DESIGN AND DEVELOPMENT OF SOLAR TOASTER

MOHD HAFIZ BIN MUSTAFA

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND DEVELOPMENT OF SOLAR TOASTER

MOHD HAFIZ BIN MUSTAFA

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

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2017

DECLARATION

I declare that this project report entitled “Design and development of solar toaster” is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design & Innovation).

Signature :. .....

Name of Supervisor : .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

. The project is about developing a solar toaster model by using a solar energy as a main energy source instead of electrical energy. This is because the solar energy is renewable free source of energy that sustainable. The objective of this study is to design, perform structural and heat analysis and also fabrication on solar toaster. There are a few disadvantages of the solar cooking from the previous studies. Sometimes solar cooking is unconsistent because the sun is too low and the angles of the collector is not right (Deziel, 2017). In accomplishing this study, the literature review was done and there are some method that has been conducted that includes internet research, concept design, concept selection, detail design, CAE analysis and ANSYS analysis. In the initial stage, all the information are gathered as guidance to complete the project. The project continues by design study on the component that will be used in this structure which is solar toaster. After that on the methodology, ideas for conceptual design are developed that fullfil the engineering design specification. In order to select the final design of the solar toaster, pugh concept selection was used. For design analysis, there are several approaches have been made to minimize the factor of safety of the design. Finite element approach is used in the study by using FEA software using CATIA to study the stress concentration on the structure frame for static load condition. From this analysis the maximum Von Mises obtain is 2.12 $\times 10^6 \frac{N}{M^2}$ while the factor of safety obtain is 44.81. Then heat or thermal analysis by using ANSYS software is conducted to analyse the thermal flow on the solar toaster. From this analysis the maximum heat flow has been recorded on the toasting area which proves theoretically that the solar toaster design going to works. Fabrication of the solar toaster prototype is used to prove experimentally whether the solar toaster works or not. It can be concluded that the new solar toaster model able to solve the previous solar cooking problem as the new improvement on the design and mechanism of the solar toaster.

ABSTRAK

Projek ini adalah kira-kira membangunkan model pembakar roti solar dengan menggunakan tenaga solar sebagai sumber tenaga utama dan bukannya tenaga elektrik. Ini kerana tenaga solar boleh diperbaharui sumber bebas tenaga yang mampan. Objektif kajian ini adalah untuk mereka bentuk, melaksanakan analisis struktur dan analisis haba dan juga fabrikasi pembakar solar. Terdapat beberapa kelemahan memasak solar dari kajian sebelumnya. Kadang-kadang memasak solar adalah tidak konsisten kerana matahari adalah terlalu rendah dan sudut pengumpul tidak betul (Deziel, 2017). Dalam mencapai kajian ini, kajian literatur yang telah dilaksanakan dan terdapat beberapa kaedah yang telah dijalankan termasuk penyelidikan internet, reka bentuk konsep, pemilihan konsep, reka bentuk terperinci, analisis CAE dan analisis ANSYS. Di peringkat awal, semua maklumat atau penyelidikan yang telah dilakukan mengenai topik ini dikumpulkan sebagai petunjuk bagi perkara yang teras. Maklumat ini kemudian perlu berkaitan dengan objektif projek. Dari ini, penyelidikan itu berterusan oleh kajian reka bentuk pada komponen yang akan digunakan dalam struktur ini yang merupakan pembakar roti solar. Selepas itu pada metodologi, idea-idea untuk reka bentuk konsep yang dibangunkan atas pembakar solar untuk memenuhi spesifikasi reka bentuk kejuruteraan. Dalam usaha untuk memilih reka bentuk akhir pembakar solar, pemilihan konsep Pugh digunakan. Untuk analisis reka bentuk, terdapat beberapa pendekatan telah dibuat untuk dikurangkan faktor keselamatan. bahan yang dipilih dan keselamatan reka bentuk adalah kriteria yang diperlukan untuk mencari faktor keselamatan yang terbaik. pendekatan unsur terhingga digunakan dalam kajian ini dengan menggunakan perisian FEA iaitu analisis perisian CATIA akan dilakukan untuk mendapatkan kepekatan tekanan pada rangka struktur bagi keadaan beban statik. Daripada analisis ini maksimum Von Mises mendapatkan 2.12 $\times$ 10^6 $\frac{N}{M^2}$ manakala faktor keselamatan mendapatkan adalah 44,81. Kemudian haba atau analisis terma dengan menggunakan perisian ANSYS dijalankan untuk menganalisis aliran haba pada pembakar solar. Daripada analisis ini aliran haba maksimum telah direkodkan di kawasan pembakar yang membuktikan secara teori reka bentuk pembakar solar akan kerja-kerja. Seterusnya, fabrikasi prototaip pembakar solar sedang berlaku untuk membuktikan uji kaji sama ada pembakar solar berfungsi atau tidak. Tempoh proses fabrikasi adalah kira-kira tiga minggu. Dapat disimpulkan bahawa model pembakar roti solar baru dapat menyelesaikan masalah memasak solar yang lepas kerana peningkatan baru kepada reka bentuk dan mekanisme pembakar solar dilakukan.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to my supervisor Dr. Shafizal Bin Mat for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Special thanks must also go to, lecturers of Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka for their advice and help. My special appreciation and thanks to all my friends for their invaluable assistance towards this project. Most of all, I am very grateful to my family especially my dearest parent, Mr. Mustafa Bin Mohd Ghause and Mrs. Romadiah Binti Abdullah and all my siblings for their unfailing encouragement and financial support given to me over the years. Thank you very much. Your sincere help and assistance will be remembered for my whole life.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CAD	Computer Aided Engineering
FEA	Finite Element Analysis
FYP	Final Year Project
FOS	Factor Of Safety

