UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

DESIGN AND ANALYSIS OF AUTOMATED WHITEBOARD CLEANER

ROSHINI D/O BASKARAN

Bachelor of Mechanical Engineering (Design & Innovation)

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A report submitted

In fulfillment of the requirement for the degree of

Bachelor of Mechanical Engineering (Design & Innovation)

Faculty of Mechanical Engineering

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2020

DECLARATION

I declare that this thesis entitled "Automated Whiteboard Cleaner" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :……

Name : ROSHINI D/O BASKARAN

Date :……

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (with Honours).

Signature :……

Supervisor Name : DR MOHD ASRI BIN YUSUFF

Date :……

DEDICATION

To my beloved family, friend and my lecturer

ABSTRACT

The whiteboard is the best writing medium during teaching across the world. At present, it is seen that almost everything is automated. The automation system can reduce the human effort and make any arrangement easier. Even the evolution of the writing board had made its user's life easier, yet there are still problems arise to the use of it. During the attempt of cleaning the whiteboard, educators sometimes get their hands and outfit dirty, which may disturb the lesson. Besides that, cleaning the whiteboard consumes time as the educators have to clean the same spot several times. Therefore, this project aims to design a automate whiteboard cleaner, which is objected to coming up with a simple design and effective automated whiteboard cleaner.and to reduce the time consumed to clean the whiteboard.The overall process of this project can be seen in the flow chart. The progress starts by reviewing the literature on the automated whiteboard cleaner to gain ideas for the design. Four conceptual design is made and the best is chosen from the Pugh Concept Selection with the highest final score among the four concepts that meet the customer requirement and engineering characteristic. Next, the project's components is been drawn by using Catia V5 and to ensure that the components of the Automated White Board Cleaner perform perfectly without any failure, analysis and simulation has been carried out to the components. Finally, the detail design of the project with the combination and assembly of all part and components was generated by using Catia V5.

ABSTRAK

Papan tulis adalah media penulisan terbaik semasa mengajar di seluruh dunia. Pada masa ini, nampaknya hampir semuanya automatik. Sistem automasi mempunyai keupayaan untuk mengurangkan usaha manusia dan membuat pengaturan lebih mudah. Bahkan evolusi papan tulis menjadikan kehidupan penggunanya lebih mudah, namun masih ada masalah yang timbul kerana penggunaannya. Untuk usaha membersihkan papan putih, pendidik mesti mengatasinya dengan mengotorkan tangan mereka dan kadang-kadang pada pakaian mereka, yang mungkin mengganggu pelajaran. Selain itu, membersihkan papan putih memakan masa kerana pendidik harus membersihkan tempat yang sama beberapa kali. Oleh itu, tujuan projek ini adalah untuk merancang pembersih papan putih automatik, yang keberatan untuk hadir dengan reka bentuk ringkas dan pembersih papan tulis automatik yang berkesan dan untuk mengurangkan masa yang diperlukan untuk membersihkan papan putih. Proses keseluruhan projek ini dapat dilihat dalam carta alir. Kemajuan dimulakan dengan meninjau literatur mengenai pembersih papan putih automatik. Empat reka bentuk konseptual dibuat dan yang terbaik dipilih dari Pemilihan Konsep Pugh dengan skor akhir tertinggi di antara empat konsep yang memenuhi kehendak pelanggan dan ciri kejuruteraan. Seterusnya, komponen projek dilukis dengan menggunakan Catia V5 dan untuk memastikan bahawa komponen Automatic White Board Cleaner berfungsi dengan sempurna tanpa sebarang kegagalan, analisis dan simulasi telah dilakukan terhadap komponen tersebut. Akhirnya, reka bentuk terperinci projek dengan gabungan dan pemasangan semua bahagian dan komponen dihasilkan dengan menggunakan Catia V5.

ACKNOWLEDGEMENTS

Firstly, I would like to take this opportunity to express my special thanks to my supervisor, Dr Mohd Asri Yusuff from the Faculty of Mechanical Engineering University Teknikal Malaysia Melaka (UTeM) for his unconditional guidance, support and continuous encouragement toward completing the thesis.

Furthermore, I would like to appreciate the Faculty of Mechanical Engineering (FKM) of University Teknikal Malaysia Melaka (UTeM) for providing the opportunity to conduct my project although the prototype was not been able to be complete due to the Covid-19 crisis and somehow it helps in completing this thesis.

Apart from that, a special thanks to my family and friends for their moral support in completing this degree and not forgetting, those who have directly or indirectly contributed to the realization of this thesis.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
ABS	Acrylonitrile Butadiene Styrene
HOQ	House Of Quality
PM	Pugh Matrix
CATIA	Computer Aided Three Dimensional Interactive Application
RM	Ringgit Malaysia
BOM	Bill Of Material
CRs	Customer Requirements
ECs	Engineering Characteristics
QDF	Quality Function Development
PDS	Product Design Specification

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

A man living in the cave early in the civilization used the wall of the cave as the writing medium. They used the wall to capture various memories or the story of their own culture and daily activities. Over the long haul and an acculturated society was being framed the situation started to change. Individuals started to utilize a major cut of the wood piece as the board and coal as the pen medium in the middle age. But it was not so comfortable, and it became nasty.

From that point forward, the writing board had been presented. It's only a dark canvas where chalk is utilized as the pen medium. Chalk is a composite of calcium carbonate and it would appear like a stick. It was agreeable however it makes dust during cleaning the board utilizing the duster. A duster is a gadget which is utilized to wipe the works from the board. Despite that, the board has not lost its ubiquity as in present time and it's being utilized broadly over the world. But it is a whiteboard which is the modified version of the blackboard. Here, man uses a marker pen for writing, and they use a piece of cloth or foam as a duster. Now, the whiteboard is the best writing medium during teaching across the world. At present, it is seen that almost everything is automated. The automation system has the capacity to reduce the human effort and to make any arrangement easier.

1.2 Problem Statement

Information is passing by writing on the whiteboard used by educators around the world. Even the evolution of the writing board had made its user's life easier, yet there are still problems arise to the use of it. To the attempt of cleaning the whiteboard, educators must handle it by getting their hands dirty and sometimes to their clothes. This causes the flow of teaching being disturbed as they must continuously keep their hands clean.

Besides that, cleaning the whiteboard consumes time as the educators have to clean the same spot several times. This is due to the uneven force applied by them. Furthermore, cleaning the whiteboard needs proper material because the wrong one will not give a proper finishing, thus contributing to time-consuming. Therefore, this project aims to design a automate whiteboard cleaner.

1.3 Objective

The objectives of the project are as follow:

I. To design a simple and effective automated whiteboard cleaner.

II. To reduce the time required to clean the whiteboard.

1.4 Scope of Project

This project will be served as one of the advanced technologies in future and will be implemented in every college, school etc.

I. Clean whiteboard automatically

II. Reduce time taken to clean the whiteboard and to achieve a clean finishing

1.5 General Methodology

The action that needs to be carried out to accomplish the objectives in this project are listed below:

I. Literature review

Journals, articles or any material concerning the task will be checked on.

II. Conceptual design

Draw a suitable sketch that is selected as the final product.

III. Design using Catia V5 software

Outline the task utilizing any plan miscreant in 2D and 3D drawing model.

IV. Report writing

A report on this study will be written at the end of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to design an Automatic White Board Cleaner, research and studies on components and mechanisms of existing projects on whiteboard cleaning method are carried out. Besides that, the early invention of manual whiteboard cleaning is disused in this chapter. Mechanisms applied in existing projects on automatic whiteboard cleaner are used to generate ideas on designing a better version of an automatic whiteboard cleaner.

2.2 Design Type 1

The International Research Journal of Engineering and Technology (IRJET) had come up with a title of **Design and Fabrication of SmartBoard Cleaner**. This concept uses ATMEGA-328P Microcontroller, Rack & Pinion and L298N motor driver to come up with a partial cleaning mechanism. The electronic kit used is portable, light in weight, compact in size and Lead Screw is used for accuracy.

Working Principle

This device functions automatically where the duster is fixed vertically which slides over the two horizontal rods and forward, the backward motion of duster is provided by rack and pinion mechanism. In this device, the cleaning action of the

duster is controlled by the mobile application used. It is controlled by a microcontroller (Arduino Uno) which can be controlled up to a 10m range by using mobile. (Mohan Umbarkar et al., year 2019).

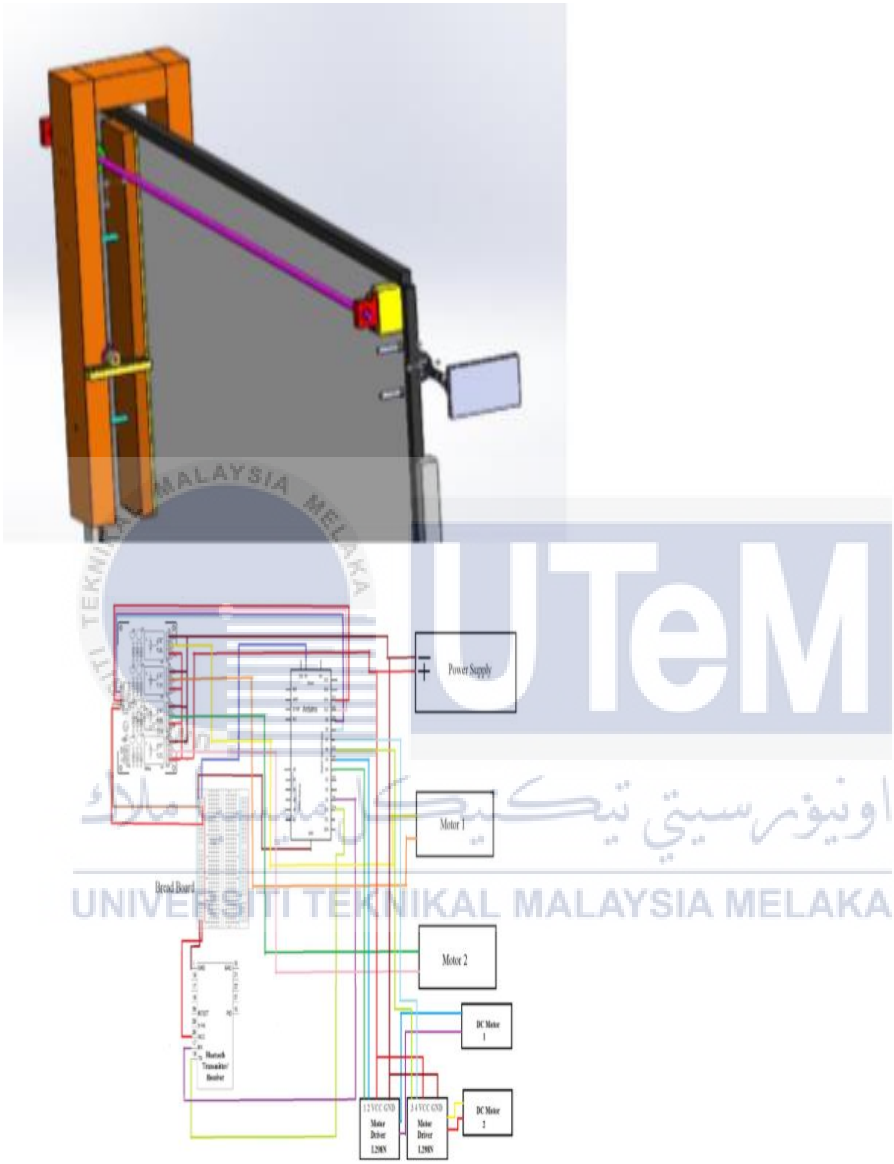


Figure 2.1: Front View and Circuit Diagram
. (Mohan Umbarkar et al., year 2019)

2.3 Design Type 2

(Mr Tumpala Uma Santhosh, et al, year 2016) **Design and Fabrication of an Automatic Black Board Cleaner**. A mechanism that can automatically detect the blackboard chalk stains, and erase the font, keep the blackboard clean. The duster includes a track structure to permit reciprocation of the duster laterally of an elongate blackboard frame. The chain which is connected to duster includes a drive motor to effect rotation of a drive duster positioned above the blackboard frame. The principal object of the present automatic blackboard duster is to provide an attachment for blackboards in the form of a power-driven erasing apparatus which can be set in operation by the throw of a switch, thus eliminating the drudgery of manually cleaning blackboards.

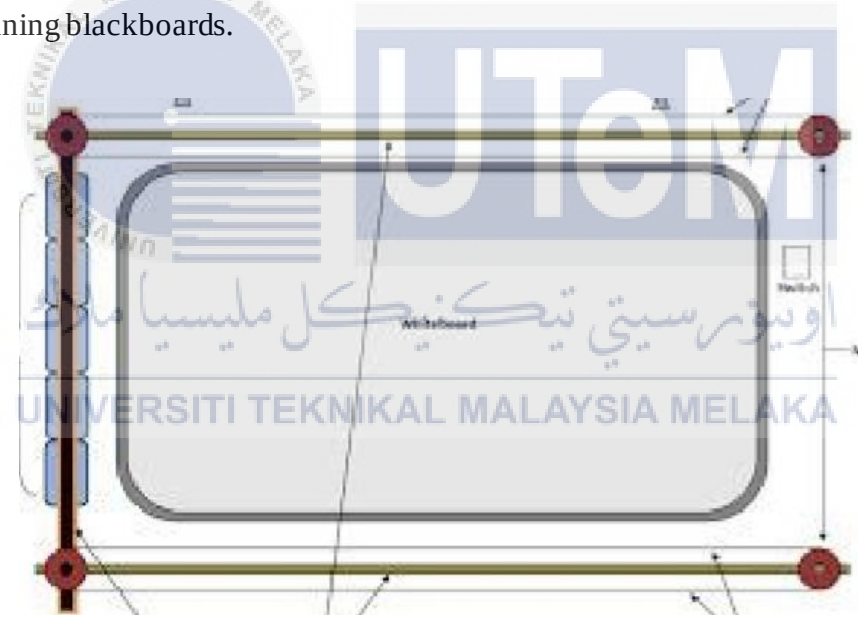


Figure 2.2: Front View of the Black Board
(Mr. Tumpala Uma Santhosh, et al, year 2016)

Working Principle

In the working of automatic blackboard duster, as the power is supplied to the motor, the shaft stars rotating. A gearbox is connected to the motor shaft is connected by another gear. Thus, movement of these gears rotates the wheel axil by which both the upper and lower wheels start rotating. By the rotation of these shafts, the wheels which are mounted on these guideways in horizontal direction start to rotate as well. A duster which is mounted on this wheel starts reciprocating left and right, thus clean the board. A switch is provided for the left and right motion. (Mr Tumpala Uma Santhosh, et al, year 2016)

2.4 Design Type 3

Design and Development of Board Cleaning System. This project works on combined principles of mechanical and electronics where rack and pinion mechanism are used for cleaning the blackboard and whiteboard with the help of the DC geared motors for rotation and limit switch to stop the motion.

Working Principle

The motors will drive the pinions which will convert the rotary motion of pinions into linear motion on the rack carrying the connecting strip with duster attached to it by bearing arrangement. DPDT switch and limit switch are also going to play a minor role in this system for stopping the pinion and rotating one gear clockwise and another anti-clockwise. A small water sprinkler is used to spray the water on the blackboard. With the help of wiper motor, the pressure will be created for sprinkling the water on the blackboard. This will save energy, time and eliminate

the load on the motor. Toggle mechanism is used in the back connecting strip to adjust the clearance between pinion and rack. (Gaurav Gangurde, year 2016).

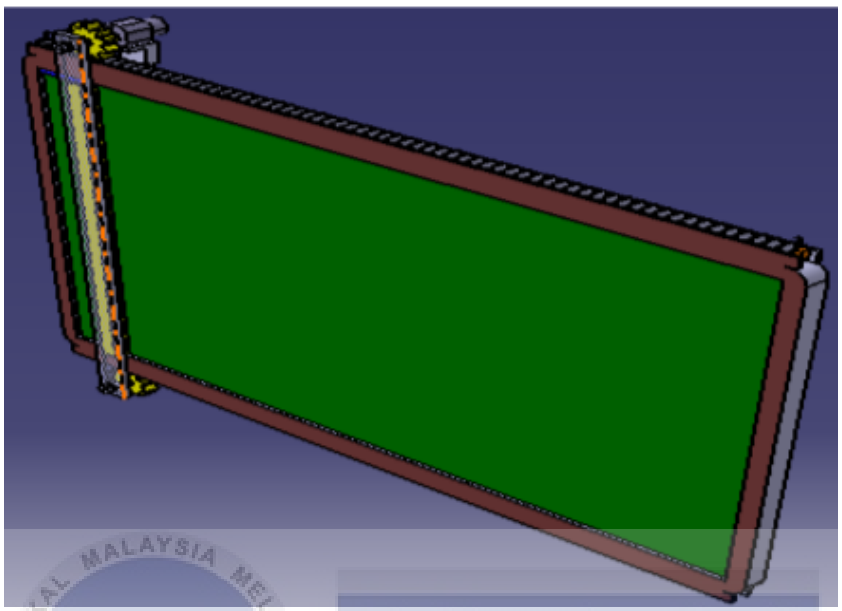


Figure 2.3:3D View of Blackboard Cleaning System
(Gaurav Gangurde, year 2016).

2.5 Design Type 4

Preliminary Design of an Automated White Board Cleaner. The automated whiteboard cleaner is a movable device; which is mostly made up of wood (plywood to be precise). The equipment is made up of a whiteboard frame, whiteboard duster, electric motor, sprocket, chain, duster and top cover. The motor to be used is a servo–motor which is to run at a relatively low speed.

Working Principle

By turning on the switch, the current is transmitted to a variable voltage supply which will decrease the amount of voltage going into the motor hence slowing

down the speed. The current is then transmitted to the motor which then drives the shaft. This shaft is attached to a sprocket and it will be driven with the help of the keyway. The sprockets are designed to be supported by bearings which are well lubricated to reduce friction between the shaft and the sprockets. As the shaft drives the sprocket, the duster which is attached to the roller chain cleans the board in a translator manner from left to right and vice–versa. Once the duster gets to either end of the board, it stops. This was done by the help of a pilot switch (sensor), which is attached either end of the frame of the board. As soon as the duster touches the pilot switch and compresses it, a signal is sent to the electric motor which triggers it to stop. (Simolowo, et al, year 2014)

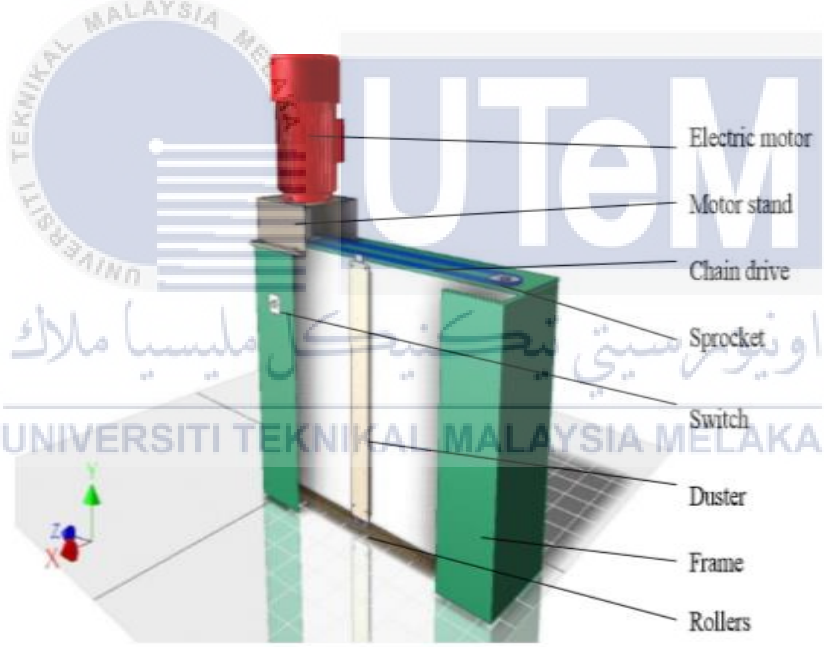


Figure 2.4: Isometric View of Automated Whiteboard Cleaner

. (Simolowo, et al, year 2014)

2.6 Design Type 5

Automated Motorized Sensing Whiteboard. This system consists of five basic units, Flexible whiteboard surface material, microcontroller and sensor unit, dusters, plastic rollers and motors. The working of this system is based on the rotation of flexible whiteboard surface material around the rollers. Rollers are controlled through motors which are further operated by microcontroller mini circuit board and IR sensors. When there's an obstacle in front of the IR sensors, it gives analogue signals to the microcontroller and power supply is given to the motors so that motors start rotating. The whiteboard surface material is rotated through motors and gets cleaned automatically by the dusters fixed on the backside of the board. (Bhushan Tukaram Chougulea, et al, year2014)

Working Principle

Two motors are fixed on the upper and lower side of the rollers. These rollers are placed on the left and right side of the wooden block and are attached to the shaft of the motors by welding. The dusters are fixed in the duster holders and are attached on the rear side of the wooden block. The microcontroller mini-board and IR sensors are fixed on the top of the wooden block and are connected to AC to DC converter. The flexible whiteboard material is rolled around the wooden block and rollers. When an object is placed in front of the IR sensors, it gives analogue output to Atmega-8 mini-board. The IC LM358N converts the analogue signal to digital signals and send it to the microcontroller unit. The microcontroller unit gives a signal to the L293D motor driver IC which drives the motors. The roller connected to the shaft of the motors gets rotated. (Bhushan Tukaram Chougulea, et al, year2014)

Figure 2.5: Front and Back View of The System

. (Bhushan Tukaram Chougulea, et al, year2014)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the procedures and methods used to design Automated Whiteboard Cleaner. Figure 3.1 shows the flow chart of the steps taken to develop an Automated Whiteboard Cleaner. The overall process of this project can be seen in the flow chart. The progress starts by reviewing the literature on the automated whiteboard cleaner. The initial steps are by studying the purpose of the automated whiteboard cleaner and its benefits towards the users. The information is obtained through myriad sources such as journals, internet sources and articles. Even a survey is been carried on to get information in term of customers perspective.

