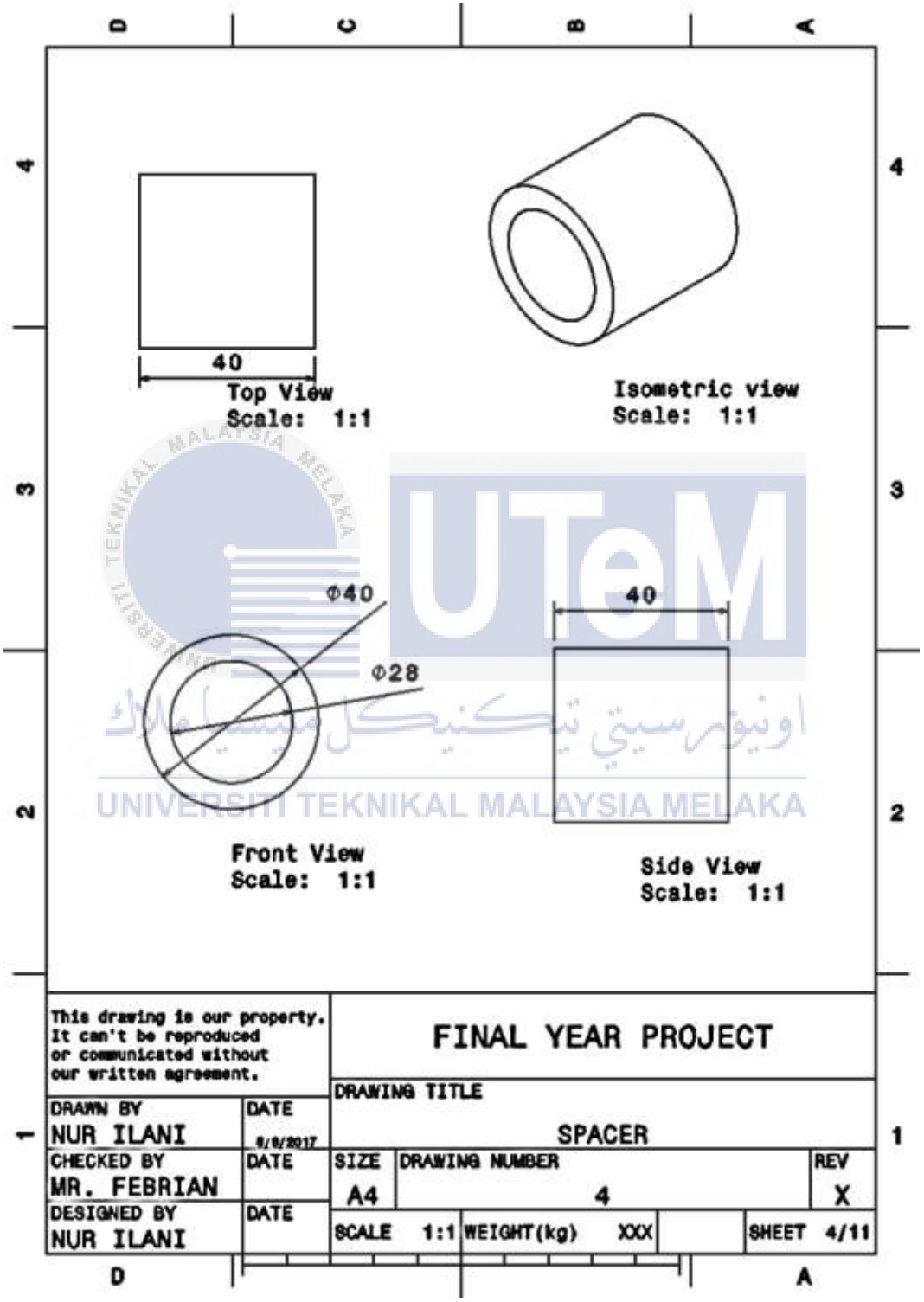
APPENDIX A3

Detail Drawing Of Centering Cone



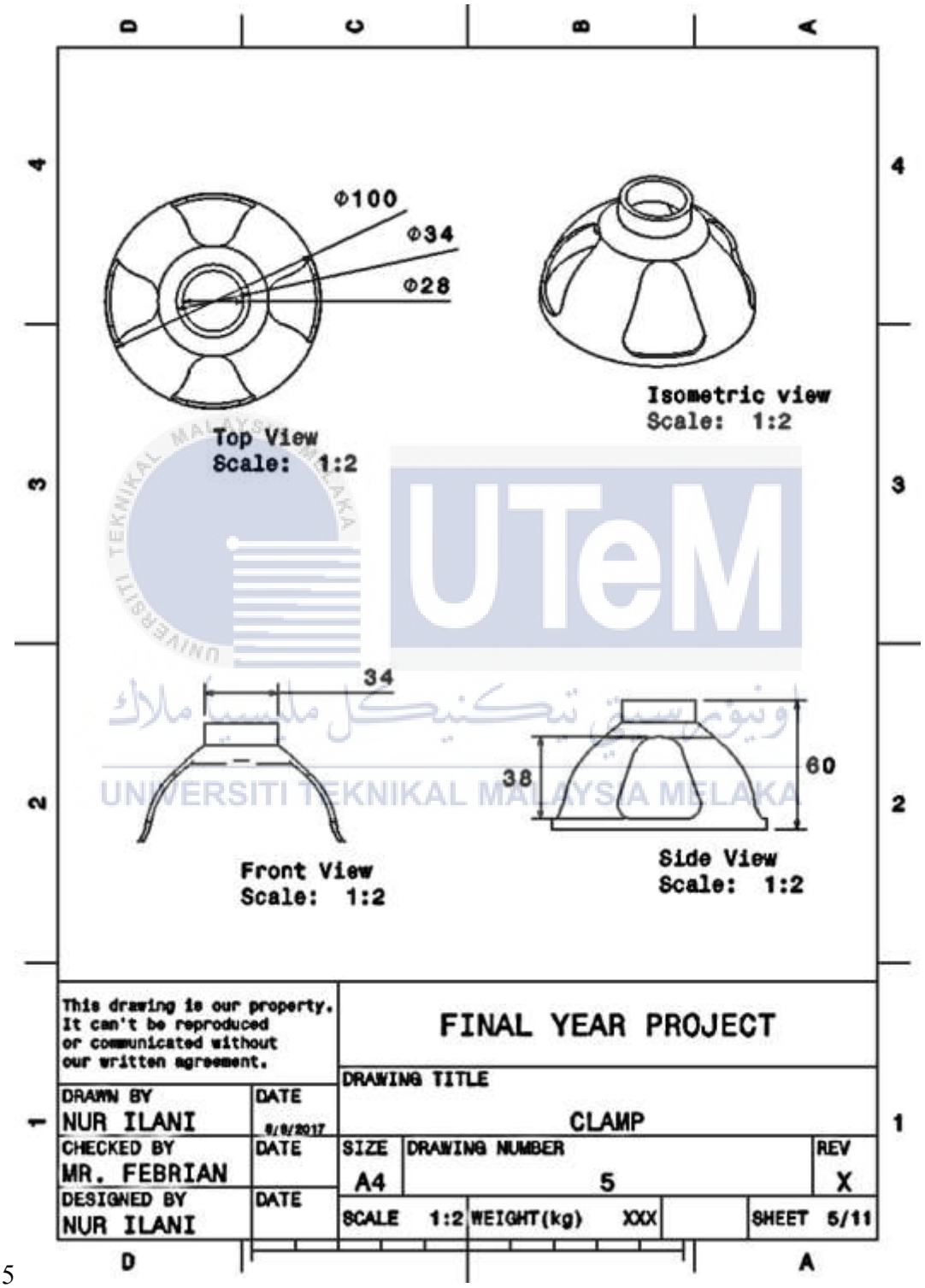
APPENDIX A4

Detail Drawing of Spacer (Datum)