LIST OF SYMBOL

^{o}C	=	Degree Celsius
%	=	Percent

LIST OF EQUATION

CHAPTER 1

INTRODUCTION

1.1 Background of study

Nowadays as we are living in a technology world and approaching 2020, It is better if we stop depend on electrical energy from home supply and start use alternative energy such as Biomass Energy, Wind Energy, Solar Energy, Geothermal Energy and Hydroelectric Energy. For this case, Solar Energy is used as a main electric source for this project as it is limitless beside its only required maintenance cost which is believed quite cheap.

Solar Energy resources are massive and widespread, it can be harnessed anywhere around the world but yet this massive and larges resources are not fully explored by us. Human beings are too dependent on non-renewable sources which are proven not sustainable such as nature gas, oil and coal. This type of resources produces a variety of pollutants which affect the people's health and damage the environment.

At this modern age, various machines has been developed to help human doing daily work but so many of it still using electric energy from home supply. It is believe by start inventing utensil that use alternative energy, it will be much meant as this project could help create awareness to society to use alternative energy which have more advantage.

1.2 Problem Statement

Solar cooking is not efficient enough compared to electrical cooking because sometimes solar cooking is unconsistent because the sun is too low and the angles of the collector is not right (Deziel, 2017). Sometimes the meat or fish is partially cooked which expose you to harmful bacteria and parasites (Zamostny, 2011). User takes longer time to use solar cooking compared to electrical cooking (Deziel, 2017). The design of the solar oven is too big to be commercialized (Olmert, 2007). Hence, continuous development on the design and the mechanism of the solar toaster is needed to close the loopholes of system.

1.3 Objective

The objectives of this project are as follows:

1. To design toaster that use solar energy as energy source.
2. To perform structural and heat analysis on the solar toaster.
3. To fabricate the prototype of solar toaster.

1.4 Scope of Project

The scopes of this project are:

1. Study the literature review of solar energy.
2. Design the solar toaster.
3. Analysis on the solar toaster.
4. Fabricate the solar toaster prototype.
5. Understand solar energy implementation.

1.5 General Methodology

Generally, there are three methods involved in this project which is design, analysis and fabrication. In the design process, four concept designs were drawn before the best design is selected. The four concept designs is different from each other as it have different advantages and disadvantages. A best design will be selected for the final design process. Structural and thermal analysis will be done on the solar toaster by using Computer Aided Engineering and ANSYS software. The purpose of thermal analysis is to collect information and data about solar energy in Malaysia. The prototype needed to be fabricated to prove experimentally that the project is successful. The fabrication process has two part which is toaster part and solar part. One of the main problem and restriction is to attach and combine both part of the prototype.

1.6 Outline of Dissertation

Chapter 1

explains the project background, problem statement, objectives of the study, scope of the study, general methodology and outline of dissertation of the study.