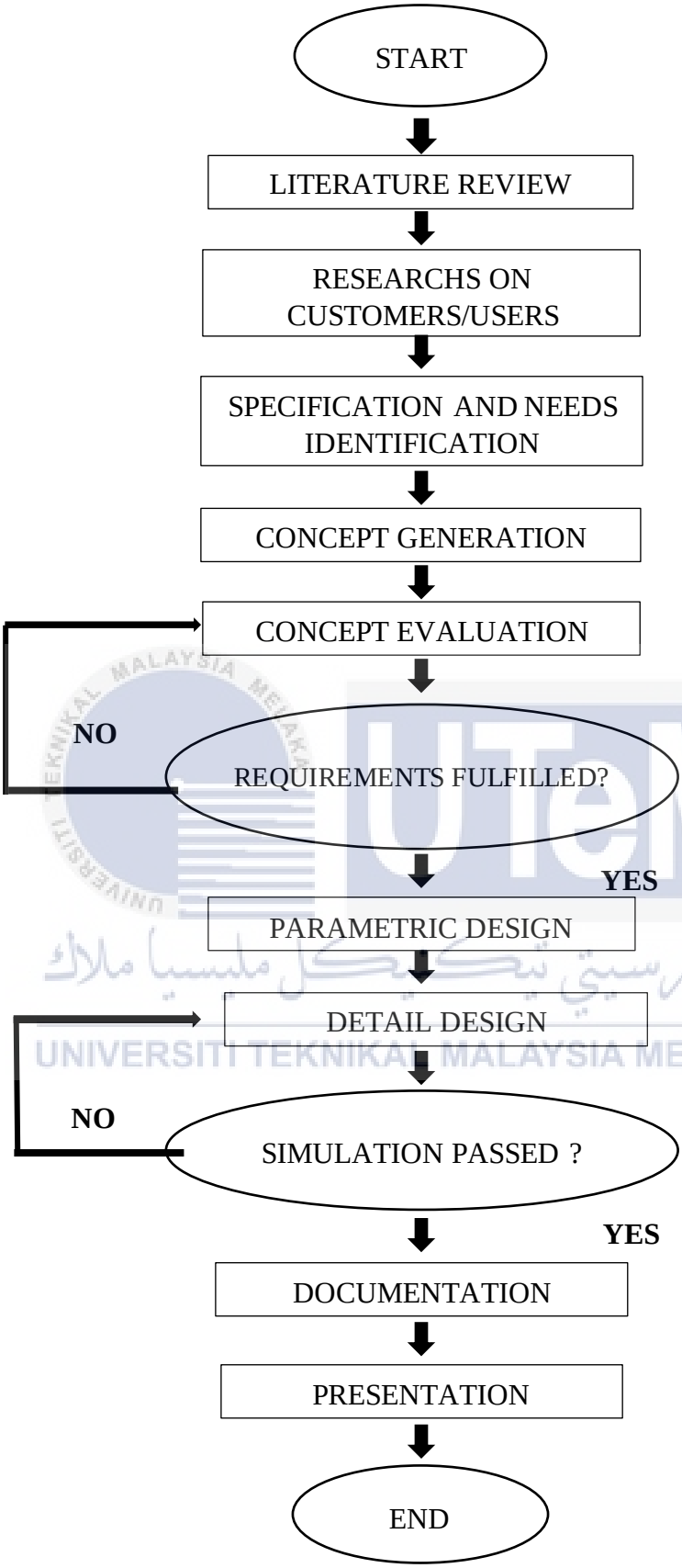


Figure 3.1: Flowchart of Project

3.2 Business Opportunity

Whiteboard is generally used widely in the education industry, as well as in the corporate world. It is used in classes for a lecture, meetings and many more. As many implements whiteboard to the use, the business opportunity is large. Therefore, the needs of an automated whiteboard cleaner are highly suggested.

The targeted end-users of this product are the Ministry of Education (MOE) because in the line of education it contributes to the largest percentage of whiteboard users. By targeting the MOE, the automatic whiteboard cleaner can reach to the maximum number of sales.

3.3 Specifications And Needs Identification

To identify the specifications and needs of product and customs, the questionnaire was done through Google Form and the results were obtained from the responses. Then, the engineering characteristic was determined to fulfil customer requirements. Followed by House of Quality (HOQ) which is a part of the Quality Function Development (QFD) is created to determine and organize design specification. Finally, the Product Design Specification (PDS) is then listed with the aid of customer requirements and engineering characteristic.

3.3.1 Questionnaire

The google form is used to gather information on the public's opinion towards the Automated Whiteboard Cleaner. The questionnaire was filled by selected public which were randomly picked, where most of them were filled by lectures. The questionnaire is divided into three sections which are Section A: Demographics of the respondent, Section B: Responses of development of an Automated Whiteboard Cleaner and Section C: Responses for Automated Whiteboard Cleaner's aspect.

Section A (Demographic of Respondent)

Question 1: Gender

This survey was answered by 50 respondents. From the pie chart analysis shown in Figure 3.2., 65% of them are the male respondent and 35% are the female respondent.

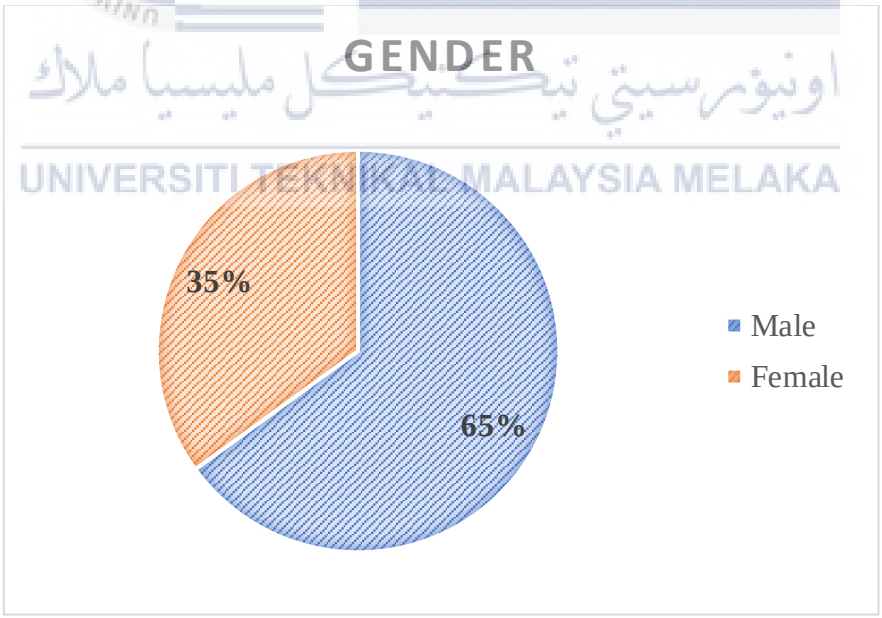


Figure 3.2: Pie Chart Analysis for Question 1

Question 2: Age

Figure 3.3 below shows the pie chart analysis for the age of respondents range 21 to 30, 31 to 40, 41 to 50 and 51 to 60 years old. The highest percentage of age range is 31 to 40 years old with a percentage of 40%.

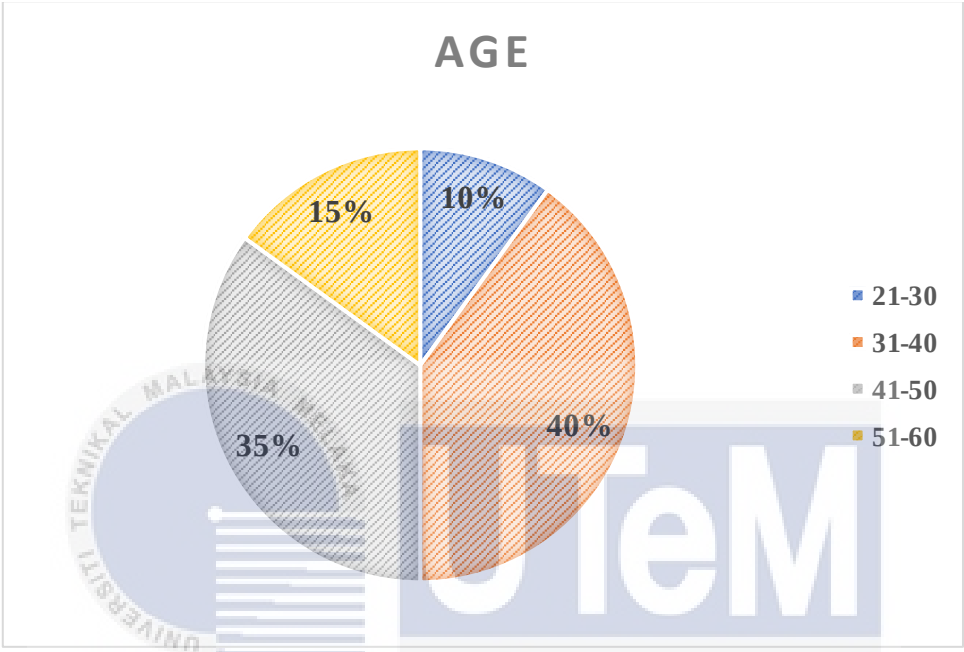


Figure 3.3: Pie Chart Analysis for Question 2

Section B (Responses of development of an Automated Whiteboard Cleaner)

Question 3: What type of whiteboard cleaner would you prefer?

Figure 3.4 shows the pie chart analysis for the 3rd question. Three options were given for the type of whiteboard cleaner preference, which is manual, semi-manually and automatic. Semi-manually falls with the highest percentage with 40%. Then followed by automatic and manually type.

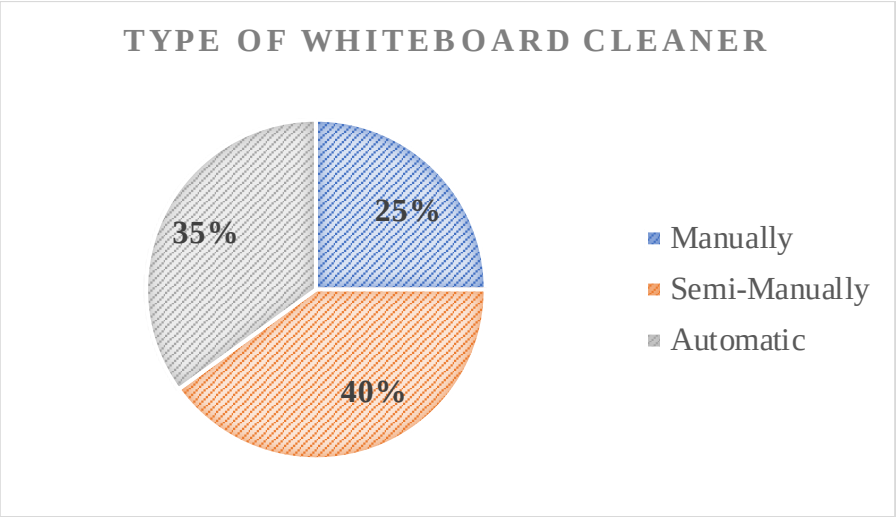


Figure 3.4: Pie Chart Analysis for Question 3

Question 4: What type of mechanism would you prefer?

Figure 3.5 shows the pie chart analysis for question 4. Four options are given, which are rack and pinion, crank and shaft, guide rail and wheel mechanism. The guide rail mechanism has the highest percentage with 59%.

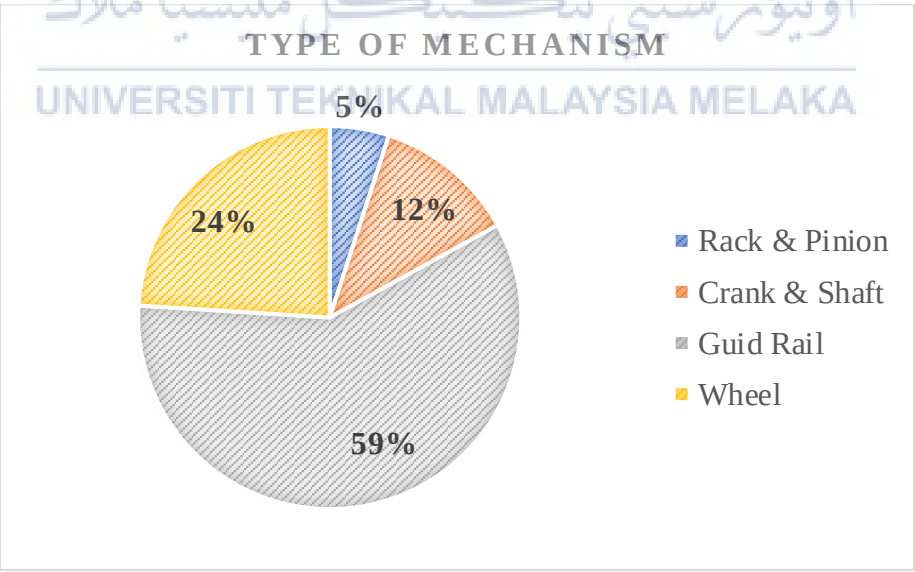


Figure 3.5: Pie Chart Analysis for Question 4

Question 5: What type of material would you prefer?

Figure 3.6 shows the pie chart analysis for question 5. Three options are given for the type of material preference. The options given are stainless steel, ABS plastic and wood. Stainless steel has the highest percentage with 47% while ABS plastic has 1% lesser compare to stainless steel material.

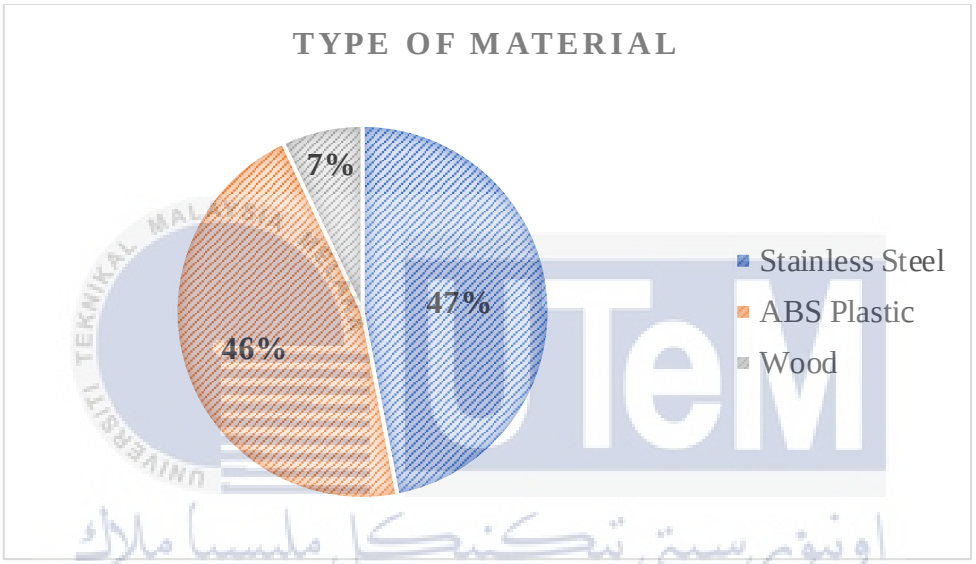


Figure 3.6: Pie Chart Analysis for Question 5

Question 6: Do you think it is necessary to implement automatic whiteboard cleaner in classrooms?

Figure 3.7 shows the pie chart analysis for question 6. 96% of the respondent answered yes, which is to implement an automated whiteboard cleaner in classrooms.

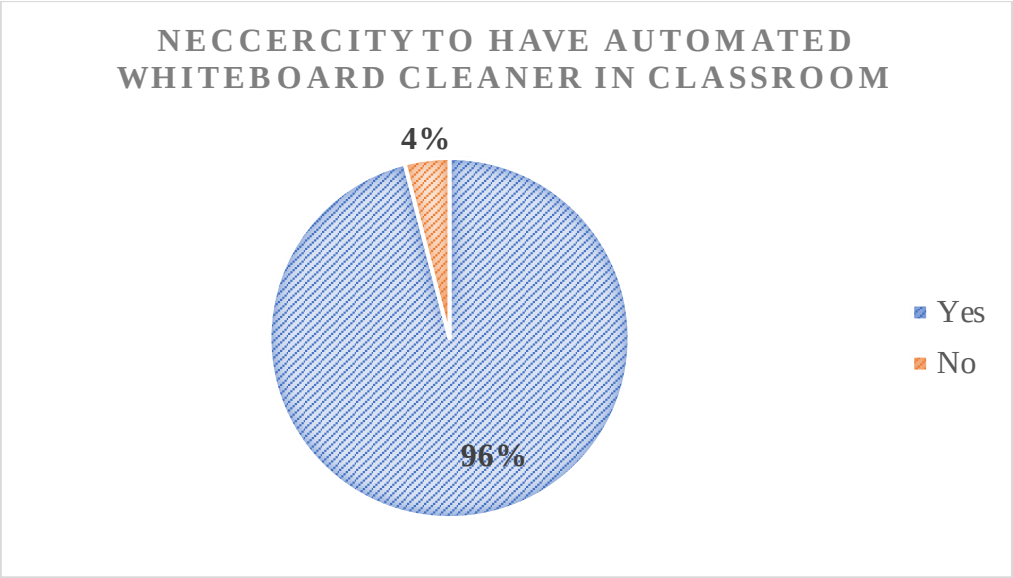


Figure 3.7: Pie Chart Analysis for Question 6

Question 7: Would you buy this product if it is available in future?

Figure 3.8 shows the pie chart analysis for question 7, where the respondents are asked whether are, they are willing to purchase this product. 98% of the respondents responded yes.

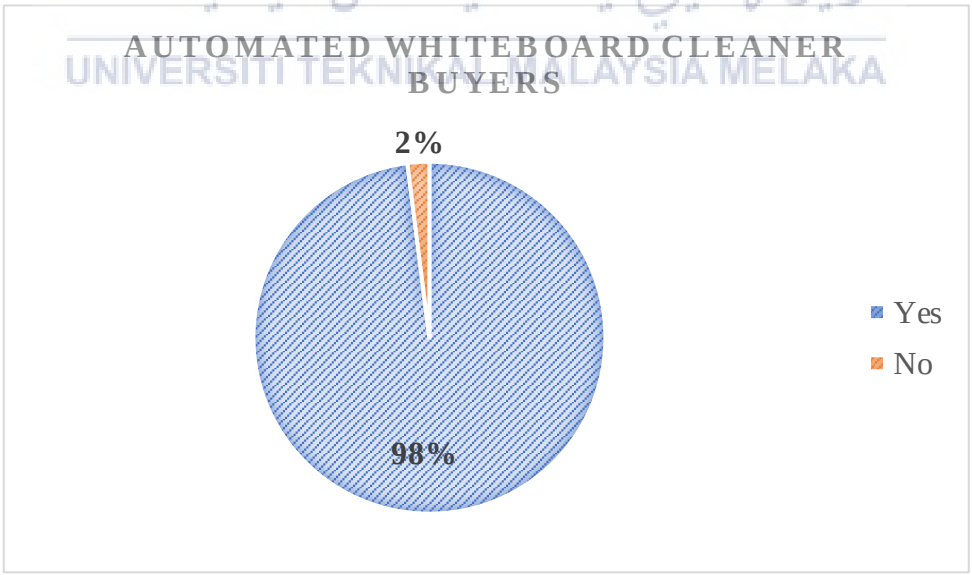


Figure 3.8: Pie Chart Analysis for Question 7

Section C (Responses for Automated Whiteboard Cleaner's Aspects)

Aspect 1: Fast Cleaning

Figure 3.9 shows the pie chart analysis for the aspect long-lasting. 90% of the respondent reacted positively towards this aspect.

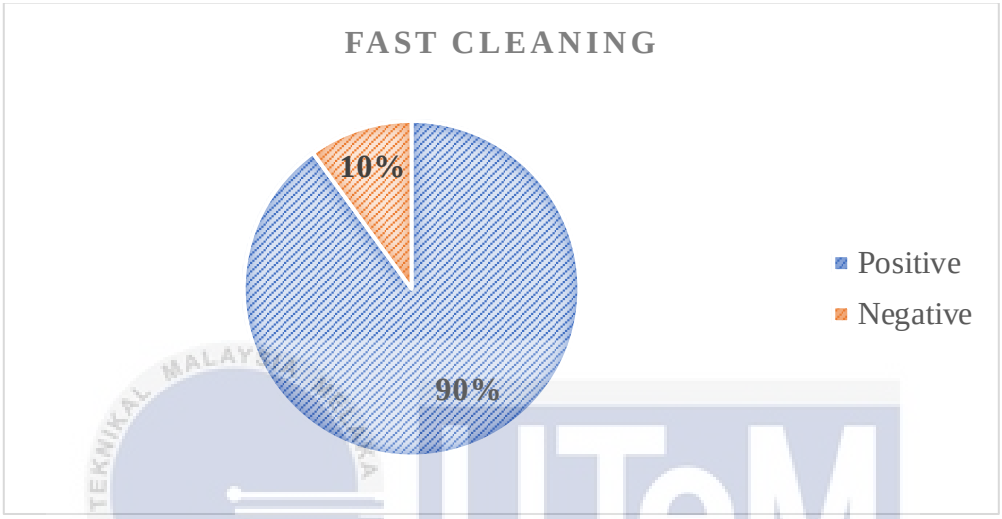


Figure 3.9: Pie Chart Analysis for Aspect 1

Aspect 2: Clean Finishing

Figure 3.10 shows the pie chart analysis for the aspect of clean finishing. 100 % or all the respondent reacted positively towards this aspect.