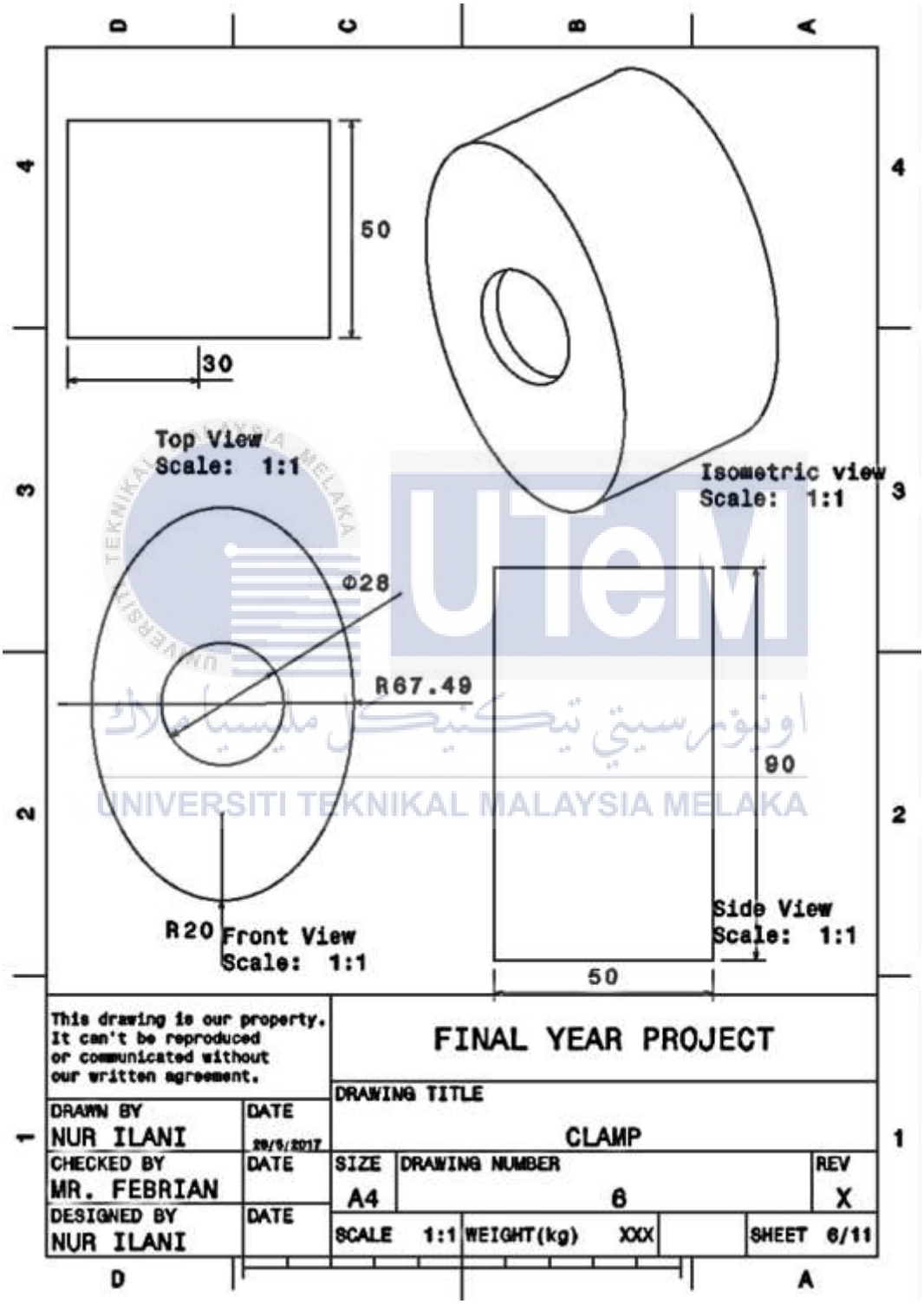
APPENDIX A5

Detail Drawing of Clamp (Datum)