Chapter 2

describes the literature review that covers on background, design and the characteristic of the solar toaster. It also show the pattern of the toaster, photovoltaic system, solar thermal system and also solar energy system.

Chapter 3

discusses the methodology of the project such as about the flowchart of project outline starting from the day the task receive until report writing. It also introduces and explains the type of analysis that were performed on the solar toaster.

Chapter 4

discusses the design and fabrication process. The design process covers about the concept design and the method to select final design. Meanwhile, the fabrication process discusses about the fabrication of the solar toaster prototype that covers the material and equipment use.

Chapter 5

discusses the result of the project, prototype fabrication and focus on explaining analysis such as on stress analysis, structure analysis, heat analysis and the mechanism design. It explains detail each component of the mechanism of the design.

Chapter 6

explains the conclusion and recommendation of the project. Conclusion is made to summarize the whole project meanwhile the purpose of recommendation is for future study and development of solar toaster.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Solar toaster is a toaster that used an energy from solar to toast a bread. This method has been implemented since 1995 to use solar energy as its energy source (Lorraine Anderson, 2006). This is the new innovation towards green technology implementation. The history of toaster back in 1909 when General Electric built first home electric toaster but the concept or idea of a toaster that using thermal insulation method to cook food start in 29000 BC when people in Central Europe used a ancient oven to cook mammoth (Olmert, 2007). However, the first recorded oven in history was created in France in 1490, this oven is made from brick and tile. (Frances, 1960)

Nowadays an oven or toaster can be found nearly in every house as people using it as one of the important cooking tool (Miller, 2013). Solar energy can be defined as an energy from the sunlight or heat from the sun which been converted into thermal or electrical energy (Goswami, 2013). Sun is the main power source which supply energy to the universe. In fact, the earth receives nearly 174 000 terrawats power of incoming solar radiation at the atmosphere which make it the largest energy source with the highest potential and space to be explore (Gavin, 2007).

The sun exist nearly about 4.6 billion years ago which been formed from solar nebula that is a giant, rotating cloud of gas and dust (McLamb, 2011). On early civilization people uses the sun to dry up their clothes, farming and as important direction tool for a traveller. Then when the civilization keep improving, the sun was

use on a multipurpose such as been use to regulate the temperature of their dwelling (Lomas, 1999).

In 400 BC, the famous Greek philisopher Socrates emphasizing the advantages of constructing the houses with overhang and south facing window (Gale, 2006). This is to enhance the usage of the sun so that the temperature of the house decrease during the summer and increase during the winter (MacEachern, 2016).

In a 212 BC, the greek scientist Archimedes used the reflective properties of bronze shields to set fire on a Roman Empire ships by focusing the sunlight (Mongillo, 2011). In 1839, Alexandre Edmond Becquerel a french scientist discovered a photovoltaic effect while experimenting the electrolytic cell which generated electricity from a sunlight (Zamostny, 2011). This finding finally bring into development of a solar energy year by year until the creation of a solar panel as can be found today.

In 1954 David Chapin, Calvin Fuller and Gerald Pearson invented the device which converted sunlight into electrical power. They later improve the conversion rate efficiency from 4% to 11% (Maehlum, 2013).

In 2008 U.S Department of Energy set a new world record of conversion rate by recording 40.8% conversion rate of light into electricity (W.Gruener, 2008).

2.2 Toaster

Basically toaster used thermal insulation method in making a toast by exposing a bread with a radiant heat (Woodford, 2016). There are many type of a toaster nowadays, one of the famous toaster been used is “Pop up toaster” which had been invested in 1919 by Charles Strite. Nowadays after undergoes series of development “Pop up toaster” can works in three minutes by inserting the bread at the slots of the toaster and press the power cord. At the end as the bread is toasted the power cord will move upwards, thus stop the toasting process (Ament, 2007).

Figure 2.1: Toaster been used during 1920-1940

(www.timetoast.com , 2014)

Figure 2.2 : Toaster been used during Year 2000

(www.timetoast.com , 2014)

Figure 2.3: Toaster been used nowadays

(http://www.best-reviews.co.uk, 2016)

Figure 2.1, 2.2 and 2.3 show both “Pop up toaster”. Figure 2.1 shows toaster from 1920-1940 , Figure 2.2 shows toaster during year 2000 meanwhile Figure 2.3 shows nowadays toaster. There is clearly a huge different between these three toaster as toaster in Figure 2.3 is more advantage in all aspects such as has a high efficiency, good factor of safety, easy to be used by customer and extra features button. This is because the toaster had undergoes series of development year by year.