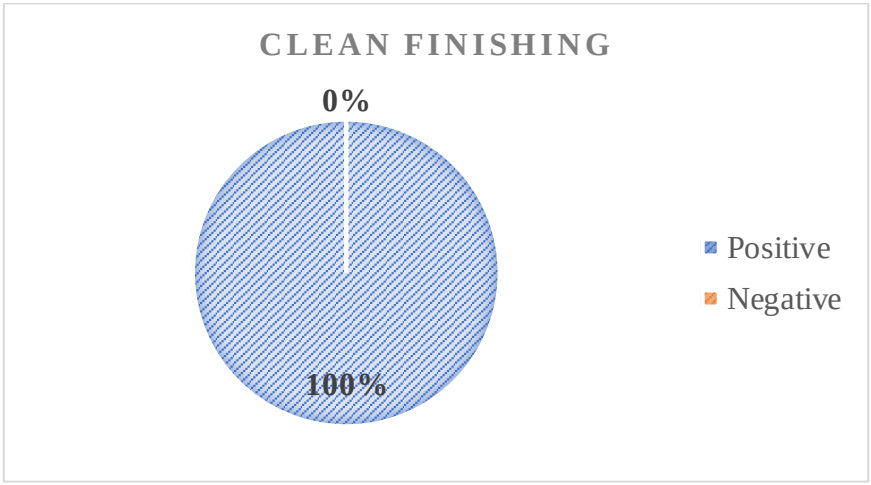


Figure 3.10: Pie Chart Analysis for Aspect 2

Aspect 3: Long Lasting

Figure 3.11 shows the pie chart analysis for the aspect long-lasting. 90 % or of the respondent reacted positively towards this aspect.

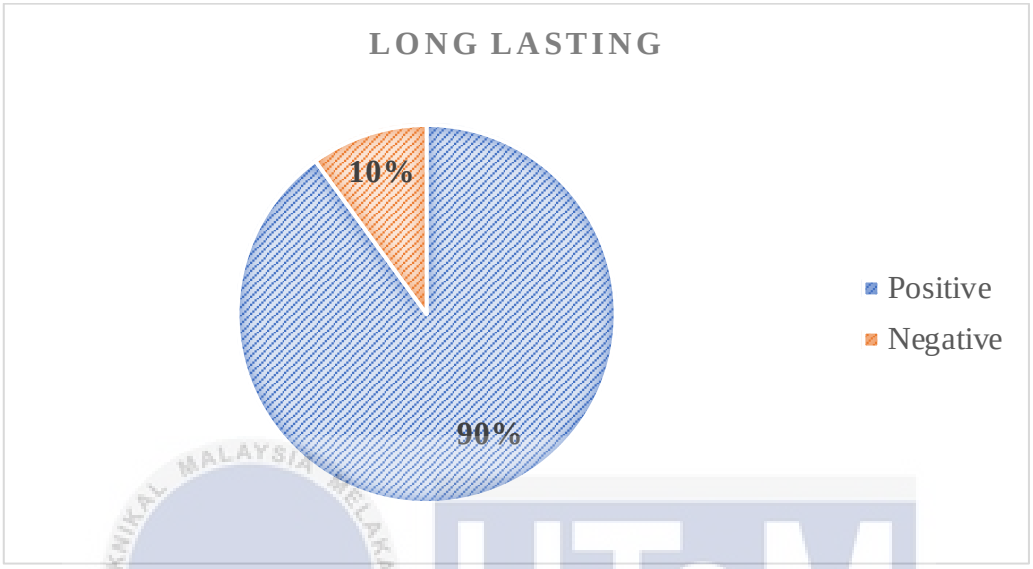


Figure 3.11: Pie Chart Analysis for Aspect 3

Aspect 4: User Friendly

Figure 3.12 shows the pie chart analysis for the aspect user friendly. 75% of the respondent reacted positively towards this aspect.

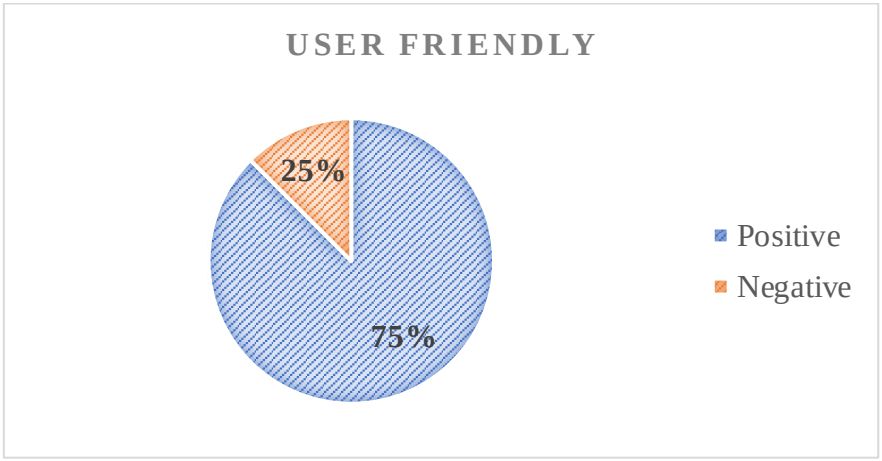


Figure 3.12: Pie Chart Analysis for Aspect 4

Aspect 5: Easy to be Install

Figure 3.13 shows the pie chart analysis for the aspect easy to be install. 90% of the respondent reacted positively towards this aspect.

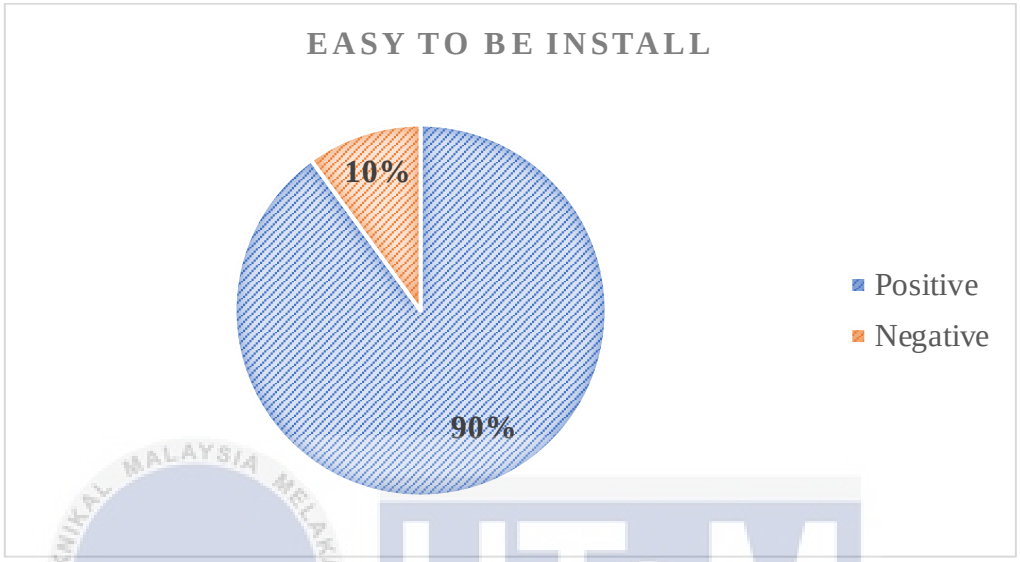


Figure 3.13: Pie Chart Analysis for Aspect 5

Aspect 6: Portable

Figure 3.14 shows the pie chart analysis for the aspect portable. 75% of the respondent reacted positively towards this aspect.

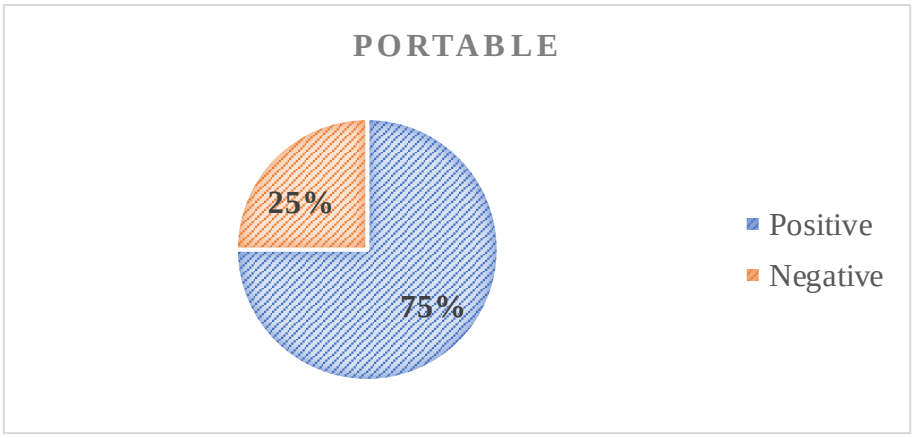


Figure 3.14: Pie Chart Analysis for Aspect 6

Aspect 7: Affordable

Figure 3.15 shows the pie chart analysis for the aspect affordable. 75% of the respondent reacted positively towards this aspect.

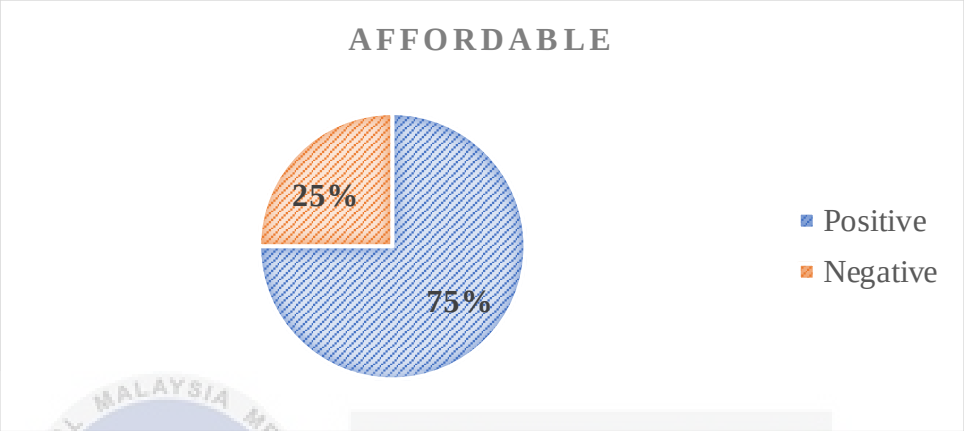


Figure 3.15: Pie Chart Analysis for Aspect 7

3.3.2 Customer Requirement

Customer requirements are the clear list of functions and sub-functions on important needs of the customer. In order to design or manufacture a product that can meet customer's satisfaction, brainstorming and literature review are done to assemble necessities to be met via Automatic Whiteboard Cleaner. Importance weight of the customer requirements is obtained from the distributed questionnaire results. From the table, it shows the customer 's requirements which were gathered through an online survey or google form. The data were tabulated from 1 to 5 to indicate it's important for each requirement from the customers' perspective.

Table 3. 1:Customer Requirements Rating

Customer Requirement	Importance Weight
Fast Cleaning	4
Clean Finishing	5
Long-Lasting	4
Easy to be Used	3
Easy to be Install	4
Portable	3
Affordable	3

(1 = not important, 2 = less important, 3 = quite important, 4 = important, 5 = very important)

3.3.3 Engineering Characteristic

Engineering characteristics are the quantitative performance parameters and their associated units of the designed product They are utilized to evaluate the measure of the fulfilment of every client necessity, it is imperative to decide designing trademark as they are the physical properties that depict the conduct of Automated Whiteboard Cleaner. The engineering characteristics of this project are listed in the table below.

Table 3. 2:Engineering Characteristic with Units

NO	DESCRIPTION	UNITS
1	Total Weight of Product	KG
2	Type of Material Used	n/a
3	Manufacturing Cost	RM/UNIT
4	Dimension	mm
5	Motor Speed	m/s

3.3.4 Quality Function Development (QFD)

In quality function development, House of Quality (HOQ) is created to find the relationship between customer requirements and engineering characteristic. It a process of interpreting what customers want into a composed arrangement, organizing steps of execution dependent on what is generally essential to the customers, and putting a practical arrangement on paper. House of Quality of Automated Whiteboard Cleaner is shown in Figure 3.2. Based on the result of the questionnaire, the importance weight of customer requirement is calculated.

The formula used to calculate the importance of weight, the total importance and relative percentage:

$$Importance\ Weight = \frac{Customer\ Requirement}{Total\ Importance} \times 100\%$$

$$Total\ Importance = \in (Correlation\ Coefficient)(Importance\ Weight\ of\ EC)$$

$$Relative\ Percentage\ \% = \frac{Total\ Importance\ of\ EC}{Sum\ of\ Total\ Importance}$$

Calculation examples;

$$Importance\ Weight\ for\ Fast\ Cleaning = \frac{4}{26} \times 100\% = 15.4$$

$$Total\ Importance\ of\ Motor\ Speed = (9 \times 15.4) + (3 \times 19.2) + (3 \times 11.5)$$

$$= 230.7$$

$$Relative\ Percentage\ of\ Motor\ Speed = \frac{230.7}{1675.5} \times 100\%$$

$$= 13.769$$

Relation Matrix Legend	
9	Strong relationship
3	Medium Relationship
1	Weak Relationship
	None

Customer Requirement	
1	Least important
5	Most Important

				Engineering Characteristic				
		Importance Weight		Total weight of product (kg)	Type of material used	Manufacturing cost (RM/unit)	Dimension (mm)	Motor Speed (m/s)
	Customer Requirement							
1	Fast Cleaning	4	15.4	3	3	9	3	9
2	Clean Finish	5	19.2	3	9	3	1	3
3	Long Lasting	4	15.4		9	9		
4	Easy to be used	3	11.5	1	3	1	1	
5	Easy to be installed	4	15.4	3	3	1	1	
6	Portable	3	11.5	9	3		3	
7	Affordable	3	11.5	1	9	9		3
	Total Importance	26	100	276.5	576.3	465.2	126.8	230.7
	Relative Percentage (%)			16.503	34.396	27.765	7.5679	13.769
	Rank			3	1	2	5	4

Figure 3.16: House of Quality of Automated Whiteboard Cleaner

Based on the House of Quality, the engineering characteristic which is in the 1st rank with the highest percentage is Type of Material. Then follow by the Manufacturing Cost and Total Weight of Product with 2nd and 3rd rank respectively. Motor Speed falls on the 4th rank and the last rank which is the 5th rank is the Dimension.

3.3.5 Product Design Specification

Before continuing to concept design, the product design specification details the requirements that must be met for the product to be effective. Table 3.3 shows the design specification of the Automated Whiteboard Cleaner.

Table 3. 3:Design Specification of Automated Whiteboard Cleaner

SPECIFICATION	DETAIL
Performance	• Suitable for different length of whiteboard • Fast and works efficiently
Function	• To safe time • To prevent the use of human energy
Ergonomic	• Suitable size • Continent and easy to operate
Life Span	• More than 5 years • Part may be replaced if there's any faulty
Material	• Lightweight and easy to be assembled • Long-lasting and high durability
Weight	• The total weight must not exceed 2kg
Cost	• Low manufacturing cost, low maintenance cost and low material cost
Health and Safety	• No sharp edges • Environmentally friendly • Customer's safety should be kept as a priority

3.4 Competitors

Table 3.4 shows the comparison of three different types of whiteboard cleaner from 3 different inventions or project. As stated, all three products show a difference in term of speed, compatibility, cleaning accuracy, size and weight.

Table 3. 4:Comparisons between three products

Type	Automated Whiteboard Cleaner Nevon Invention	Automated Whiteboard Cleaner Korean Invention	Automated Whiteboard Cleaner IDP
Image			
Compatibility	Attach to a certain type of whiteboard	Attach to a certain type of whiteboard	Attach to all type of whiteboard
Speed	Fast	Slow	Average
Size and Weight	Light and Average	Heavy and Large	Light and Average
Accuracy for Cleaning	High	High	Low

3.5 Concept Generation

The Automated Whiteboard Cleaner's concept is generated based on features and specification of a combination of a few project's ideas. The ideas are combines to come up with a product which can benefit the customer. The features can be divided into four categories as shown in Table 3.5.

Table 3. 5:Features of Automated Whiteboard Cleaner

FEATURES	DESCRIPTION
Operating Mechanism	Motor to move the duster and limit switch to stop
Duster's Movement	X-Axis
Motor Rotation	Clockwise and Anticlockwise
Mechanism's Position	Horizontally above the whiteboard

3.5.1 Morphological Chart

Table 3.6 shows the morphological chart used to develop alternative parts or system of Automated Whiteboard Cleaner. The characteristics include the method of operation, type of motor, the quantity of duster holder, movement axis, motor rotation, type of power transmission, type of bracket and type of sensor.

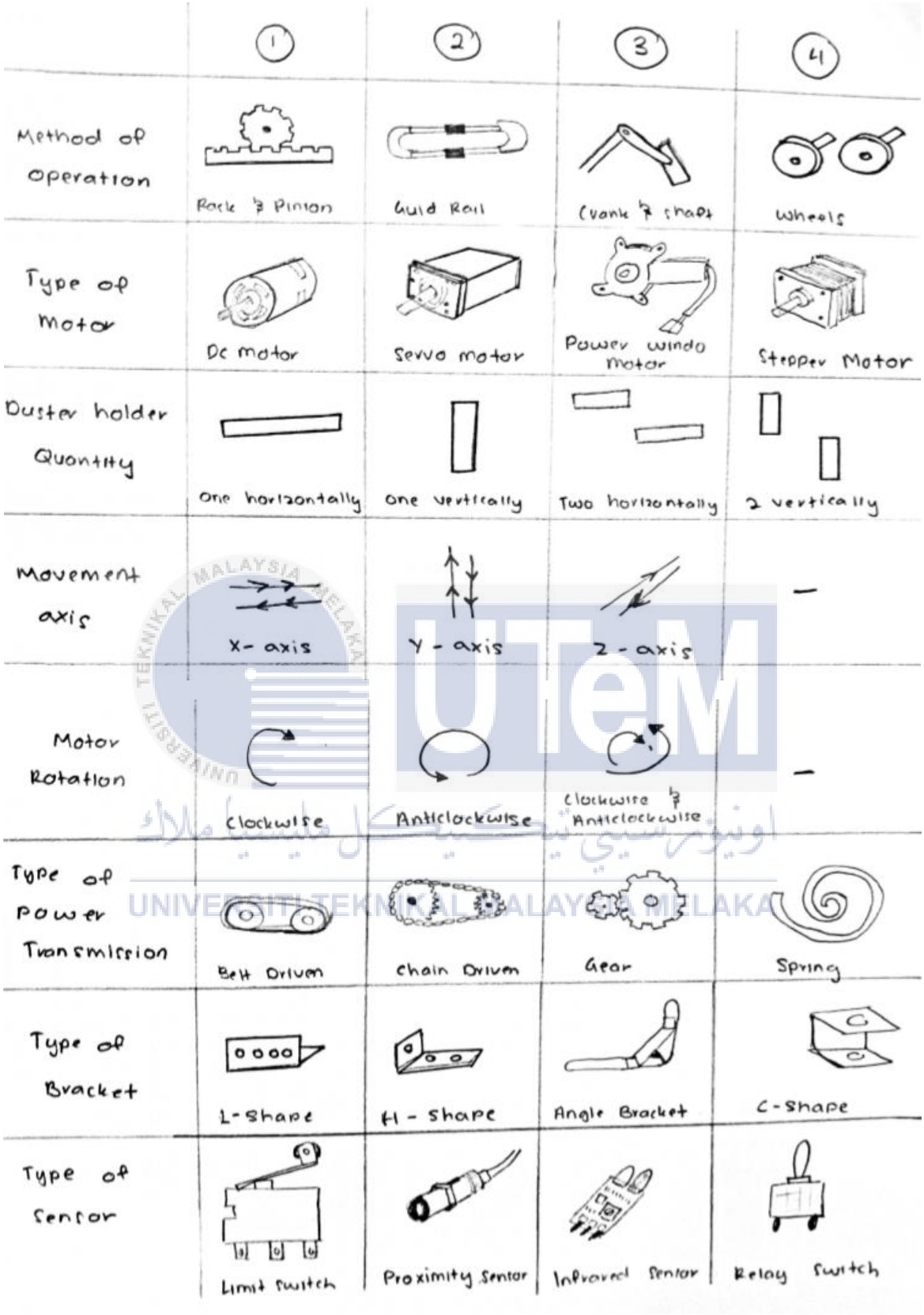


Figure 3.17: Morphological Chart of Automated Whiteboard Cleaner

3.5.2 Conceptual Design

I. Conceptual Design 1

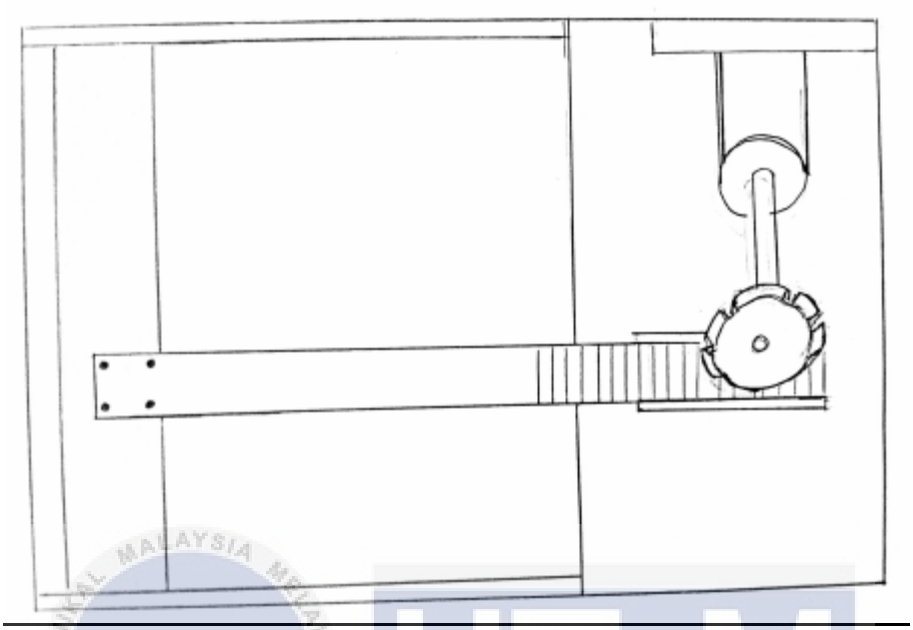


Figure 3.18: Concept Design 1

Figure 3.18 shows the first concept design of Automated Whiteboard Cleaner. The option chosen from the morphological chart from each characteristic is shown in Table 3.6. This design operates with a rack and pinion mechanism with one vertical duster compartment which moves in x-axis motion. As the motor rotates in the clockwise direction the duster moves in-words and vies-versa. It stops when it's been detected by the IR sensor.