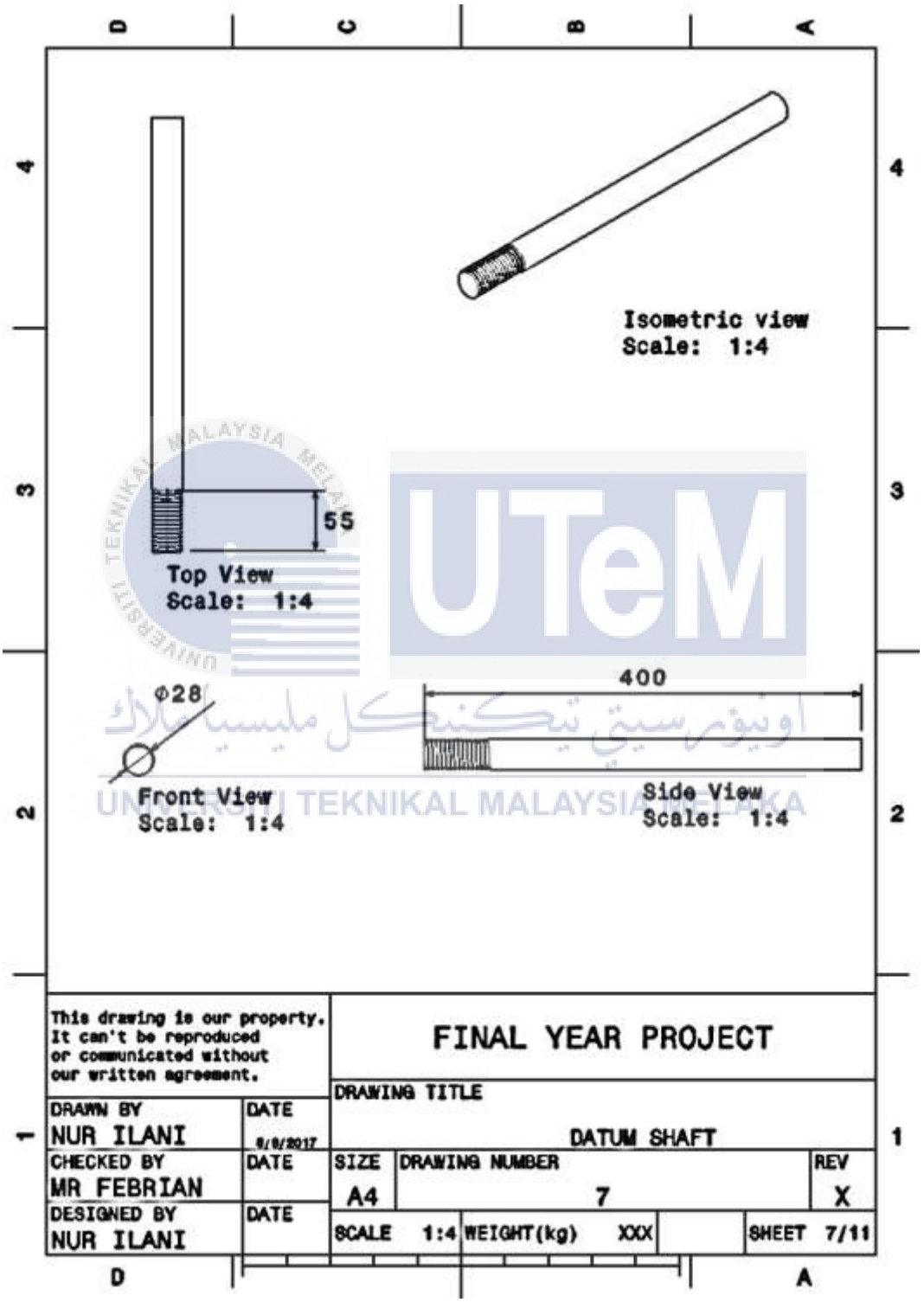
APPENDIX A6

Detail Drawing of Clamp (Fifth Design Concept)