2.3 Pattern of Toaster

The solar toaster shown in the Figure 2.4 below is patented on 10 Jun 2009 by Brian Brock and John D. Barnes which is the inventor of the toaster. The patent no of this toaster Patent No USD615343 S1 with No. of patented recorded is US 29/338,395. This toaster has a few characteristic on it such as it has a simple patent to ease customer to use it and has a high efficiencies to toast a bread.

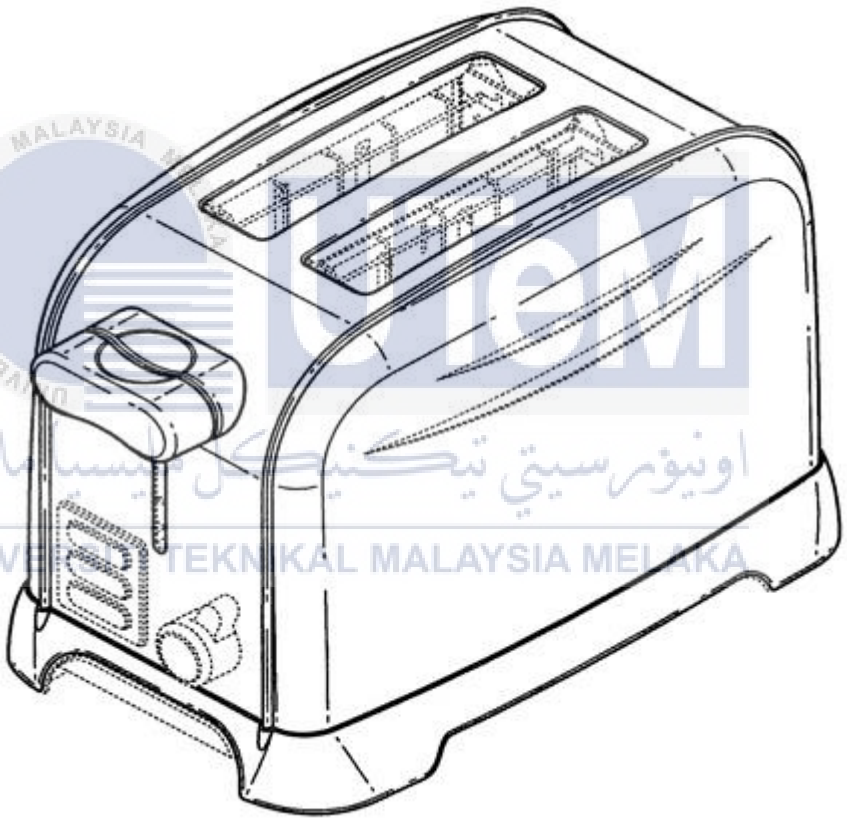


Figure 2.4: Patent of Toaster No USD615343 S1

(patents.google.com)

The solar toaster shown in the Figure 2.5 below is patented on 4 Jun 1999 by Paul Michael Brown which is the inventor of the toaster. The patent no of this toaster Patent No US6543337 B1 with No. of patented recorded is US 09/980,368. This toaster has a few characteristic on it such as it relates to toasting devices for toasting food which automatically control the degree browning of food toasted within them.