Table 3. 6:Number of options chosen for 1st Concept Design

CHARACTERISTIC	OPTION
Method of Operation	1
Type of Motor	2
Duster Holder Quantity	2
Movement Axis	1
Motor Rotation	3
Type of Power Transmission	3
Type of Bracket	1
Type of Sensor	3

II. Conceptual Design 2

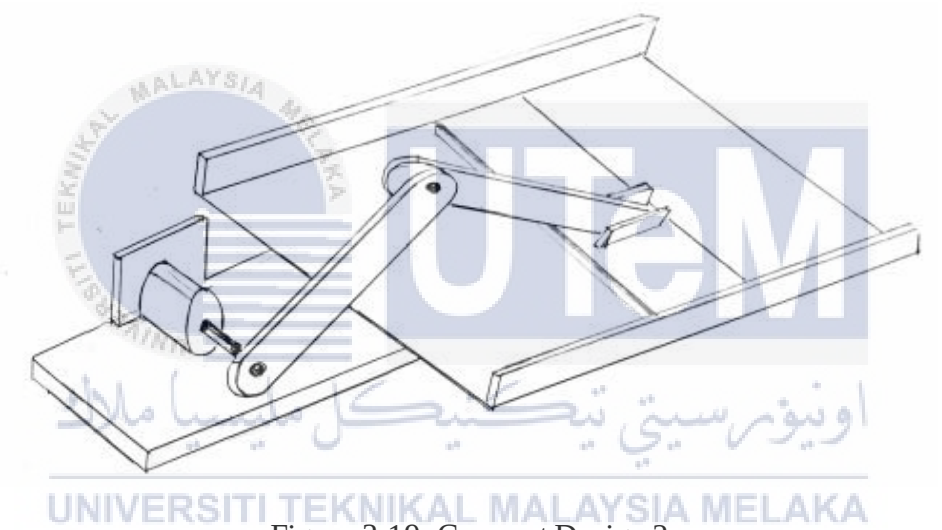


Figure 3.19: Concept Design 2

Figure 3.19 shows the second concept design of Automated Whiteboard Cleaner. The option chosen from the morphological chart from each characteristic is shown in Table 3.7. This design operates with crank and shaft mechanism with one horizontally placed duster which moves in y-axis motion. As the motor rotates the duster moves downwards and back to upwards and stops when it's been detected by the proximity sensor.

Table 3. 7:Number of options chosen for 2nd Concept Design

CHARACTERISTIC	OPTION
Method of Operation	3
Type of Motor	1
Duster Holder Quantity	1
Movement Axis	2
Motor Rotation	3
Type of Power Transmission	-
Type of Bracket	1
Type of Sensor	2

III. Conceptual Design 3

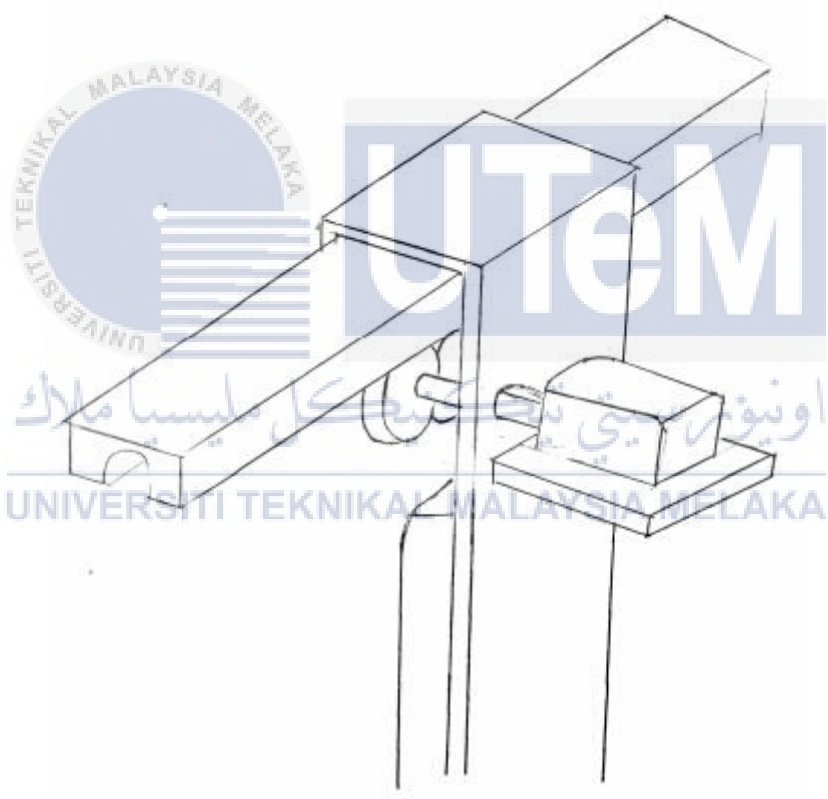


Figure 3.20: Concept Design 4

Figure 3.20 shows the third concept design of Automated Whiteboard Cleaner. The option chosen from the morphological chart from each characteristic is shown in Table 3.8. This design operates with the use of wheels with one vertically

placed duster which moves in x-axis motion. As the motor rotates the duster moves towards left and right. It stops when it's been detected by the proximity sensor.

Table 3. 8:Number of options chosen for 3rd Concept Design

CHARACTERISTIC	OPTION
Method of Operation	4
Type of Motor	3
Duster Holder Quantity	2
Movement Axis	1
Motor Rotation	3
Type of Power Transmission	3
Type of Bracket	2
Type of Sensor	2

IV. Conceptual Design 4

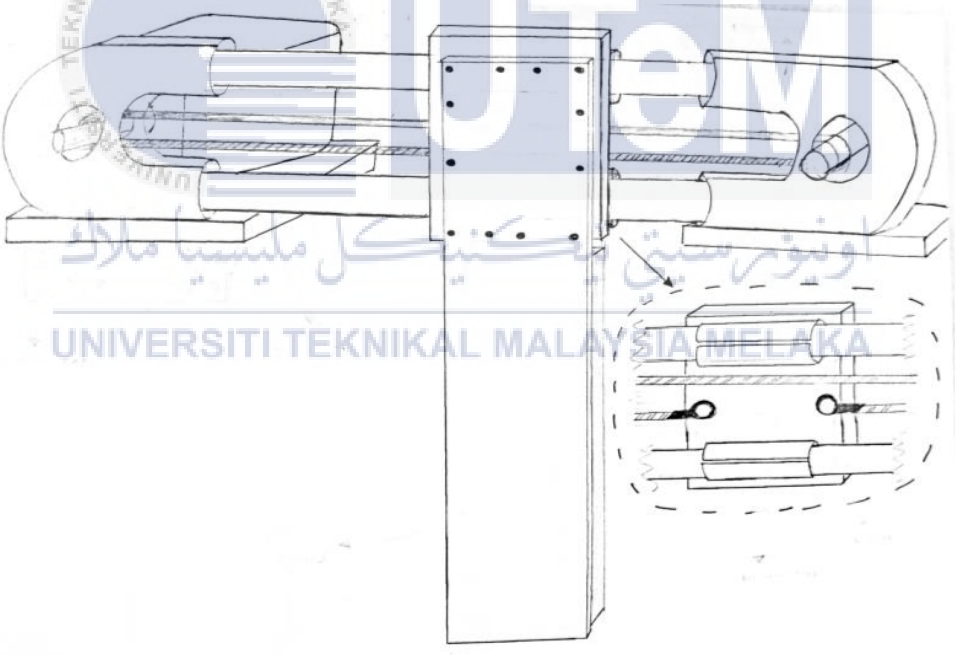


Figure 3.21: Concept Design 5

Figure 3.21 shows the fourth concept design of Automated Whiteboard Cleaner. The option chosen from the morphological chart from each characteristic is shown in Table 3.9. This design operates with the use of guide rail mechanism with one vertically placed duster which moves in x-axis motion. As the motor rotates in

clockwise and anticlockwise motion, the duster moves towards left and right It stops after hitting the second limit switch which is after one cycle.

Table 3. 9:Number of options chosen for 4th Concept Design

CHARACTERISTIC	OPTION
Method of Operation	2
Type of Motor	1
Duster Holder Quantity	2
Movement Axis	1
Motor Rotation	3
Type of Power Transmission	1
Type of Bracket	3
Type of Sensor	1

3.6 Concept Evaluation

3.6.1 Pugh Concept Selection

For concept evaluation of the Automated Whiteboard Cleaner, Pugh Matrix (PM) is used. The best idea among the four-concept design is assessed by comparison by their qualities and weakness with selected datum in term of criterion stated in Table 3.10. Design and Development of Automated Whiteboard Cleaner for Effective Cleaning Mechanism using Arduino (M.Suresh, et al, year 2018) is chosen as DATUM.

Table 3.10: Concept Evaluation of Automated Whiteboard Cleaner

	IMPORTANCE		CONCEPT 1	CONCEPT 2	CONCEPT 3	CONCEPT 4
CRITERION						
Performance	HNL	DATUM	-	-	+	+
Functionality			-	-	+	+
Ergonomics			+	+	+	+
Size			-	-	+	+
Material			S	S	S	S
Weight			+	+	-	+
Cost			S	+	-	+
Safety			+	+	+	+
ADDITION			3	4	5	7
SUBSTRUCTION			3	3	2	0
FINAL SCORE			0	1	3	7

3.6.2 Best Concept

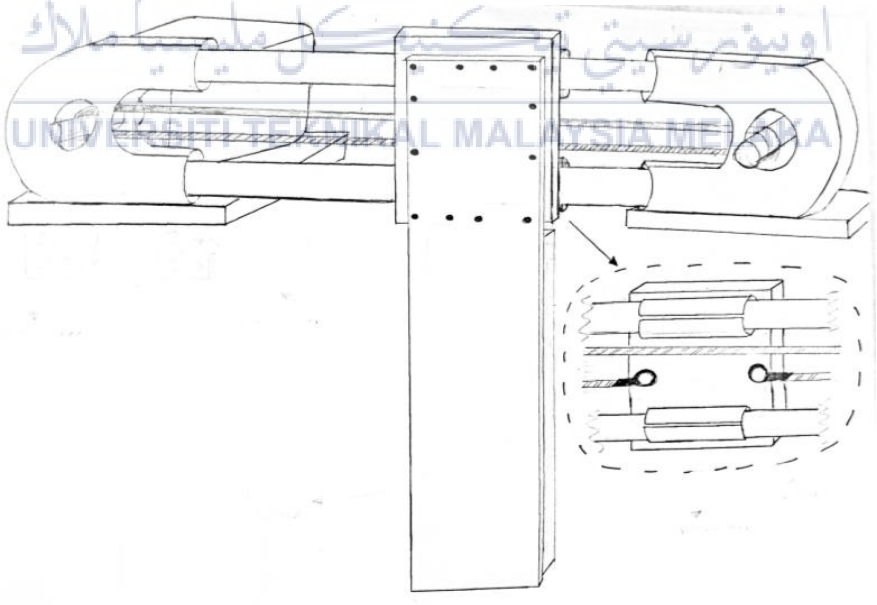


Figure 3.22: The Best Concept

Based on the Pugh Concept Selection in Table 3.10, the fourth concept design is the best among all four concepts. This is because concept 4 has the highest final score among the four concepts and besides that, this concept has met the customer requirement and engineering characteristic.

3.7 Material Selection

This section discusses the material selection of components for the Automated Whiteboard Cleaner. The material selected is based on the aspect of long-lasting, user- friendly and efficient.

3.7.1 6061 Aluminium Alloy

Few parts of the Automated Whiteboard Cleaner which are the guide rail and pulley will be made of this material. This material contains magnesium and silicon as its major alloying element, which is a particle hardening aluminium alloy. Besides that, it has ultimate tensile strength and yield strength, does not rust and long-lasting.

Figure 3.23: AL6061 Guide Rail

Figure 3.24: Pulley

3.7.2 Stainless Steel – Grade 316

Few of the components of Automated Whiteboard Clearer are made of stainless steel, which are the 100mm shaft, additional block and the housing. The reason why this material is chosen is due to low cost, hight life span, high in strength and easy to fabricate.

Figure 3.25: Stainless Steel Materials

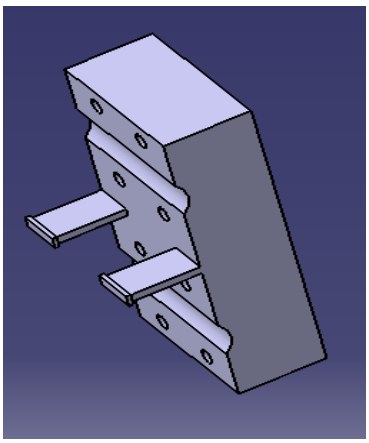


Figure 3.26: Additional Block

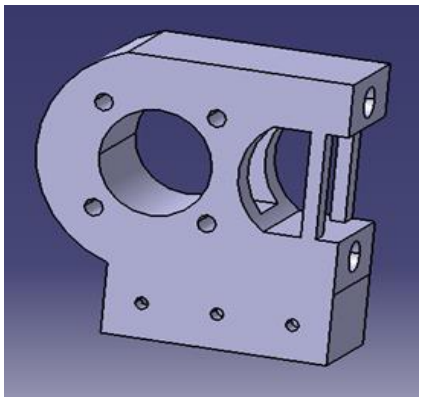


Figure 3.27: Housing

3.7.3 Rubber

The timing belt is one of the main components used in this concept. Therefore, the material selected for this component is a rubber. This is because rubber is a high-tensile material which can be used continuously as it will be able to withstand heat and lightweight.

Figure 3.28: Rubber Timing Belt

3.7.4 Acrylic Board

The duster holder material chosen is the acrylic board. The purpose of the use of this material is due to the properties of this material which are light in weight, rigid, high impact strength and weather resistance.

Figure 3.29: Acrylic Board

CHAPTER 4

RESULT AND DISCUSSION

4.1 Parametric Design

4.1.1 Product Architecture

The Automated White Board Cleaner is inspired by a few project's ideas. Innovation is done by combining those designs and ideas to come up with a new design for this project. Figure 4,1 shows the drawing of the project which is done by using Catia V5. The drawing is complete with stepper motor, housing, guide rail with its bearing, additional block, pulley, shaft and duster holder.

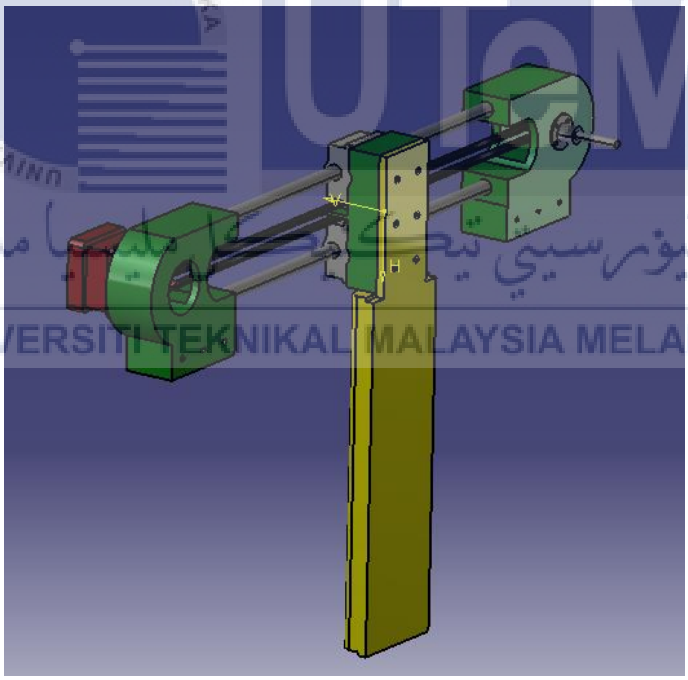


Figure 4.1: Drawing of Automated White Board Cleaner

4.2 Analysis And Stimulation

To ensure that the components of the Automated White Board Cleaner perform perfectly without any failure, analysis and simulation are been carried out to the components. Besides that, the torque required for the motor is calculated as well as the strength and maximum force that can be applied for the housing, guide rail and additional block are analysed.

4.2.1 Analysis On Housing

The housing consist of two sections, the left side and the right side with two different dimensions in the centre. This part of the project holds the guide rail in a horizontal position, which is one of the main components for this project. Figure 4.2 shows the left section housing with the dimension of 30mm in the center, which will be attached to the motor that will drive the timing belt in the left and right motion. While figure 4.3 shows the right section housing with the dimension of 5mm in the center. This housing will be attached to the 100mm shaft and pully which will be driven by the motor. Both components have a similarity of 30mm thickness and the diameter of 9mm at the section where the guide rail rod will be inserted.

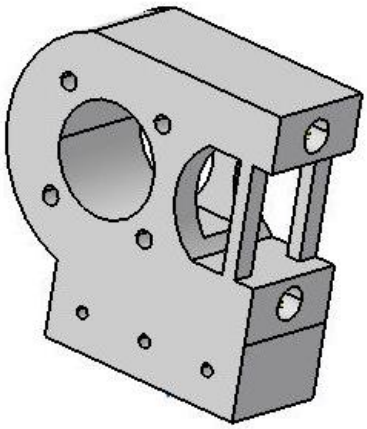


Figure 4.2:Left Housing

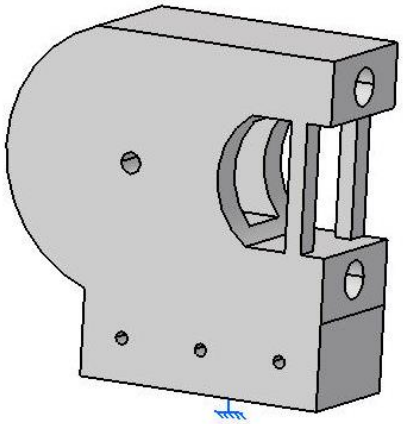


Figure 4.3:Right Housing

To identify the strength of these both components a strength analysis is done using CATIA V5. Figure 4.4 and 4.5 shows the result of the analysis for the components, where a distributed force of 100N is applied to estimate the region of failure.

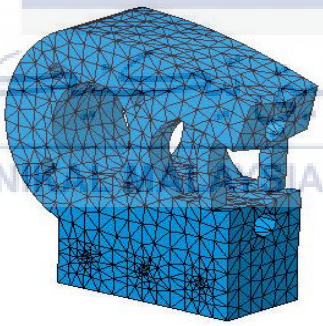


Figure 4.4: Deformation on the Left Housing

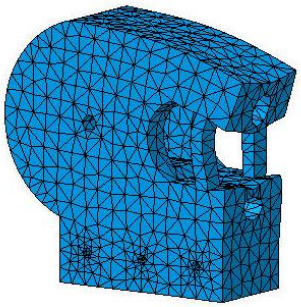


Figure 4.5: Deformation on the Right Housing

While figure 4.6 and 4.7 shows the Von Mises Stress result. From figure 4.6, the maximum value of the von mises stress is at 1.03 KN_m2 and the minimum value is at 7.93 N_m2. For figure 4.7, the maximum value of the von mises stress is at 9.2 KN_m2 and the minimum value is at 6.32 N_m2.

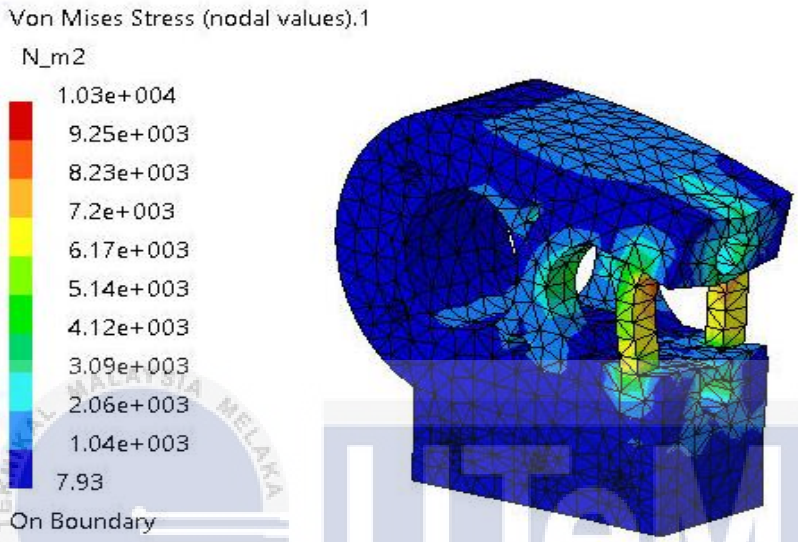


Figure 4.6: Von Mises Stress of Left Housing

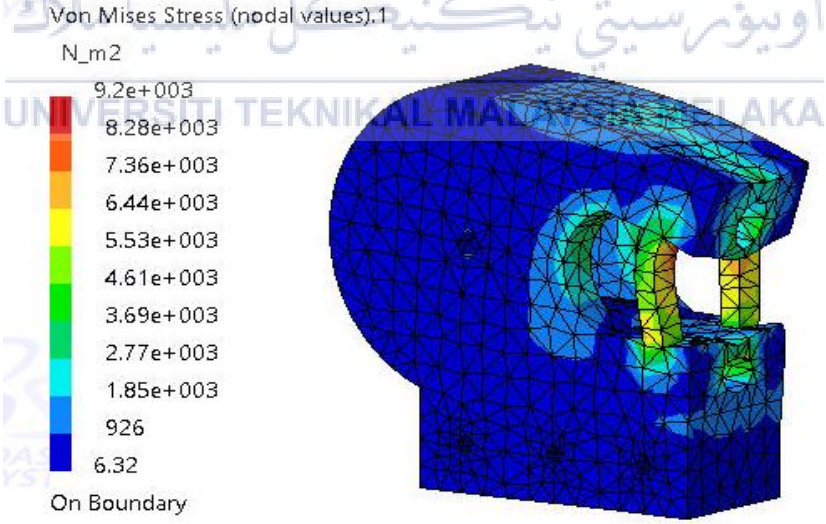


Figure 4.7: Von Mises Stress of Right Housing

Next, the factor of safety of both components is calculated using the Von Mises Stress value which was gathered through the analysis. Since the left and right housing shares the same material, therefore both components have the same yield strength or metal properties. Table 4.1 shows the properties of stainless steel.