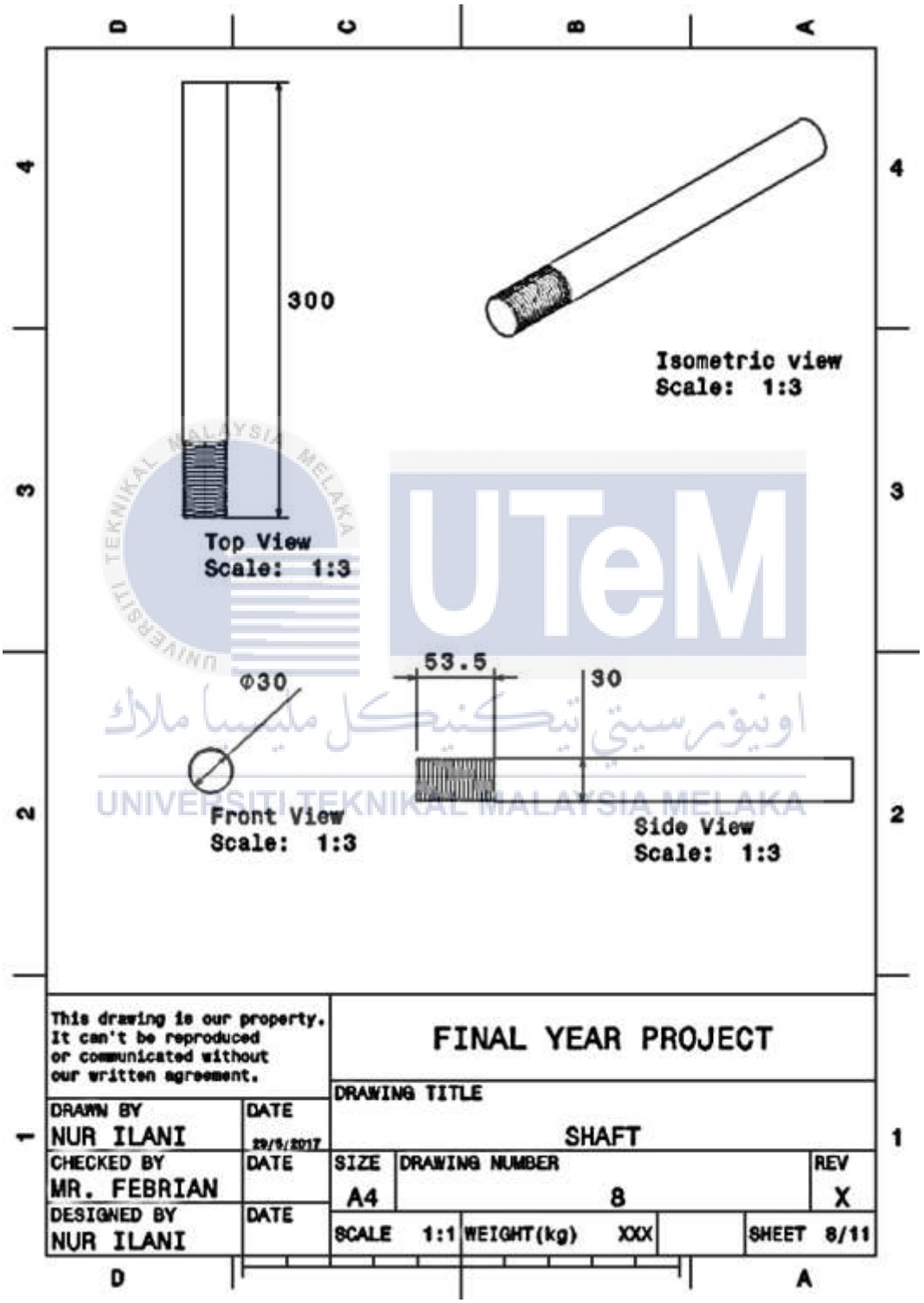
APPENDIX A7

Detail Drawing of Shaft (Datum)