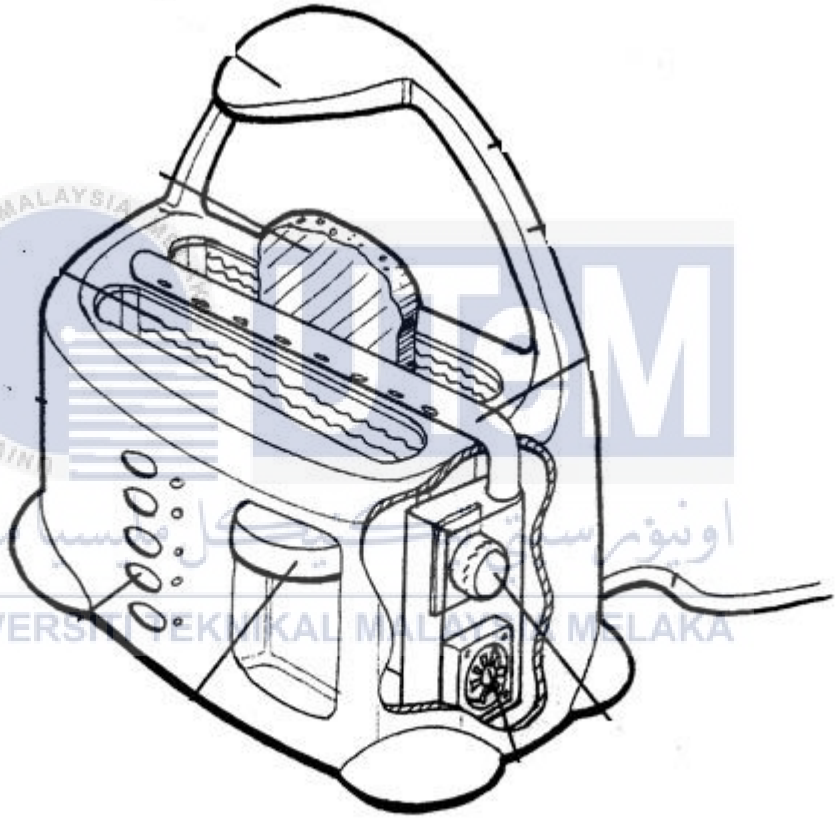


Figure 2.5: Patent of Toaster No US6543337

(patents.google.com)

The solar toaster shown in the Figure 2.6 below is patented on 19 Jun 1992 by Arthur S. Trujillo which is the inventor of the toaster. The patent no of this toaster Patent No US5216944A with No. of patented recorded is US5216944A. This toaster has a few characteristic on it such as it has a cover door structure is arranged for mounting to a top wall of a toaster assembly to selectively overlie the bread receiving slots directed through the top wall of the associated toaster for heat conservation and accelerated toasting of bread directed within the toaster structure.

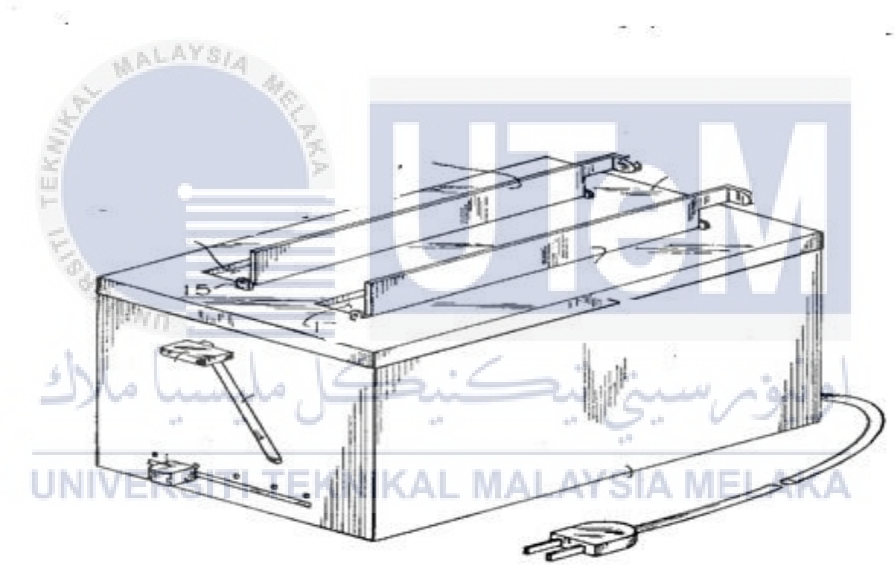


Figure 2.6: Patent of Toaster US5216944A

(patents.google.com)

The solar toaster shown in the Figure 2.7 below is patented on 17 February 2005 by Brian K. Beesley and Eric Hales which is the inventor of the toaster. The patent no of this toaster Patent No US7238921 B2 with No. of patented recorded is US 11/519,983. The toaster has a few characteristic on it such as it has combination bread toaster and steamer device and method includes inserting at least one piece of bread into a bread slot of a combination bread toaster and steamer device.