Table 4.1: Properties of Stainless Steel

Material	Stainless Steel
Young Modulus	1.9e+011N_m2
Poisson Ratio	0.3
Density	8000kg_m3
Thermal Expansion	1.59e+006_Kdeg
Yield Strength	2.05e+008N_m2

$$F.S = \frac{Mechanical\ Strength}{Max\ Von\ Mises\ Stress}$$

$F.S\ left\ housing = 205MPa/1.03KPa = 19.9 \times 10\text{^}4$

$F.S\ right\ housing = 205MPa/9.2KPa = 22.3 \times 10\text{^}3$

In a nutshell, the factor of safety of the left and right housing is 19.9K and 22.3K respectively. This indicates that both components can withstand load more than 1N.

4.2.2 Analysis On Bearing

The bearing is a component which will be slot into the shaft and placed between both housings. It is located one at the top and one at the bottom shaft to have a stronger hold and to balance the weight of the additional block and the duster

holder. The bearing moves horizontally which is in the left and right direction, that guides the other parts or components. Figure 4.8 shows the bearing with the dimension of 30mm length, 34mm height and 30mm thick.

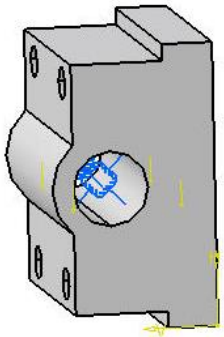


Figure 4.8: Bearing

To understand the amount of weight and to ensure that the bearing will be strong enough to withstand the overall weight enforce to it, an analysis of strength is done through CATIA V5. Therefore, Figure 4.9 shows the result of the analysis after a total amount of 100N_m3 force is applied to the component.

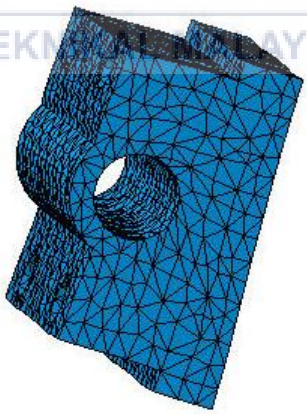


Figure 4.9: Deformation on Bearing

The analysis was done thought Von Mises Stress method and Figure 4.10 shows the result of Von Mises Stress where the maximum and minimum value are 6.99N_m2 and 0.004666N_m2 respectively.

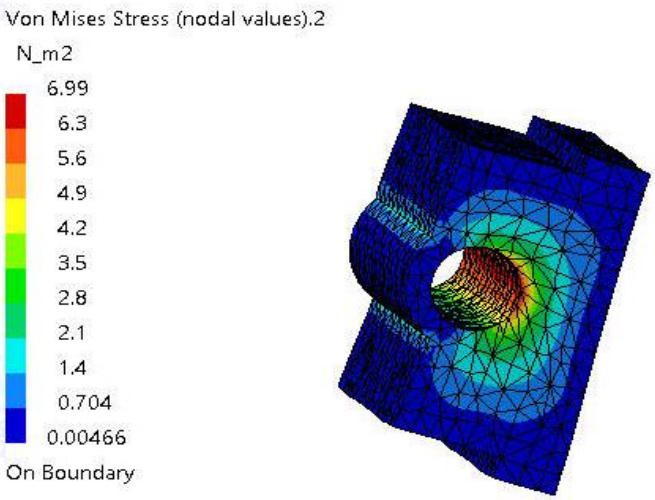


Figure 4.10: Von Mises Stress on Bearing

4.2.3 Analysis On Additional Block

The additional block is a component which is found between the bearing and the duster holder. The purpose or function of it is to make extra space in between the duster holder and the board to prevent collusion between both surfaces and it also fully supports the weight of the duster holder, Figure 4.11 shows the additional block with the dimension of 40mm length, 78mm height and with the thickness of 20mm.

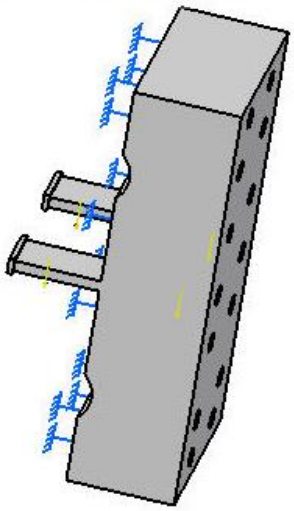


Figure 4.11:Additional Block

To determine the strength and to understand the region of failure of the additional block, an analysis of strength has been carried out through CATIA V5. Therefore, Figure 4.12 shows the result of the analysis when a force of 100N_m3 is been applied to the component.

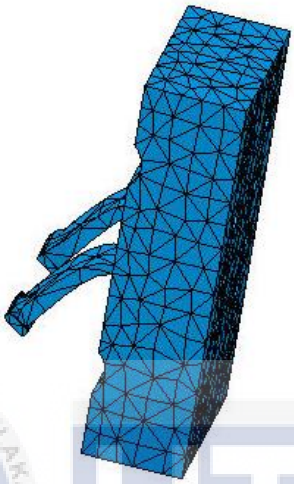


Figure4.12:Deformation Of Additional Block

The result was collected through the Von Mises Stress method. Figure 4.13 shows the result of Von Mises Stress. Therefore, the maximum and minimum value achieved are 35.2N_m2 and 0.00772N_m2 respectively.

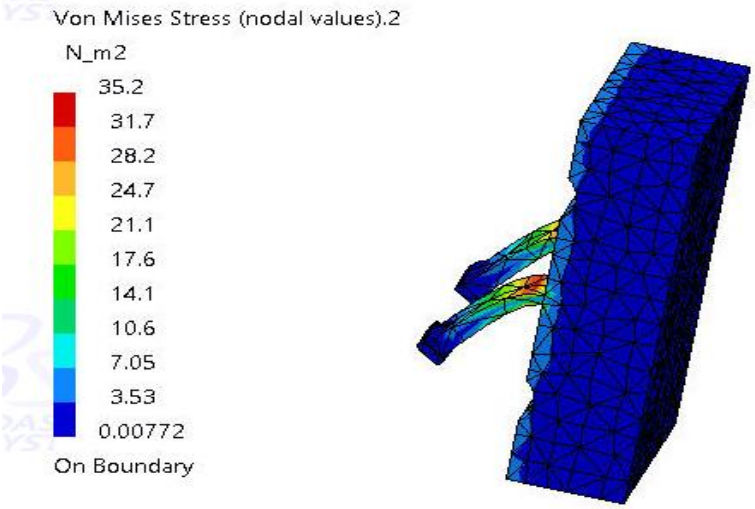


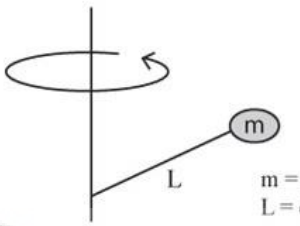
Figure 4.13:Von Mises Stress on Additional Bock

4.2.4 Motor Torque

To determine the suitable sizing of the motor, three factors were needed which are Moment of inertia, Torque and Speed. (ORIENTAL MOTOR USA CORP,2018)

Moment of Inertia is determined through the calculation for a rotating object,

$$J = mL^2$$



m = mass
L = distance between the center of gravity and the center of rotation

$m = 400g, L = 16.377mm$

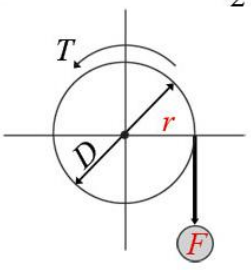
$J = ML$

$= 400g\ X\ 16.377mm$

$= 6550.8g/mm$

Torque is determined through Load Torque Calculation of Pulley Drive,

$$T = F \times r = F \times \frac{D}{2}$$



r = distance between the center of rotation
F = force point

$F = 20N,$

$T = F\ X\ r = 20N\ X\ 16.377MM$

$= 327.54Nmm$

Acceleration Torque,

$$Ta = J \times A$$

Ta : Acceleration Torque
J : Moment of Inertia
A : Acceleration Rate

$$Acceleration, A = \frac{V\,final - V\,initial}{t\,final - t\,initial}$$

$$= \frac{\frac{10mm}{s} - 0}{180s - 0}$$

$$= 0.055mm/s^2$$

$$T = 360.294NmmX\ 0.055mm/s^2$$

=3.53Nmm

The calculation for Required Torque,

$$T_M = (T_L + T_a) \times S_f$$

T_M : Required torque
T_L : Load torque
T_a : Acceleration torque
S_f : Safety factor

$$Tm = (327.54 + 3.53)X\ 2$$

$$= 1361.08Nmm$$

$$= 1.36Nm$$

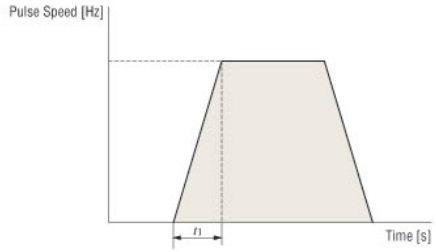
Speed ,

Standard Speed Calculation

Speed = Distance / Time

For Stepper or Servo Motors

Speed = Distance / (Time - Acceleration Time (*t1*)



$$D = 1800mm, T = 3mint$$

$$S = 1800mm\ \div (3 \times 60)$$

$$= 10mm/s$$

4.3 Detail Design

Detail design is the phase where the design is refined and plans, specifications and estimates are created. Therefore, the detail design for the Automated White Board Cleaner is done by using Catia V5 software to show it in the form of 3D The drawing in Figure 4.14 shows the combination and assembly of all part and components of the Automated White Board Cleaner.

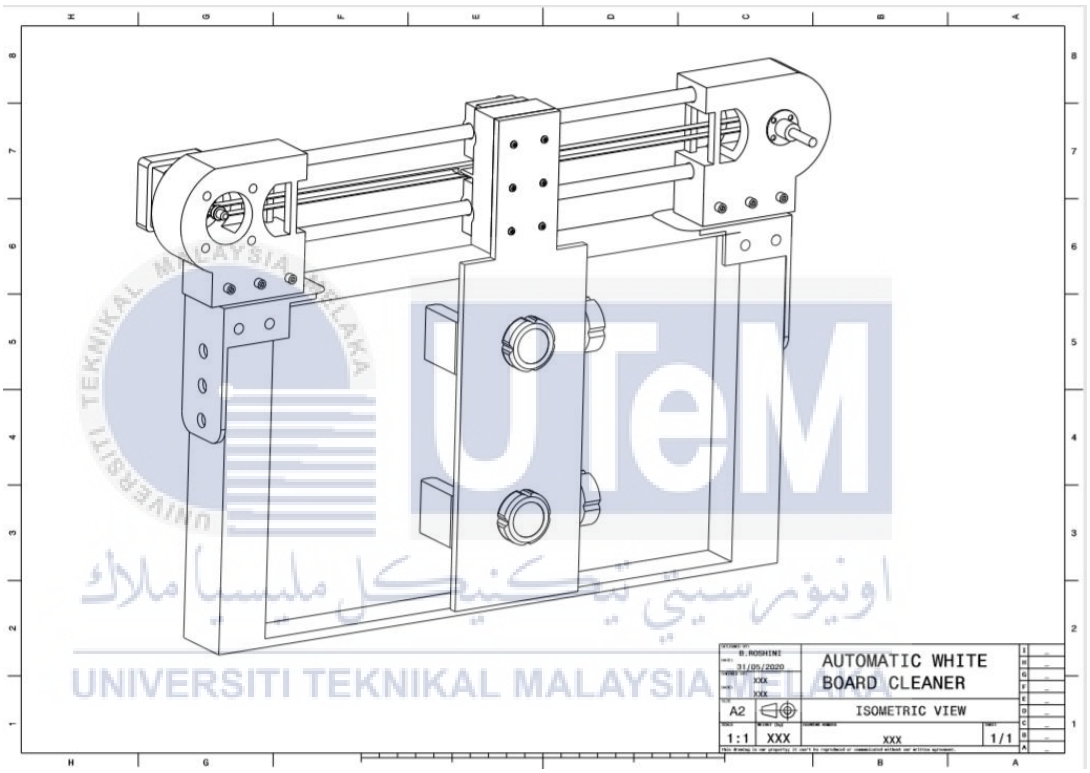


Figure 4.14: Isometric View 3D Drawing

4.3.1 Product Structure

The Automated White Board Cleaner is divided into two structures which are the body and the duster holder. This breakdown is for a better understanding where each component are located at. Therefore, Figure 4.15 and 4.16 shows the product structure for the body and duster holder.

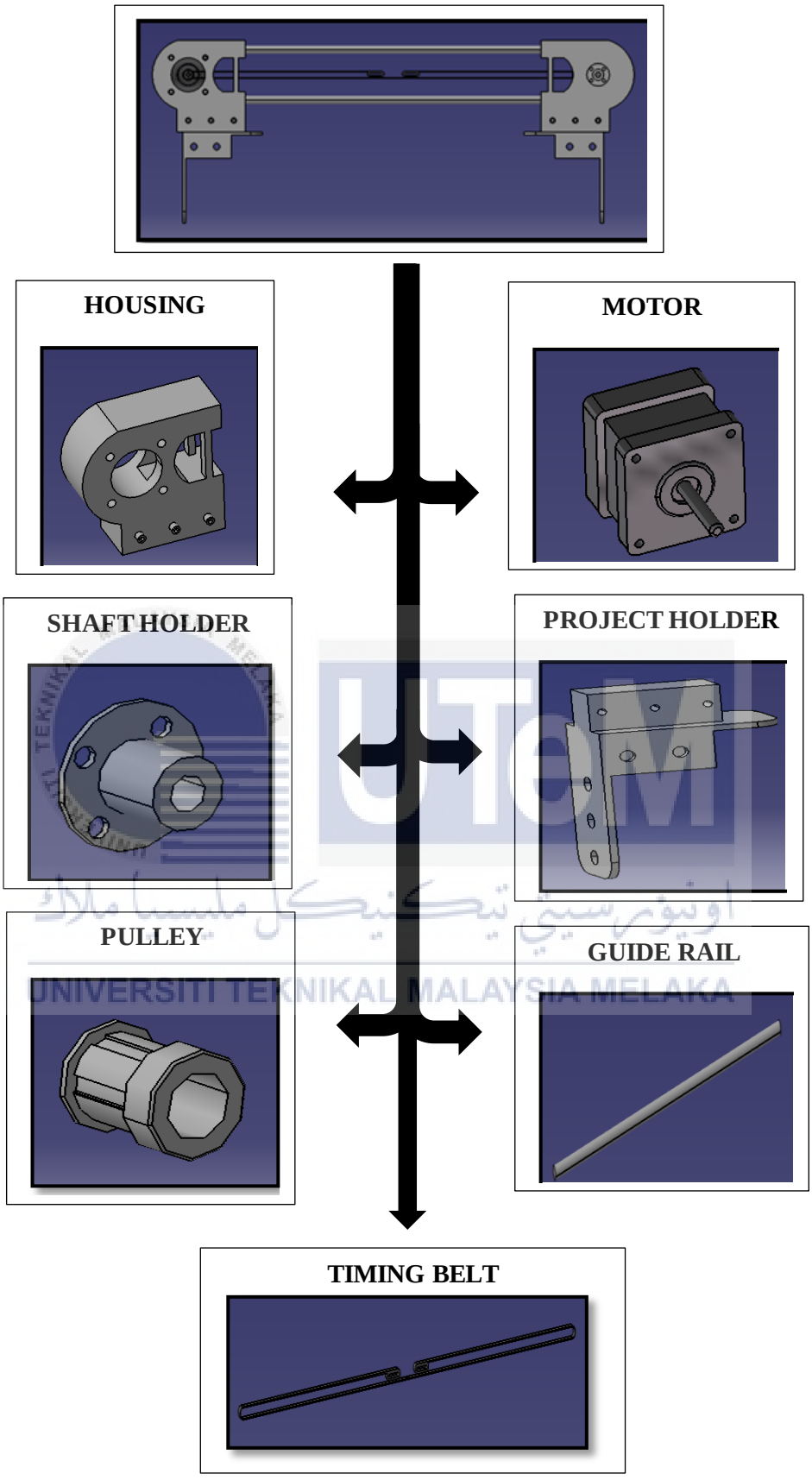


Figure 4.15: The Body Of Automated White Board Cleaner

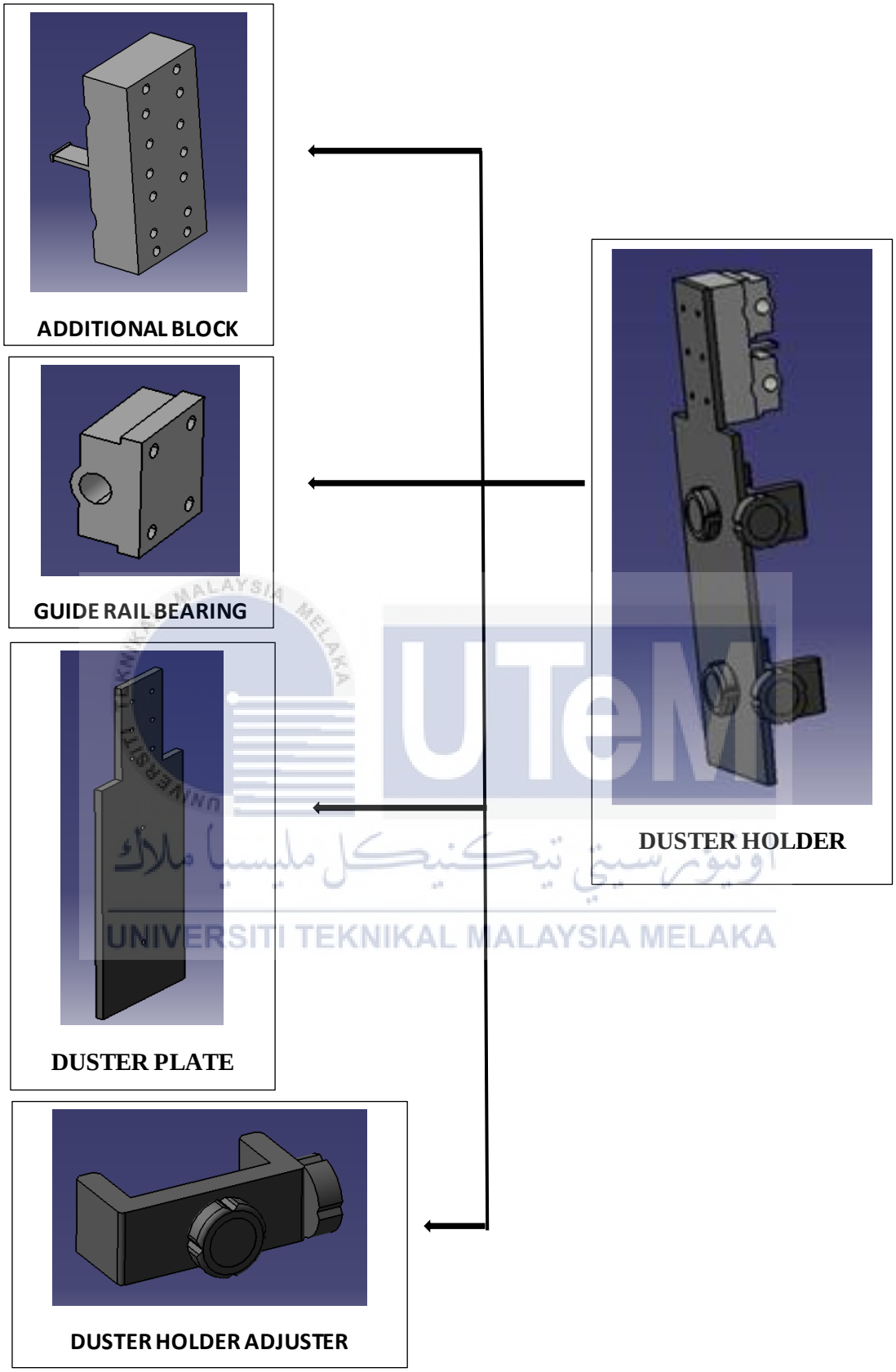


Figure 4.16: Duster Holder of Automated White Board Cleaner

4.3.2 List Of Components

The Automated Whiteboard Cleaner consists of a few numbers of components. To ensure a better understanding of how the design of the project going to be Figure 4.17 shows the orthographic view of the project, which shows the front, left and back view. Furthermore, the Bill Of Material (BOM) of the Automated Whiteboard Cleaner which consists of the number of components and its quantity is shown in Figure 4.18.