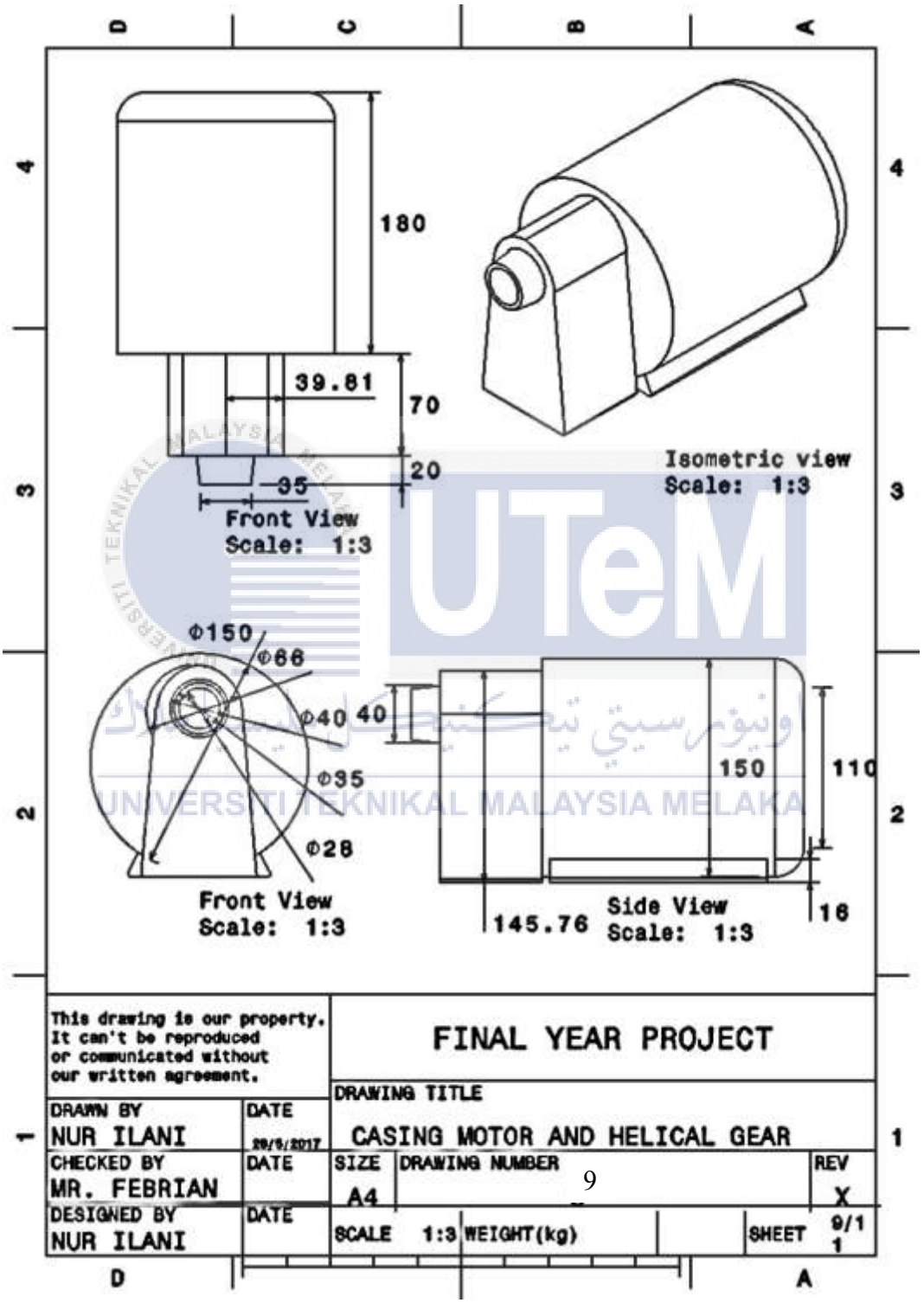
APPENDIX A8

Detail Drawing of Shaft (Fifth Design Concept)