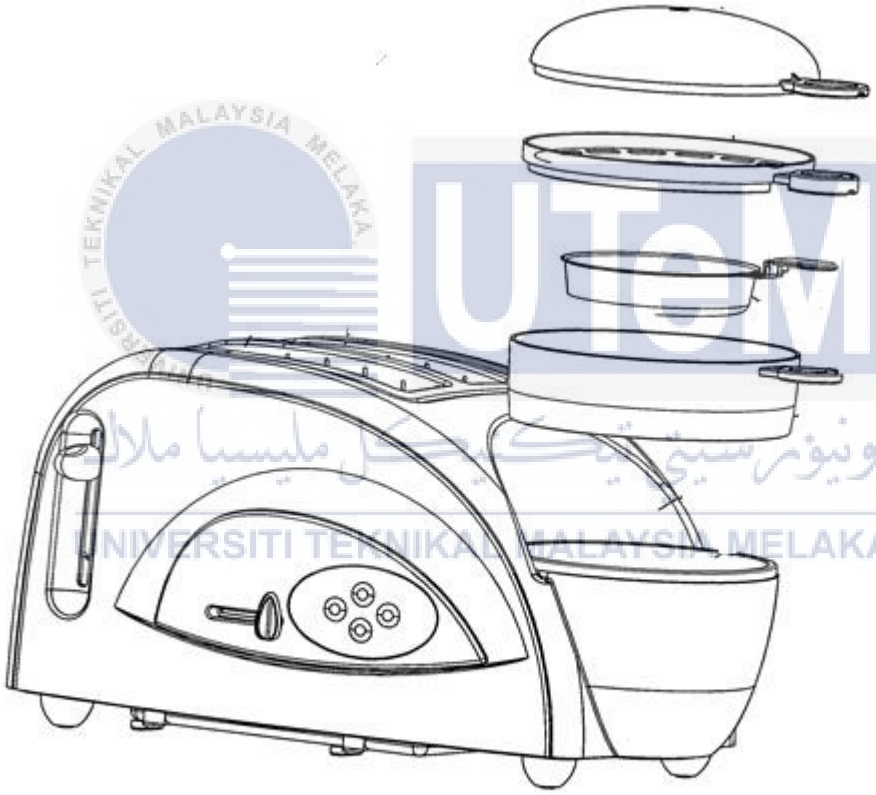


Figure 2.7: Patent of Toaster US7238921 B2
(patents.google.com)

The solar toaster shown in the Figure 2.8 below is patented on 20 Jun 2000 by Guy Mauffrey which is the inventor of the toaster. The patent no of this toaster Patent No US6799505 B2 with No. of patented recorded is US 10/311,878. This toaster has a few characteristic on it such as the toaster shell is open at the top, and it was reinforced by a ring. This is to ease the user during using the toaster. Besides it also has a high toasting efficiency.

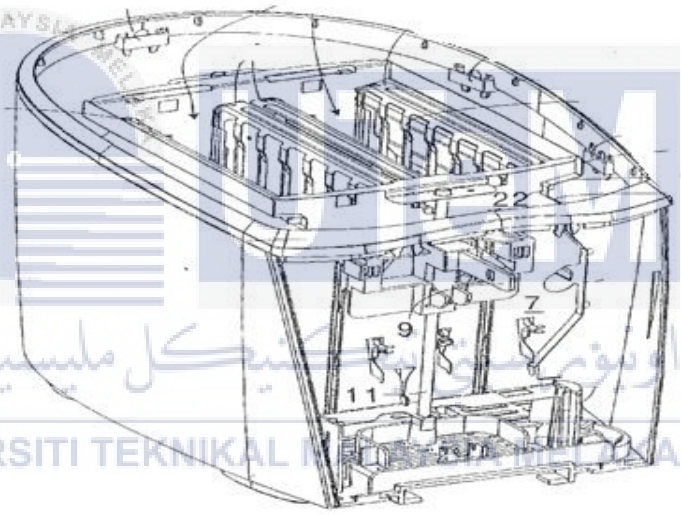


Figure 2.8: Patent of Toaster US6799505 B2
(patents.google.com)

2.4 The Equator

An equator is a fanciful line that circles the surface of a planet (Bessenbache, 2009). It is perpendicular to the earth axis rotation. An equator divided the earth into two parts which is Northern Hemisphere and Southern Hemisphere. The length of this line is 40,008.6 kilometres at latitude 0° (Chain, 2015). Figure 2.9 below shows the position of the equator on the earth.