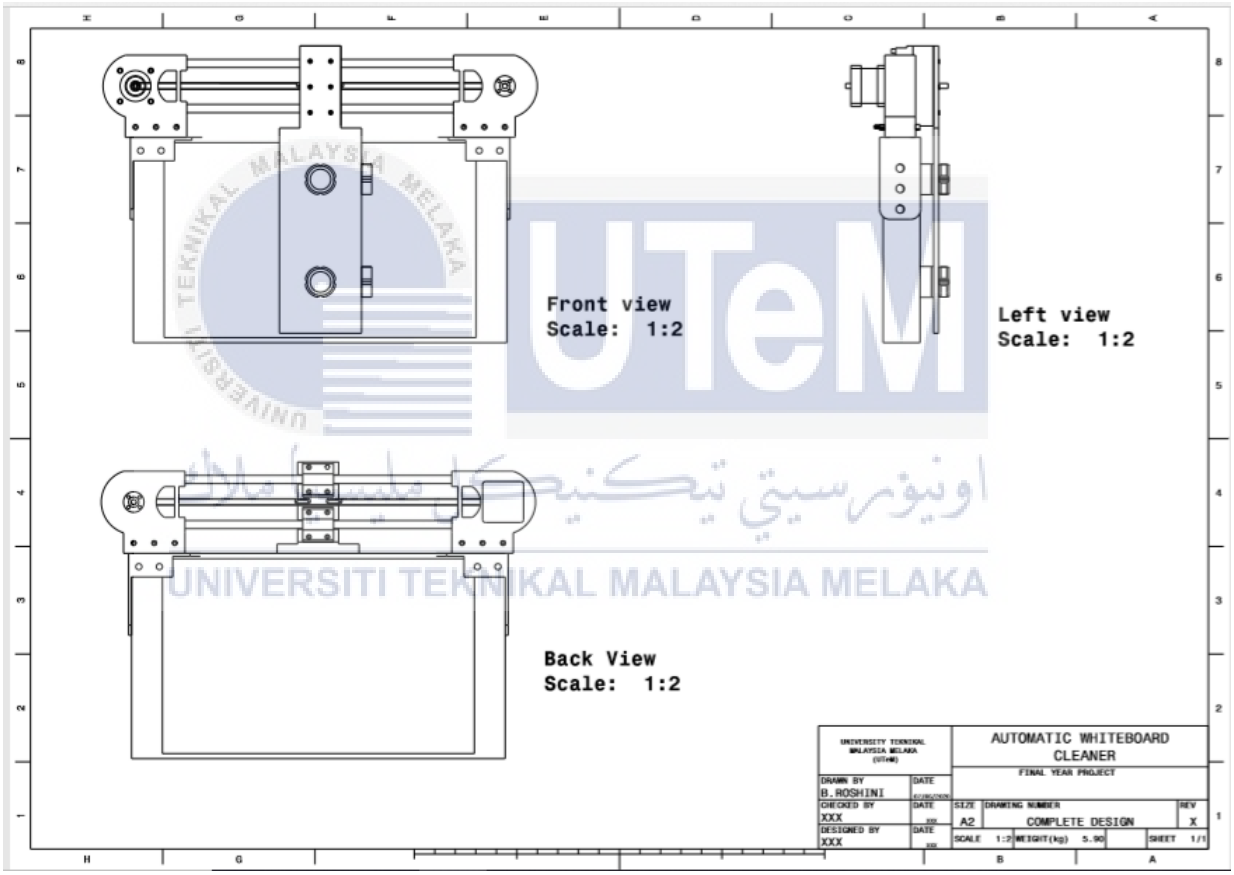


Figure 4.17: Orthographic View of Automated Whiteboard Cleaner

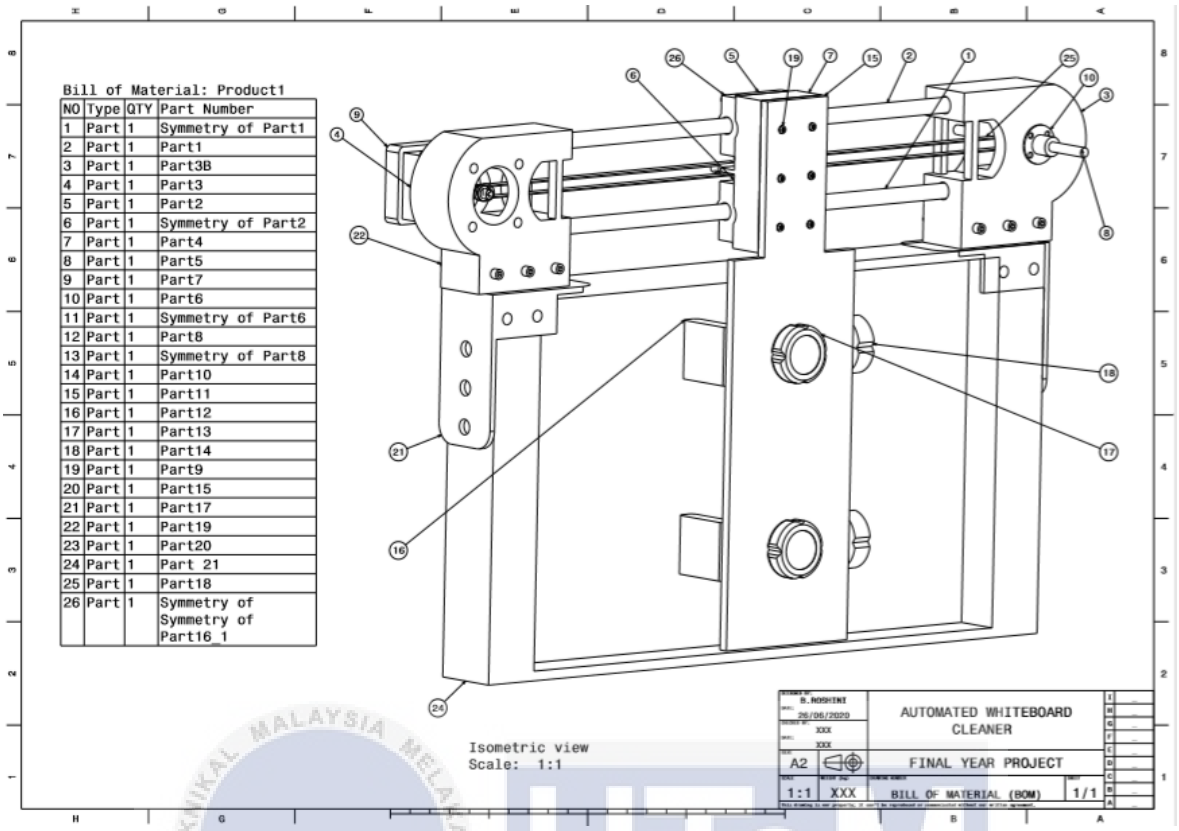


Figure 4.18: Bill of Material of Automated Whiteboard Cleaner

4.4 Manufacturing Process And Cost

Manufacturing process and cost for each of the components of the Automated Whiteboard Cleaner is determined to ensure that the project achieves an overall low cost and functional mechanism. Besides, to determine the cost for each component and its process needed to achieve the components final product. Table 4.2 shows the list of all components and the materials along with the manufacturing process for each particular component. There are few components which require customized design and a suitable manufacturing process according to its design and material. Therefore, the components are divided into two groups which are standard parts and custom parts. In addition, Table 4.3 is used to determines the costing of the components of the project through value analysis. A total of RM251 is estimated.

Table 4,2: Manufacturing Process of Automated Whiteboard Cleaner's Components

NO.	COMPONENT	MATERIAL	TYPE	MANUFACTURING PROCESS
1	Guide Rail	Aluminium Alloy	Standard	
2	Guide Rail Bearing	Aluminium Alloy	Standard	
3	Housing Left and Right	Stainless Steel	Custom	Injection molding, Turning, Milling
4	Additional Block	Stainless Steel	Custom	Injection molding, Turning, Milling
5	Shaft	Aluminium Alloy	Standard	
6	Pully	Stainless Steel	Standard	
7	Timing Belt	Rubber	Standard	
8	Duster Board	Acrylic	Standard	
9	Duster Holder	Plastic	Custom	3D printing, Extrusion, Injection Molding
10	L-Clamp	Stainless Steel	Custom	Injection molding, Turning, Milling

Table 4.3: Manufacturing Cost of Automated Whiteboard Cleaner's Components

N0	COMPONENT	Manufacturing Cost		TYPE OF COST,%		
		RM	%	Material	Production	Assembly
1	Guide Rail	30	11.9	Purchase	Purchase	Purchase
2	Guide Rail Bearing	12	4.78	Purchase	Purchase	Purchase
3	Housing Left and Right	55	21.9	40	50	10
4	Additional Block	30	11.9	30	50	20
5	Shaft	7	2.9	Purchase	Purchase	Purchase
6	Pully	17	6.7	Purchase	Purchase	Purchase
7	Timing Belt	15	5.9	Purchase	Purchase	Purchase
8	Duster Board	40	15.9	Purchase	Purchase	Purchase
9	Duster Holder	25	9.9	30	60	10
10	L-Clamp	20	7.9	20	60	20

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Evolution of whiteboard had made a life for students and educators easier, yet in this future world of technology, everything that we see is automated. This technology implementation makes humans life, less complex as the usage of human power toward a product minimize. Therefore, this project is been carry out to ease educators or consumers in daily life.

The main objective of this Automated Whiteboard cleaner is to come up with a simple effective design which can clean faster. Therefore, few designs were created and among the four concepts, concept number four has been chosen to be the best concept because it has the highest score in the Pugh Matrix. This concept uses the guide rail mechanism with the vertically placed dusted on the whiteboard with x-axis motion. The movement of the duster and motor will be controlled by the limit switch, where after one cycle the duster and motor stop automatically after hitting the second limit switch and push-button for switching the mechanism on.

To ensure that the design is suitable according to customer requirement and engineering characteristic, detail design is done by using CATIA V5. Each component is made respectively from material such as stainless steel, aluminium alloy and plastic. Besides that, the parts have gone through Von Misses Stress analysis to determine the most affected area or area wich most likely to cause deformation when certain load or pressure is applied. The calculation has also been

done to determine the motor sizing, the speed and acceleration of the motor. This is essential to make sure the cleaning process achieve a smooth and clean finish. Finally, detail design is generated to shows the combination and assembly of all part and components of the Automated White Board Cleaner.

5.2 Recommendation

The Automated Whiteboard Cleaner is a device which will be an aid to the users. Altho, it hasn't been out in the market, the possibility of it being a demand in the market is high. Therefore, research is carried on the Automated Whiteboard Cleaner which is recommended to fulfil the market demand in future. Eventho, the thesis for the innovation is done, there's still improvement can be made to the Automated Whiteboard Cleaner. In the future design, much easier design can be made to have an easier assembly and to lighten the overall weight of the Automated Whiteboard Cleaner. Besides that, the Automated Whiteboard Cleaner can be improved to x and y-axis motion to cover more areas of the whiteboard surface and to ensure a cleaner finishing.

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APPENDIX

APPENDIX A1 GANTT CHART FOR PSM 1

ACTIVITY	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Briefing 1														
Objective & Scope Review														
Research & Studies														
Flow Chart														
Questionnaire Distribution														
Concept Generation														
Progress Report Submission														
Concept Evaluation														
PSM 1 Report Writing														
Report Submission														
Presentation														

APPENDIX A2 GANTT CHART PSM 2

ACTIVITY	WEEK													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Briefing 2														
Parametric Design														
Design Improvement														
Detail Design														
3D Printing														
Analysis and Stimulation														
Data Collection														
Progress Report Submission														
Cost Determination														
PSM II Report Writing														
Prototype														
Presentation														
Report Submission														

APPENDIX B SURVEY FORM

UNIVERSITY TEKNIKAL MALAYSIA MELAK

Karung Berkunci No 1752, Pejabat Durian Tunggal, Malaka

I'm a final year student from faculty of mechanical engineering, here to do a survey regarding my final year project on the title Design and Analysis Automated Whiteboard Cleaner. The purpose of this survey is to seek opinion and information from the respondent regarding my final year project.

Your feedback and time are very much appreciated.

SECTION A: Demographics of Respondent

INSTRUCTION: Kindly answer the following questions by putting a (/) in the provided space.

Question 1: Gender

☐ Male ☐ Female

Question 2: Age

☐ 21-30

☐ 31-40

☐ 41-50

☐ 51-60

SECTION B: Responses of development of an Automated Whiteboard Cleaner

INSTRUCTION: Kindly answer the following questions by putting a (/) in the provided space.

Question 3: What type of whiteboard cleaner would you prefer?

☐ Manually

☐ Semi manually

☐ Automatic

Question 4: What type of mechanism would you prefer?

☐ Rack and Pinion

☐ Crank and Shaft

☐ Guide Rail

☐ Wheel

Question 5: What type of material would you prefer?

☐ Stainless Steel

☐ ABS Plastic

☐ Wood

Question 6: Do you think it is necessary to implement automated whiteboard cleaner in classrooms?

☐ Yes ☐ No

Question 7: Would you buy this product if it is available in future?

☐ Yes ☐ No

SECTION C: Responses for Automated Whiteboard Cleaner's Aspects

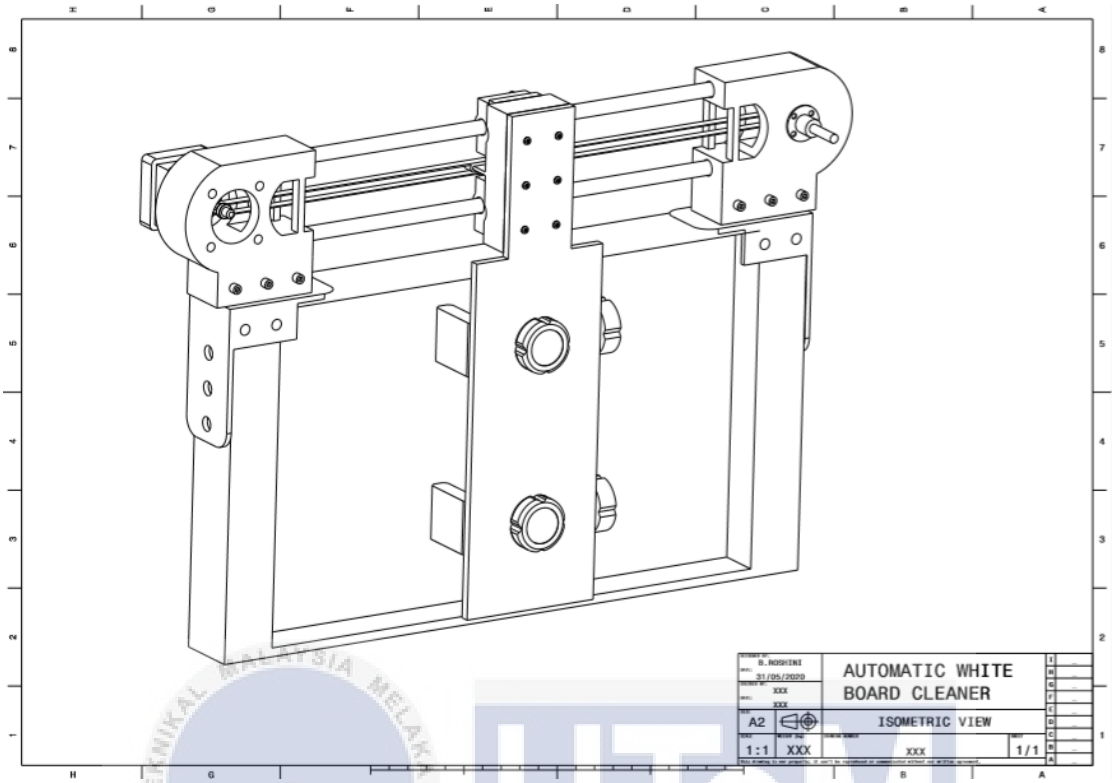
INSTRUCTION: Kindly mark a tick (/) in the provided box based on 1 to 5 scale.

1	2	3	4	5
Not Important	**Less Important**	**Neutral**	**Important**	**Very Important**

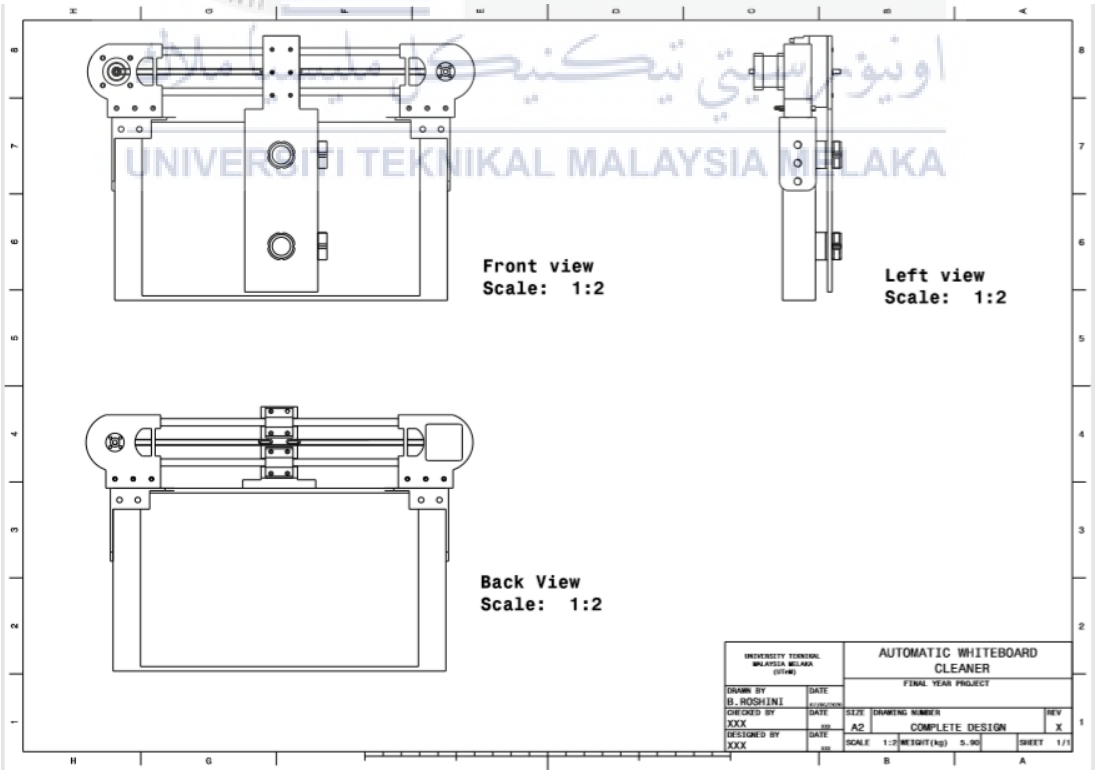
No	Aspects	1	2	3	4	5
1	Fast Cleaning					
2	Clean Finishing					
3	Long-Lasting					
4	User Friendly					
5	Easy to be Install					
6	Portable					
7	Affordable					