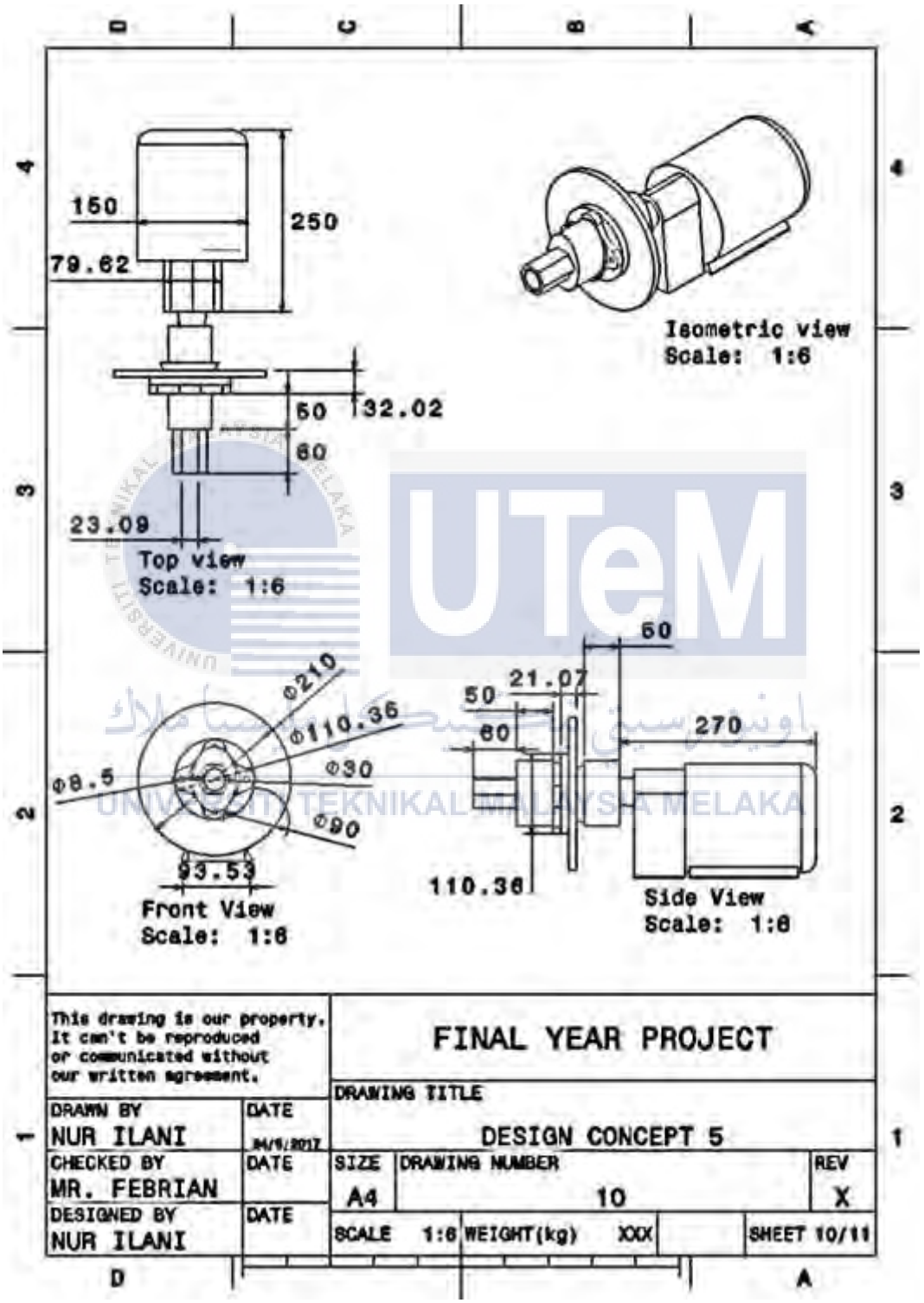
APPENDIX A9

Detail Drawing of Transfer Gear Casing



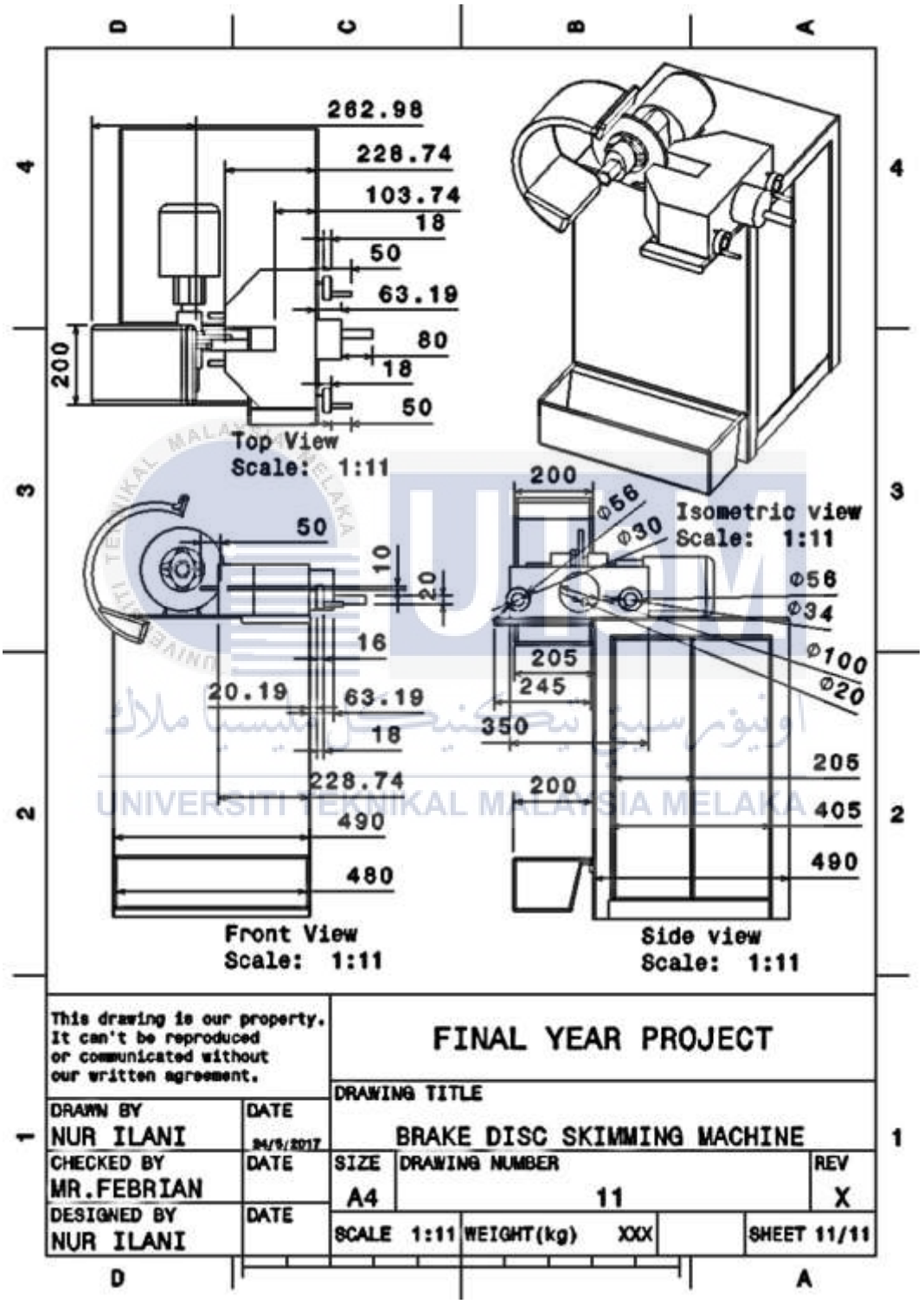
APPENDIX A10

Detail Assembly Drawing of Fifth Concept



APPENDIX A11

Detail Assembly Drawing of Brake Disc Skimming Machine



APPENDIX B1

Operation Specification of Datum

Installation Instructions

Receiving

The shipment should be thoroughly inspected as soon as it is received. The signed bill of lading is acknowledgement by the carrier of receipt in good condition of shipment covered by our invoice.