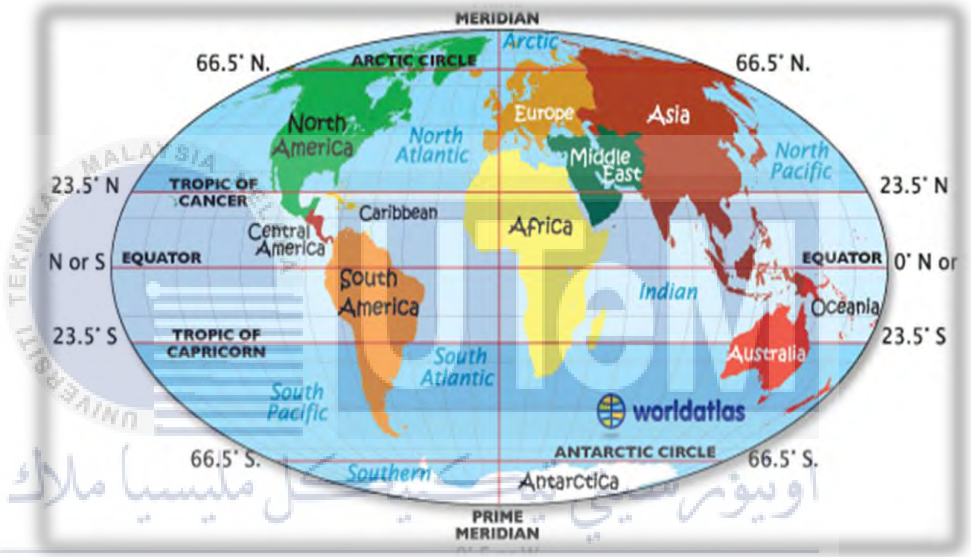


Figure 2.9: The position of equator line
(Source: www.worldatlas.com, 2016)

There are 13 countries that lie on the equator line which is Ecuador, Colombia, Brazil, Sao Tome & Principe, Gabon, Republic of the Congo, Democratic Republic of Congo, Uganda, Kenya, Somalia, Maldives, Indonesia and Kiribati (Rosenberg, 2017).

Temperatures at the equator are very high this is because the sun is directly crosses the equator. Countries that near the equator line receives 12 hours of night time and 12 hours of day time which is consistent year-round (Miller, 2014). Figure 2.10 below shows the temperature at the equator line.

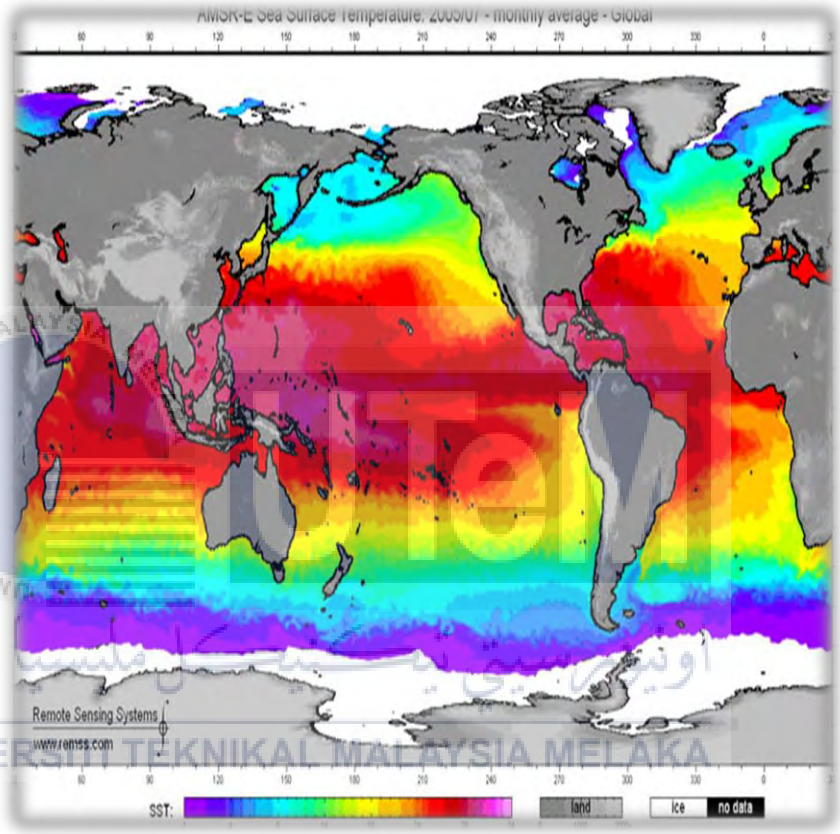


Figure 2.10: Sea temperature of the earth
(Source: www.nasa.gov, 2007)

Solar energy most likely suitable for the countries with in equatorial and subequatorial climate zones due to high heat energy received. (Gavin, 2007).