……THANK YOU……

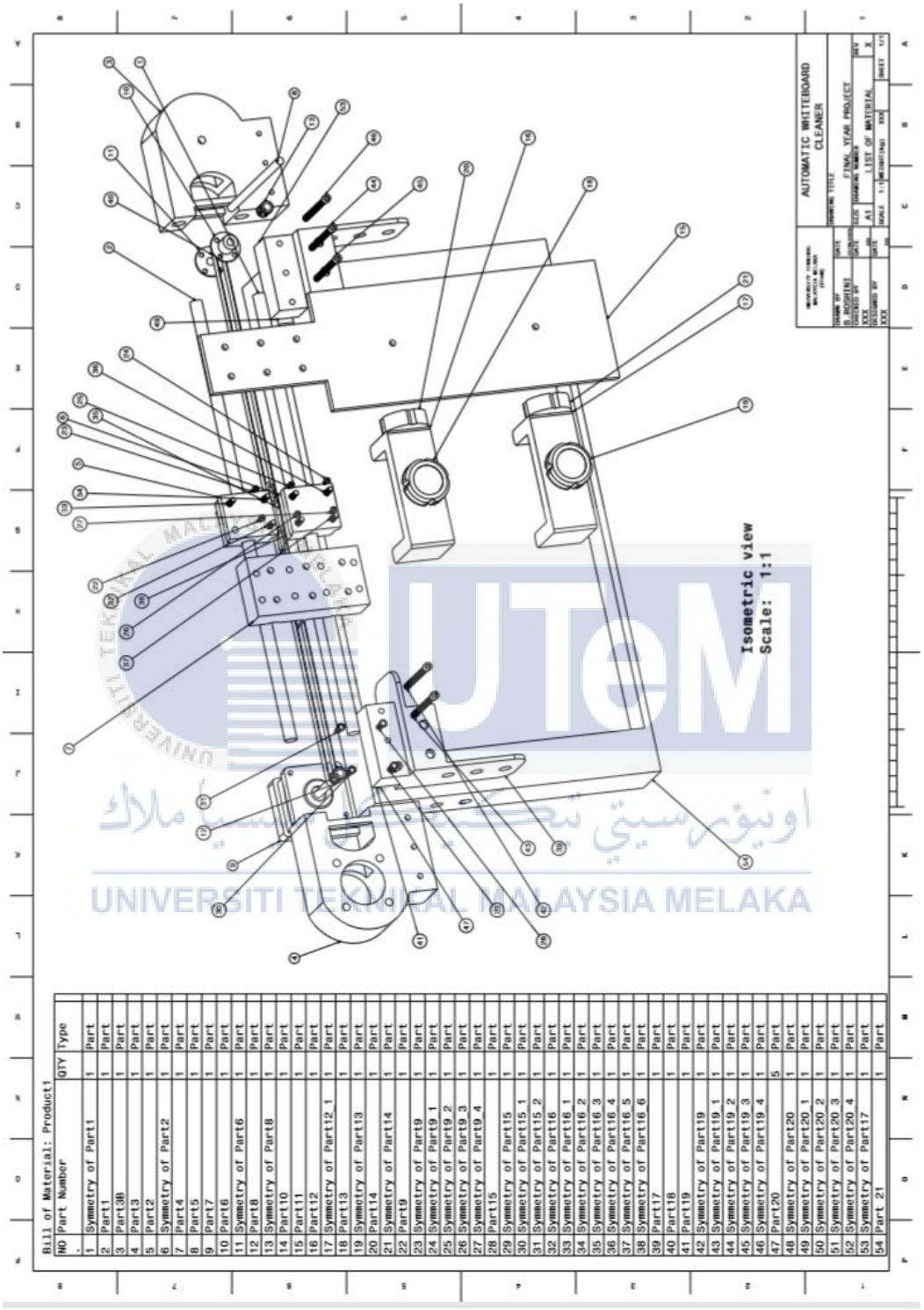
APPENDIX C1 ISOMATRIC VIEW



APPENDIX C2 ORTHOGRAPHIC VIEW



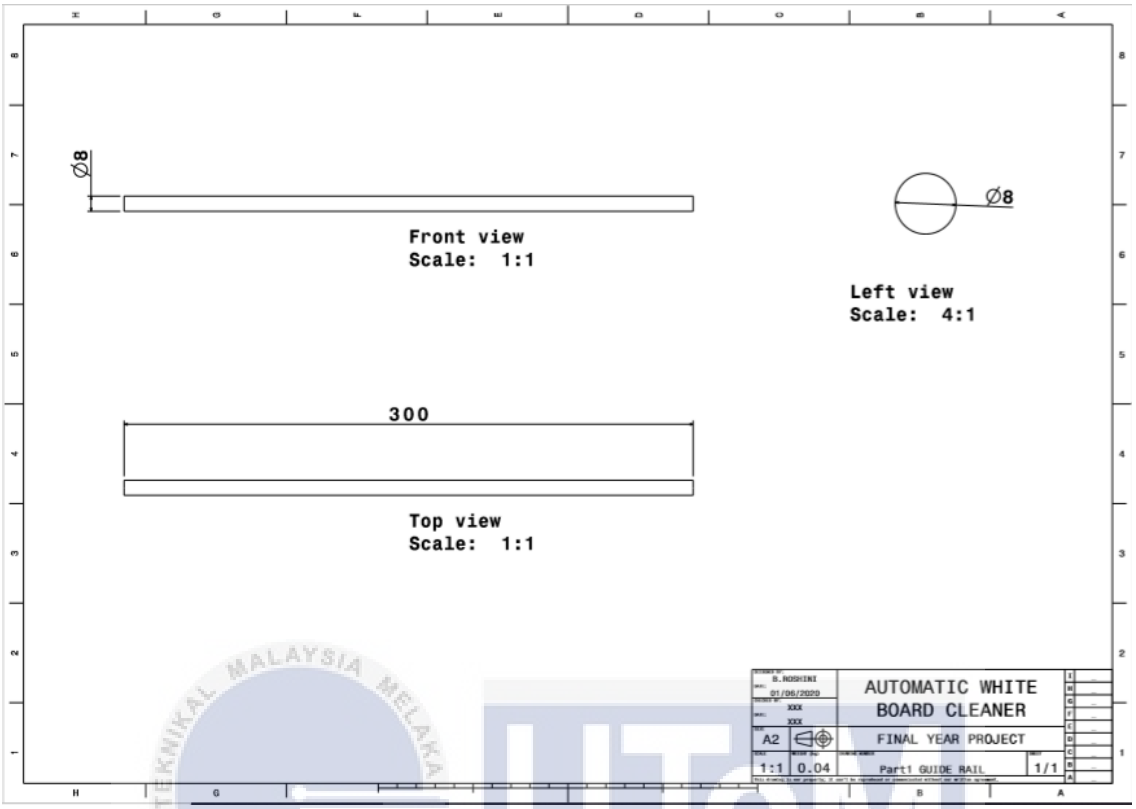
APPENDIX C3 EXPLODED VIEW



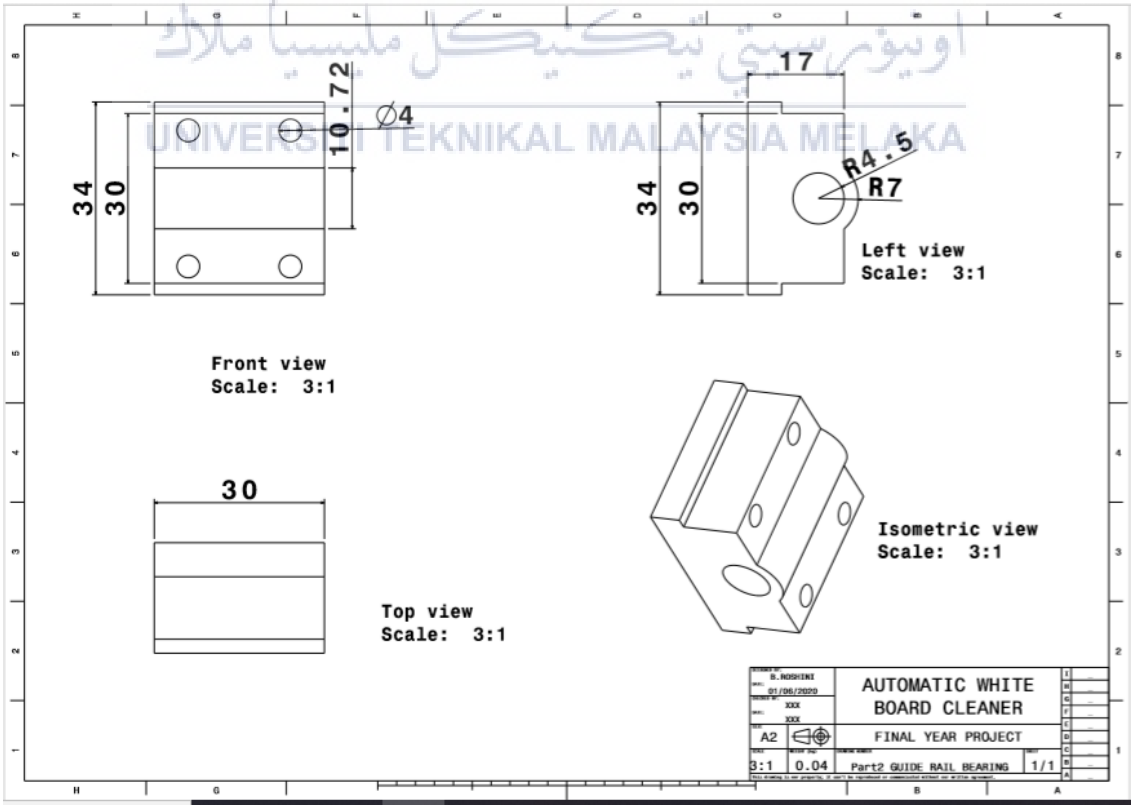
Bill of Material: Product1

NO.	Part Number	QTY	Type
1	Symetry of Part1	1	Part
2	Part1	1	Part
3	Part30	1	Part
4	Part3	1	Part
5	Part2	1	Part
6	Symetry of Part12	1	Part
7	Part4	1	Part
8	Part5	1	Part
9	Part7	1	Part
10	Part6	1	Part
11	Symetry of Part6	1	Part
12	Part8	1	Part
13	Symetry of Part8	1	Part
14	Part10	1	Part
15	Part11	1	Part
16	Part12	1	Part
17	Symetry of Part12_1	1	Part
18	Part13	1	Part
19	Symetry of Part13	1	Part
20	Part14	1	Part
21	Symetry of Part14	1	Part
22	Part9	1	Part
23	Symetry of Part9	1	Part
24	Symetry of Part9_1	1	Part
25	Symetry of Part9_2	1	Part
26	Symetry of Part9_3	1	Part
27	Symetry of Part9_4	1	Part
28	Part15	1	Part
29	Symetry of Part15	1	Part
30	Symetry of Part15_1	1	Part
31	Symetry of Part15_2	1	Part
32	Symetry of Part16	1	Part
33	Symetry of Part16_1	1	Part
34	Symetry of Part16_2	1	Part
35	Symetry of Part16_3	1	Part
36	Symetry of Part16_4	1	Part
37	Symetry of Part16_5	1	Part
38	Symetry of Part16_6	1	Part
39	Part17	1	Part
40	Part18	1	Part
41	Part19	1	Part
42	Symetry of Part19	1	Part
43	Symetry of Part19_1	1	Part
44	Symetry of Part19_2	1	Part
45	Symetry of Part19_3	1	Part
46	Symetry of Part19_4	1	Part
47	Part20	5	Part
48	Symetry of Part20	1	Part
49	Symetry of Part20_1	1	Part
50	Symetry of Part20_2	1	Part
51	Symetry of Part20_3	1	Part
52	Symetry of Part20_4	1	Part
53	Symetry of Part17	1	Part
54	Part_21	1	Part