If any of the goods called for on this bill of lading are shorted or damaged, do not accept them until the carrier makes a notation on the freight bill of the shorted or damaged goods. Do this for your own protection.

NOTIFY THE CARRIER AT ONCE if any hidden loss or damage is discovered after receipt and request the carrier to make an inspection. If the carrier will not do so, prepare a signed statement to the effect that you have notified the carrier (on a specific date) and that the carrier has failed to comply with your request.

IT IS DIFFICULT TO COLLECT FOR LOSS OR DAMAGE AFTER YOU HAVE GIVEN THE CARRIER A CLEAR RECEIPT.

File your claim with the carrier promptly. Support your claim with copies of the bill of lading, freight bill, invoice, and photographs, if available.

Although AMMCO's responsibility ceases upon delivery of the shipment to the carrier, we will gladly assist in tracing lost shipments. Our willingness to assist in every possible manner does not make AMMCO responsible for collection of claims or replacement of lost or damaged materials. Shipping damage claims will not be handled under warranty.

Electrical Requirements

The lathe must be properly grounded to protect the operator from shock. The lathe is equipped with an approved 3-conductor cord and a 3-prong grounding type plug to fit the proper grounding-type receptacle. Should an extension cord be required, use 3-conductor cords with 3-prong grounding plug and 3-prong grounding receptacle properly rated to handle this electrical power tool only. Do not modify a cord or plug to match a receptacle; have a qualified electrician install an appropriate outlet to match the lathe requirements. Repair or replace any worn or damaged power cords immediately.

Verify that the lathe plug and grounding-type receptacle match as shown in Figure 29.

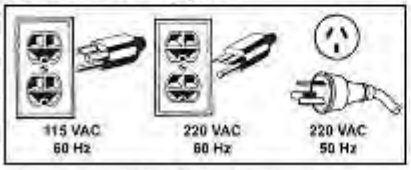


Figure 29 - Power Cord Plug and Receptacle Types

Setup

A factory trained COATS® Service Technician must perform the install, setup, and initial test procedures on your brake lathe. Do not attempt to install and setup the unit yourself. Accurate and reliable operation of your unit depends on proper installation. Please contact COATS® directly at 1-800-688-9240 for the Certified Service Partner nearest you.

Connect to Power

Your factory trained COATS® Service Technician should do the final check to verify the power installation before connecting the brake lathe to a power supply. Failure due to improper power connection may void the warranty.

Operating Specifications

- Overall Lathe Height ..... 17.25" (438 mm)
- Lathe Shipping Weight ..... 410 lbs (186 kg)
- Floor Space Requirements:
  - Width ..... 48" (1219.20 mm)
  - Deep ..... 34.5" (901.70 mm)
  - Spindle to Floor ..... 39.375" (1000 mm) *(mounted to optional bench)*
- Electrical Requirements *(unless otherwise specified)*:
  - Standard: 115 VAC, 60 Hz, single-phase, fused at 20 amps
  - Optional: 220 VAC, 60 Hz, single-phase, fused at 15 amps
- Spindle Motor ..... 1 HP, 60 Hz, 115/230 VAC
- Spindle Travel ..... 9.875" (251 mm)
- Spindle Speed Lever Positions:
  - Lower Groove 100
  - Middle Groove 150
  - Upper Groove 200
- Spindle Feed Speeds ..... Variable
- Cross Feed Speed ..... Variable
- Handwheel Graduations ..... 0.002" (0.050 mm)
- Maximum Brake Rotor:
  - Diameter ..... 15" (381.0 mm)
  - Thickness ..... 1.9" (48.26 mm)
- Brake Drum Diameter:
  - Minimum ..... 6" (152 mm)
  - Maximum ..... 28" (711 mm)
- Maximum Drum Depth ..... 9.875" (251 mm)
- Maximum Load:
  - 1" Arbor ..... 200 lbs (90.72 kg)
  - 1.875" Arbor ..... 200 lbs (90.72 kg)