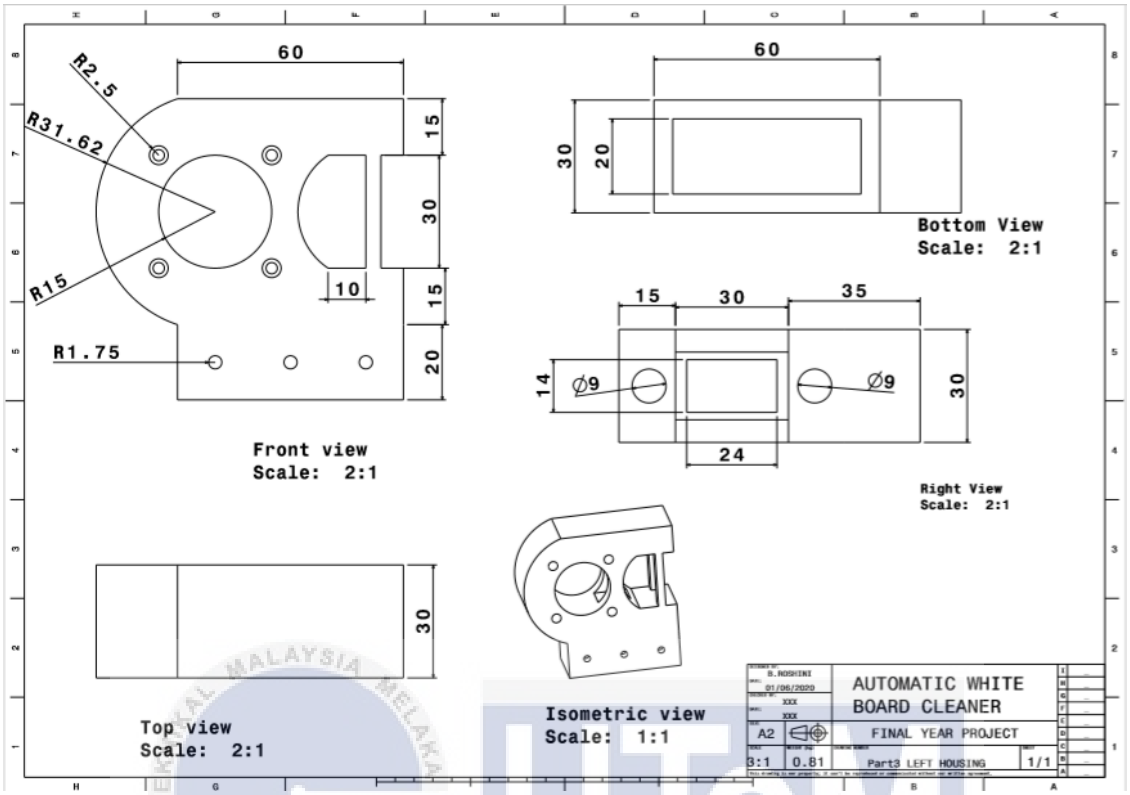
APPENDIX C4 PART 1 GUIDE RAIL



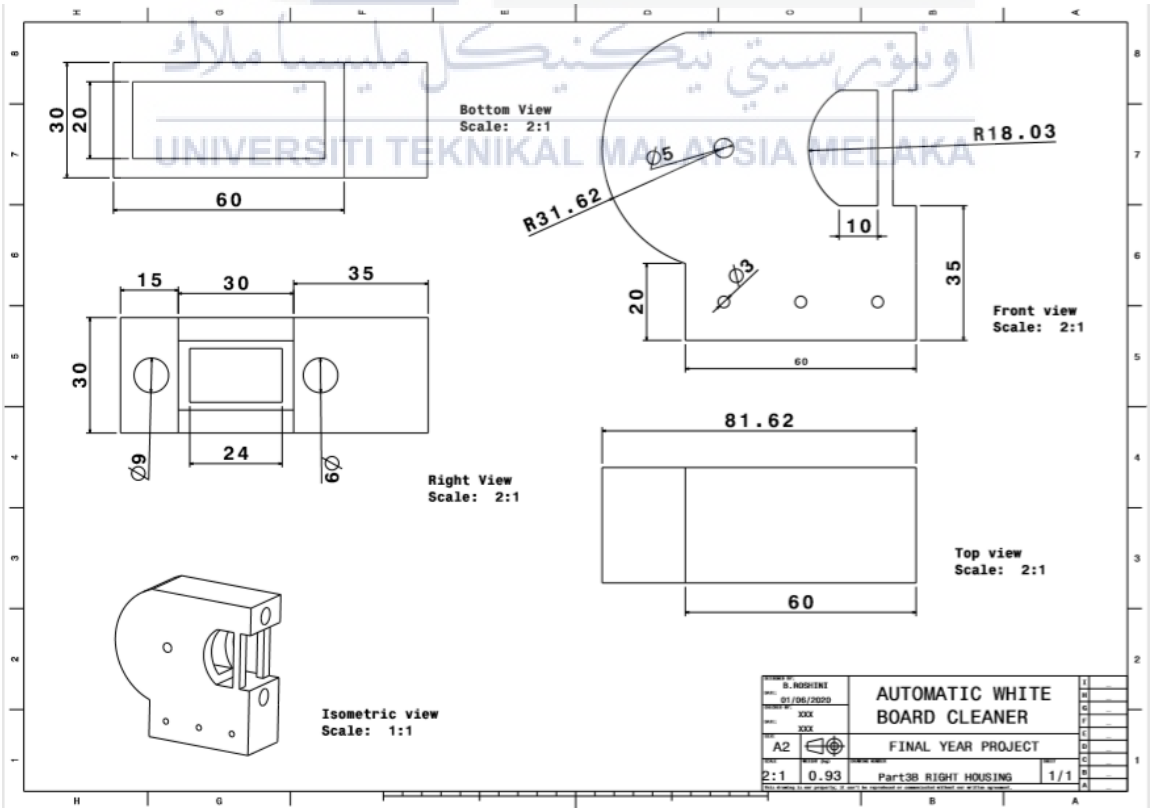
APPENDIX C5 PART 2 GUIDE RAIL BEARING



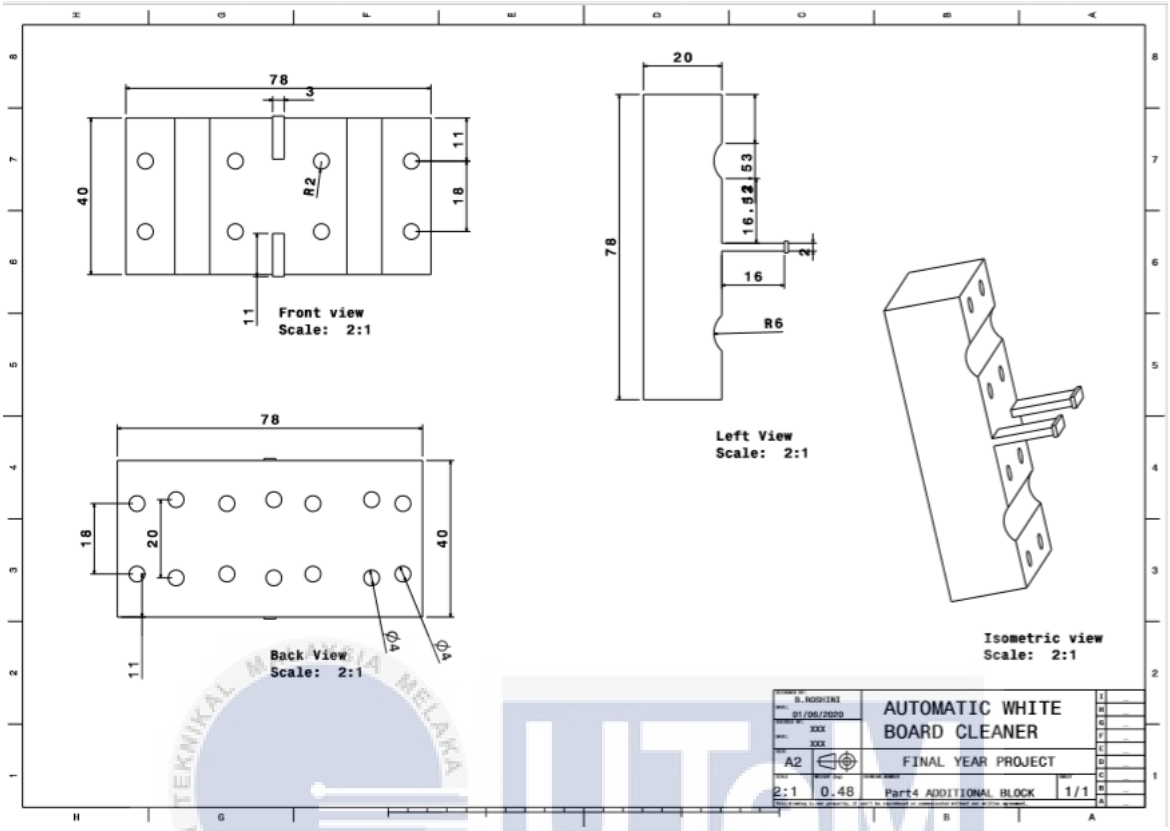
APPENDIX C6 PART 3 LEFT HOUSING



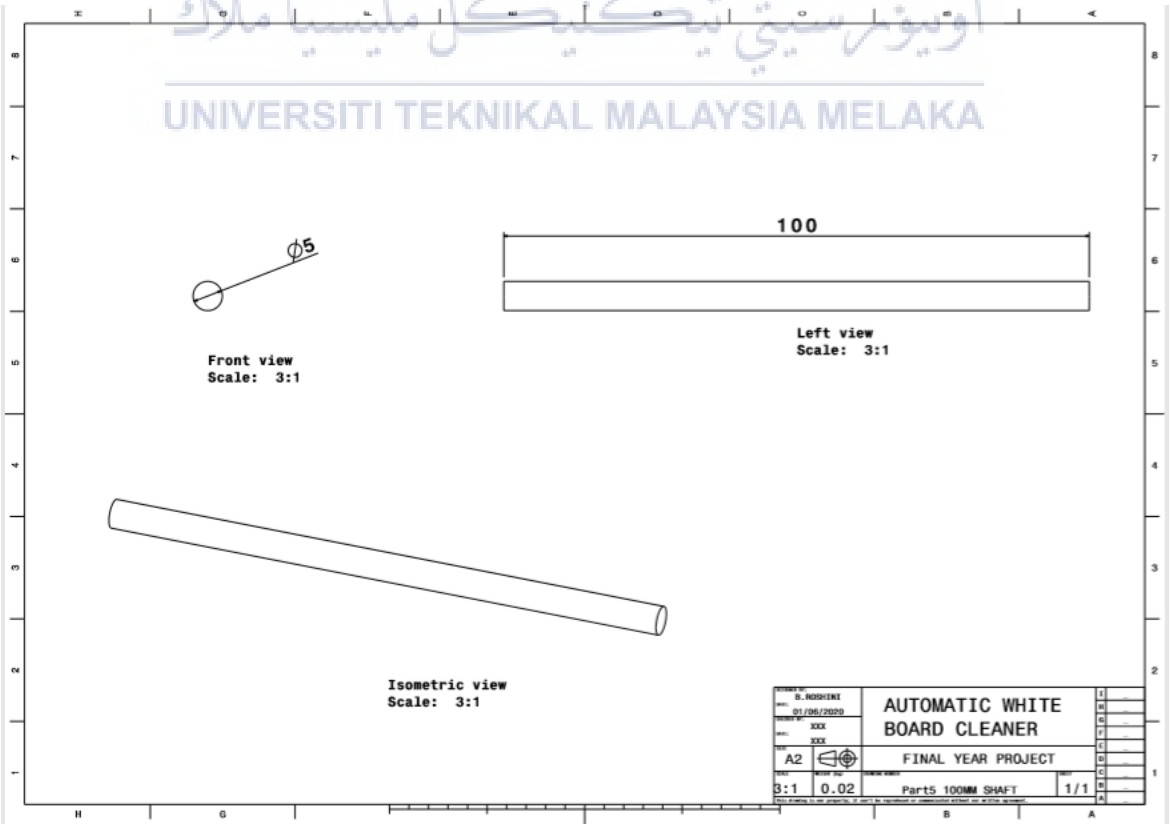
APPENDIX C7 PART 3B RIGHT HOUSING



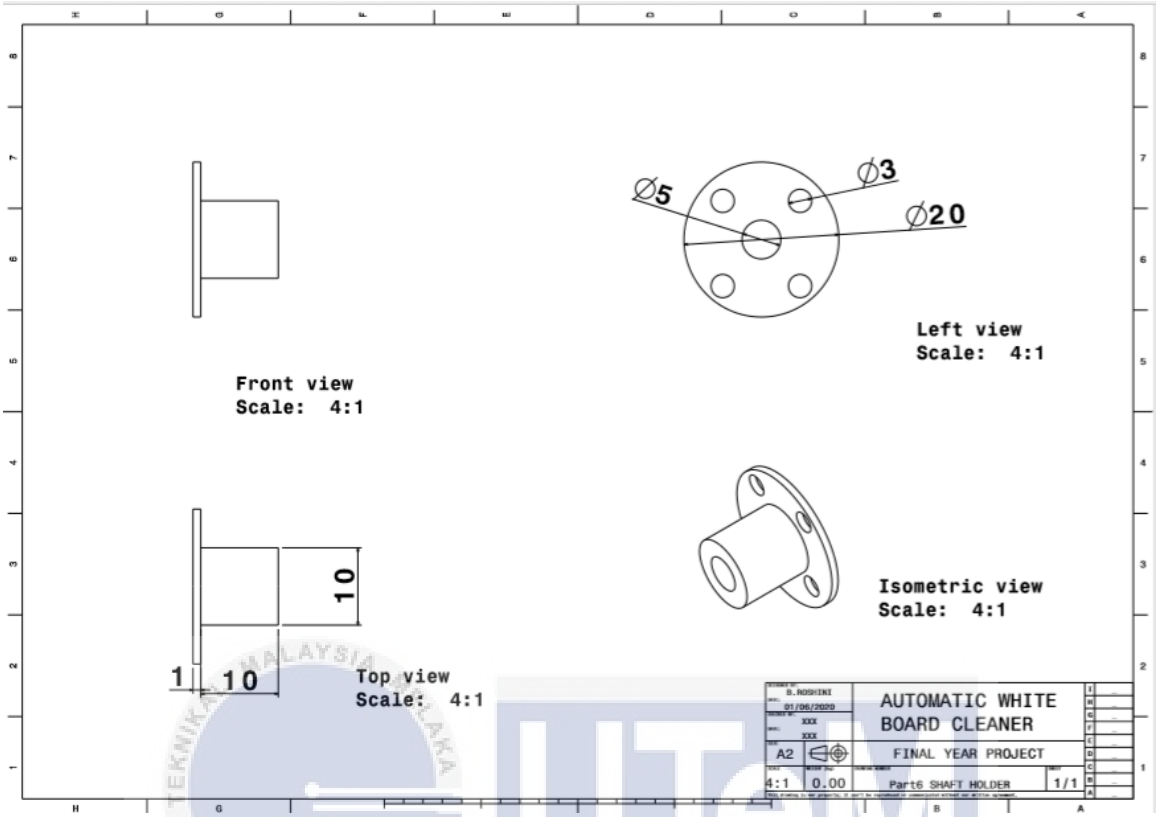
APPENDIX C8 PART 4 ADDITIONAL BLOCK



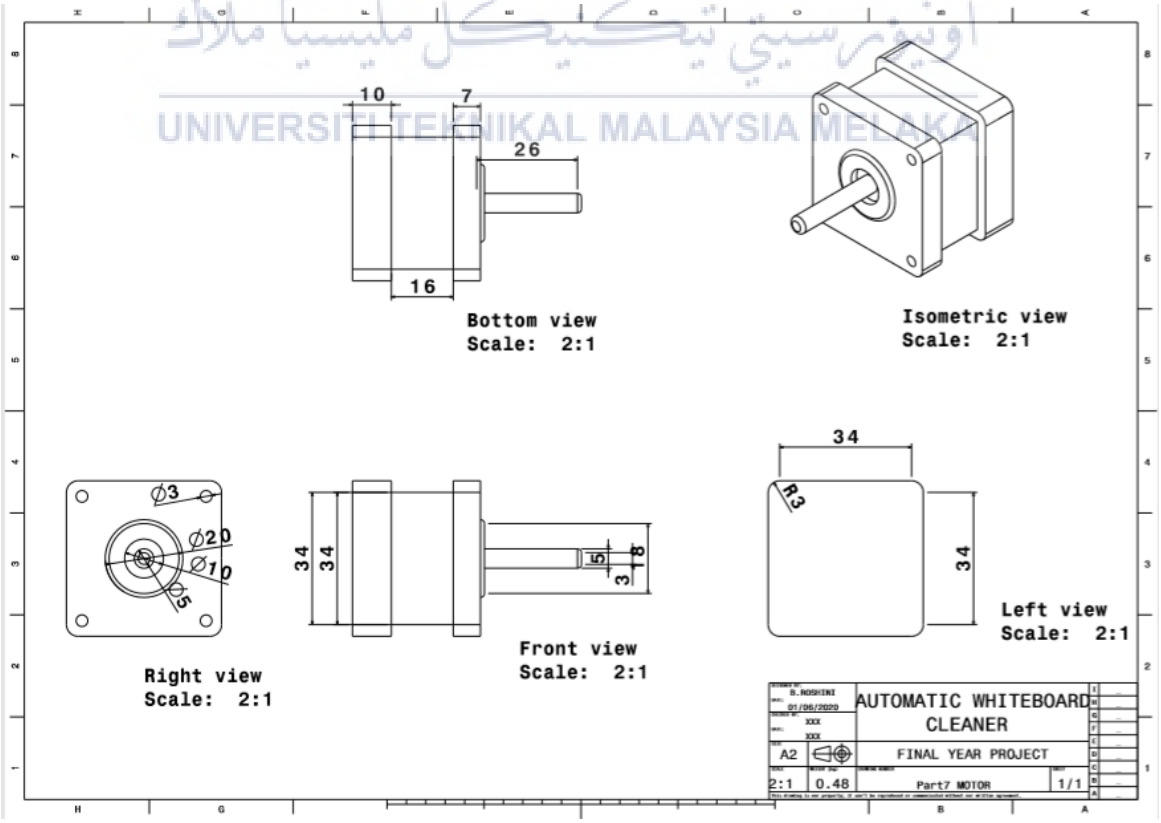
APPENDIX C9 PART 5 100MM SHAFT



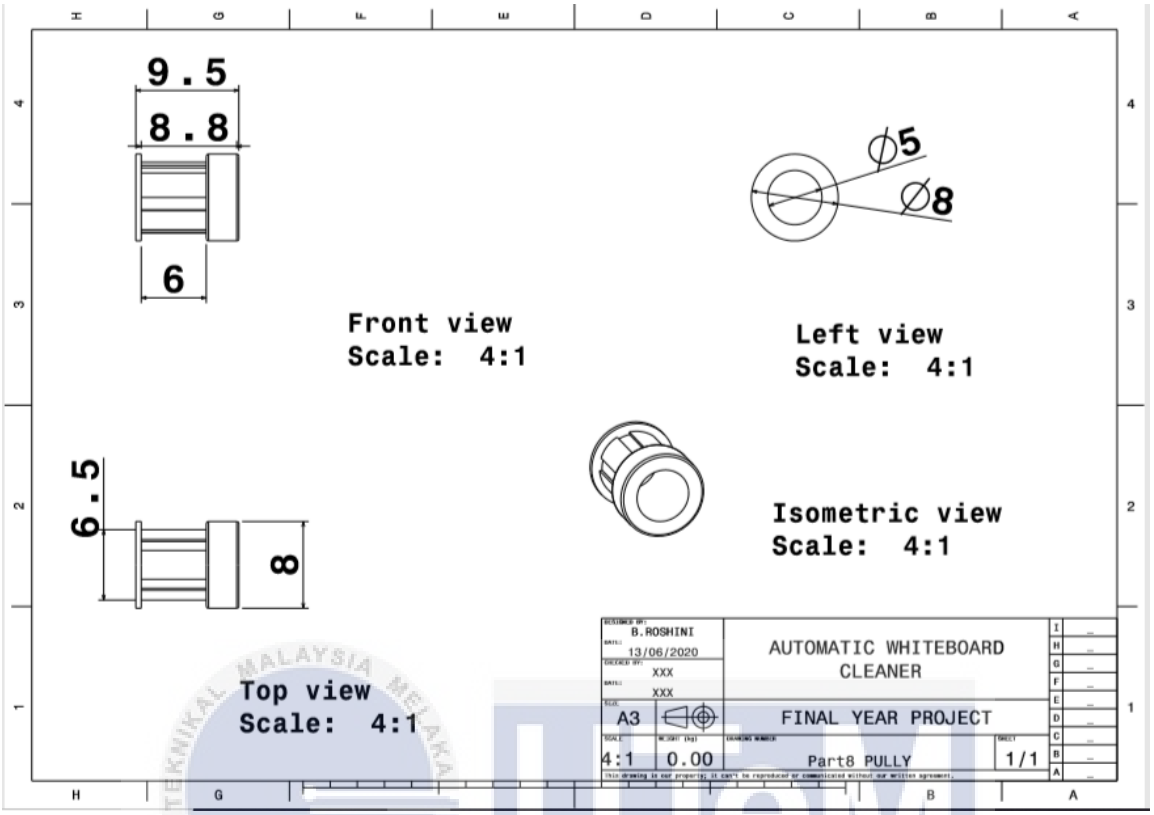
APPENDIX C10 PART 6 SHAFT HOLDER



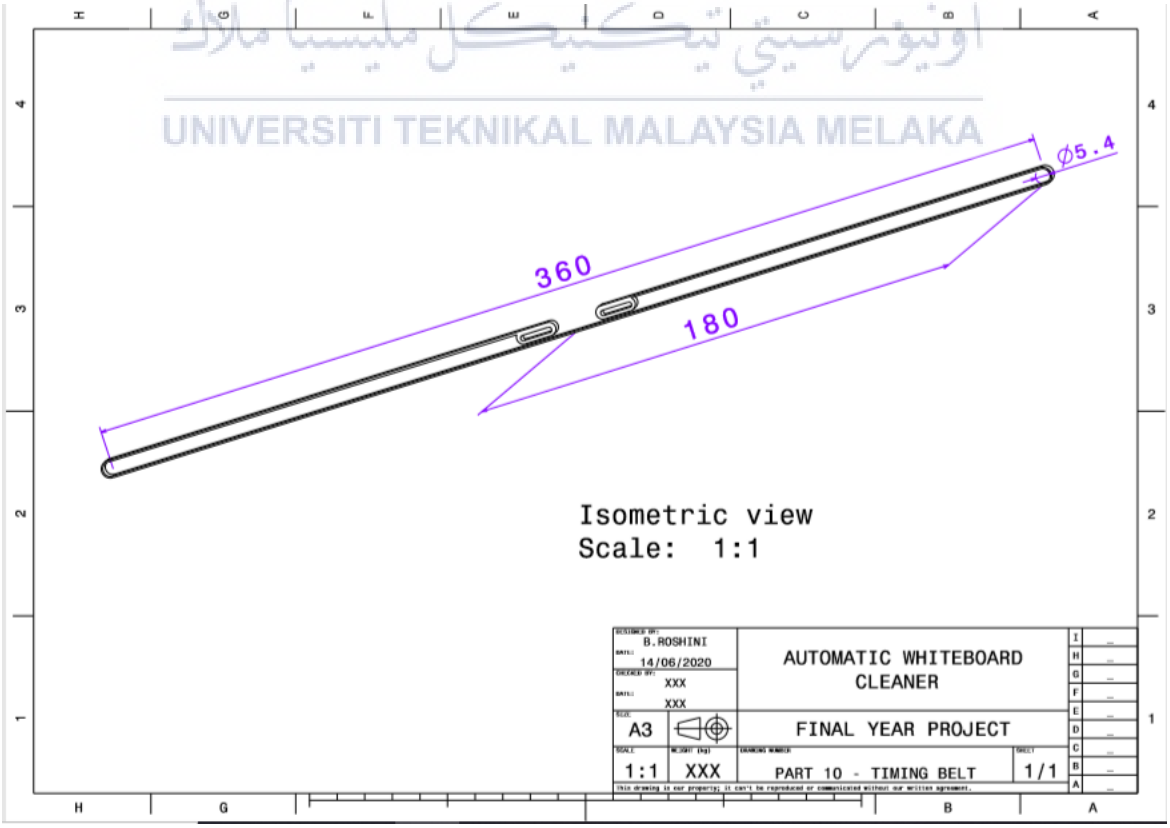
APPENDIX C11 PART 7 MOTOR



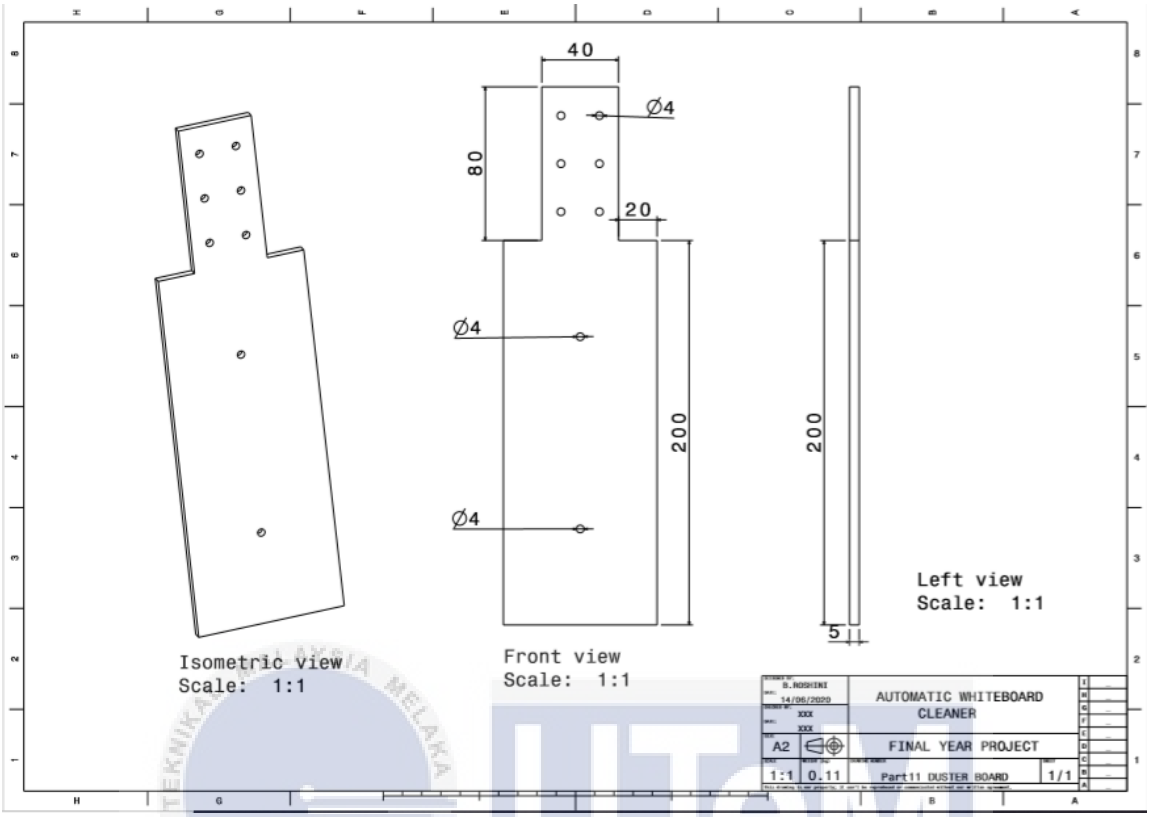
APPENDIX C12 PART 8 PULLY



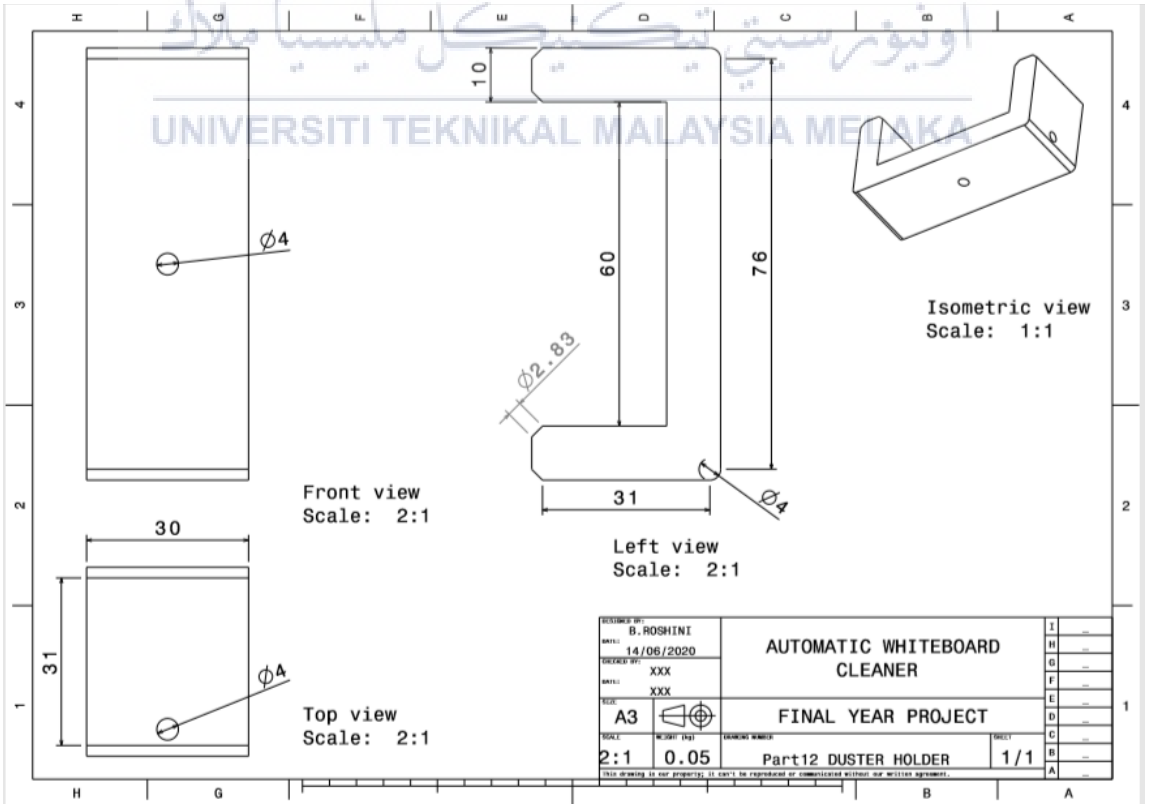
APPENDIX C13 PART 10 TIMING BELT



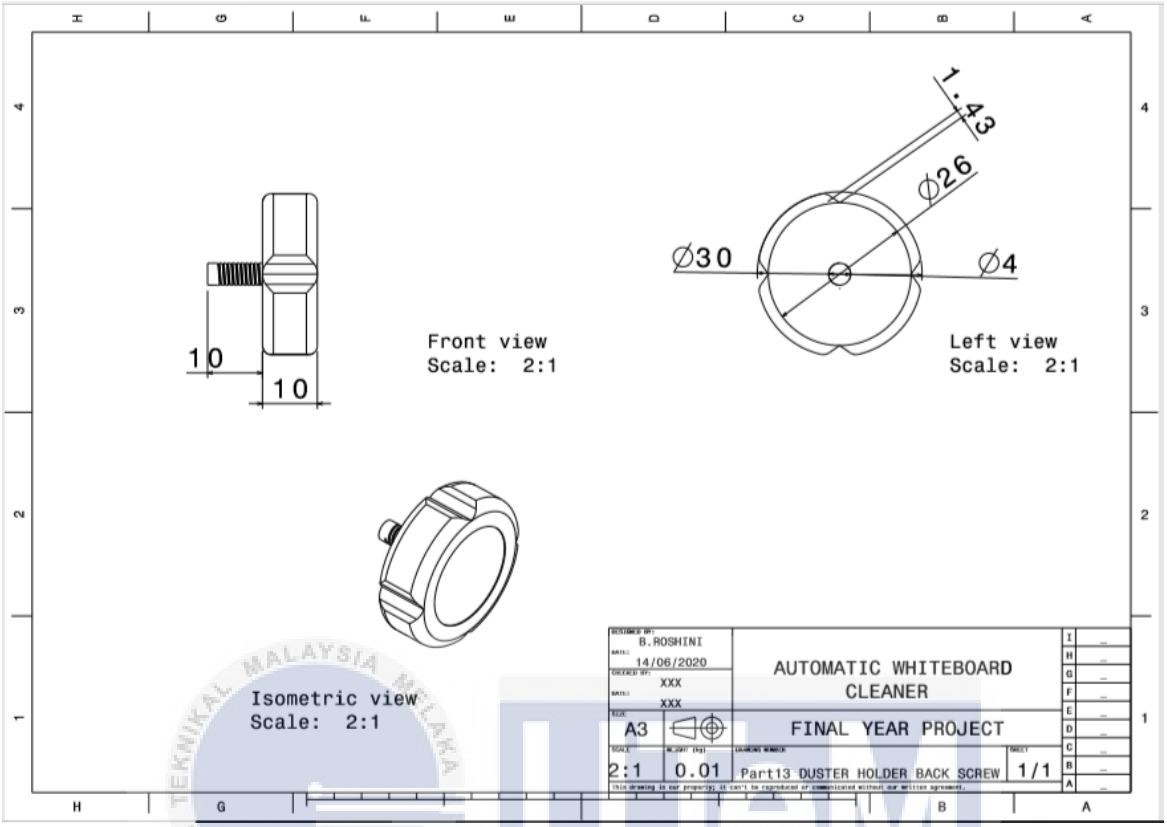
APPENDIX C14 PART 11 DUSTER BOARD



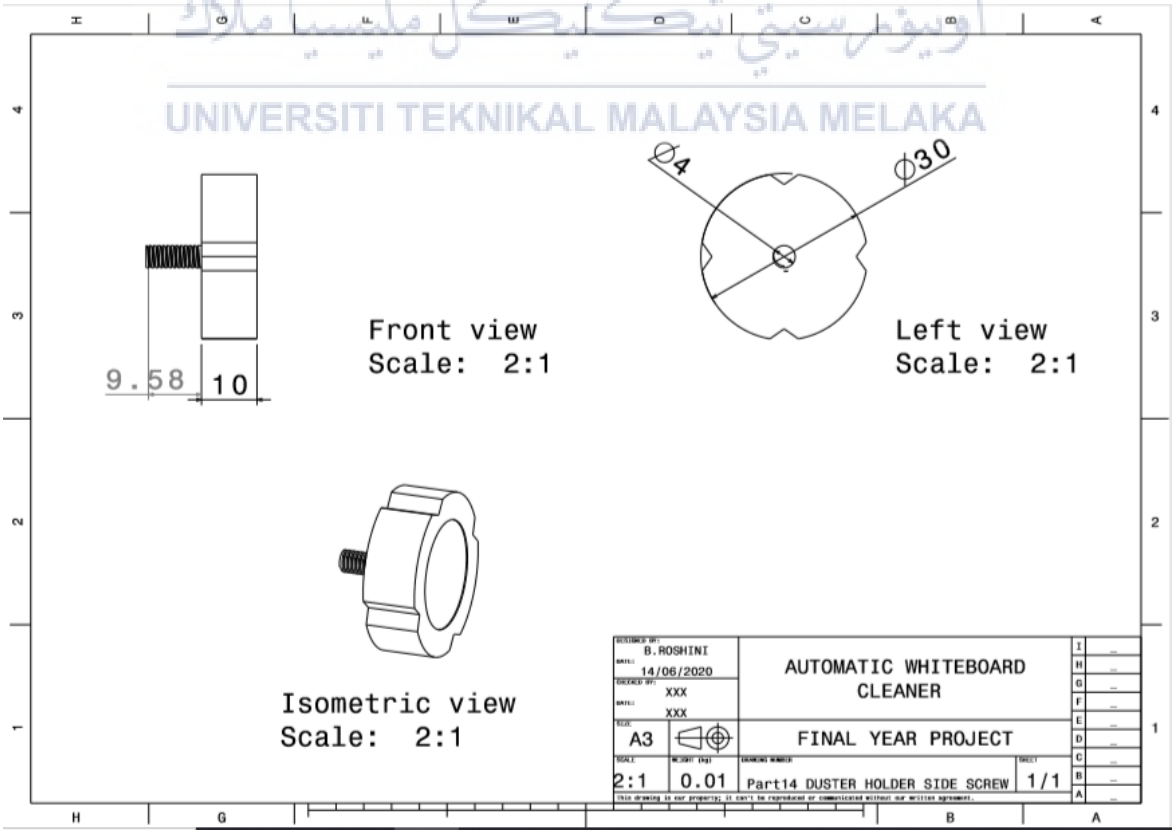
APPENDIX C15 PART 12 DUSTER HOLDER



APPENDIX C16 PART 13 DUSTER HOLDER BACK SCREW



APPENDIX C17 PART 14 DUSTER HOLDER SIDE SCREW



APPENDIX C18 PART 17 PROJECT HOLDER