2.5 Solar Energy

Solar energy is the most readily available source of energy (Pedigo, 2010). This is because this energy has a huge potential and space to be develop as the sun is universal resources. Nowadays people are still using non-renewably energy such as fossil fuels as a main source to generate energy (Saxenaa, 2011).

Statistic showed that coal-fired power plants currently fuel 41% of the global electricity. This type of energy is among the main reason of the pollution that happens around the world. People should use solar energy to overcome the previous energy effect which causes the pollution into the environment (Ebieto, 2012). By using solar energy the effect of the pollution can be reduce efficiently (Masson, 2014). Hence, green technology usage which are more environmental friendly can be maximize. Solar cooking method can be used for multipurpose and enhanced solving problem in daily life (Diffie Hellman, 1974).

Besides of environmental friendly solar energy has a drastic impact on economical, ecological and social. The reasons for economical is for example as the fuel for cooking keep rising the low income family can afford to buy it, in terms of ecological is the usage of wood cause deforestation to took place and for social is people can saved the money from buying the fuel for cooking to improved their social life (Shahzad, 2013).

Solar energy can be used for various purpose, for example it can generated electricity by using photovoltaic and can also produced heat by using solar thermal technology (Thiele, 2017). Photovoltaic modules is converting the lights from the sun to DC electric energy when the light strike the surface (Willey). Unfortunately not all sunlight are converted to electricity, majority of it is lost (Rinkesh, 2009).

There are other factors that should be considered which may affect the efficiency of sunlight to be converted into electricity such as temperature wavelength, reflection and recombination (Bailey, 1980). The mechanism of how photovoltaic system works is shown in the Figure 2.11 below:

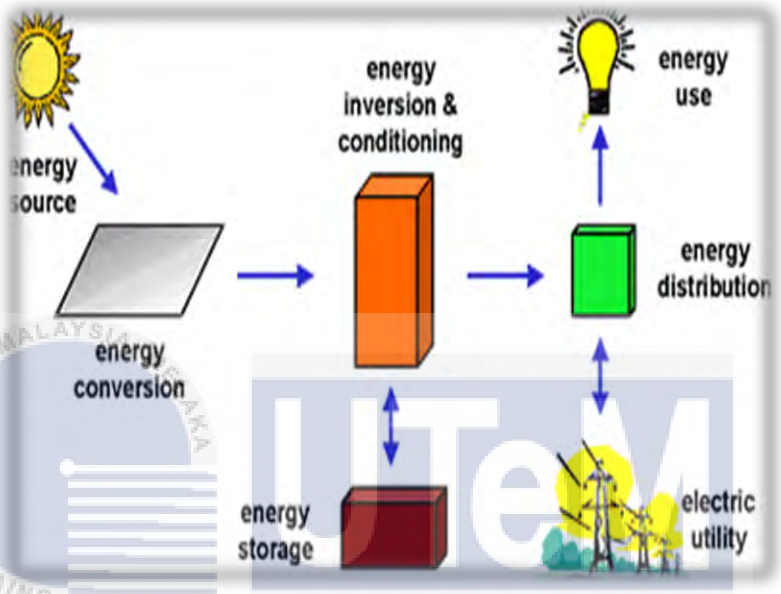


Figure 2.11 : The basic mechanism of Photovoltaic system in producing electricity.

(www.fsec.ucf.edu, 2014)

In the photovoltaic system, the batteries often been used as an energy storage to store energy obtained from the sun. The uses of the batteries is an advantage to this system as it give energy support when there is no more sunlight to be generated into electricity (Hottel, 1982). This prevented the user from having a sudden loss of electric energy.

More details about photovoltaic mechanism is shown in the Figure 2.12 below:

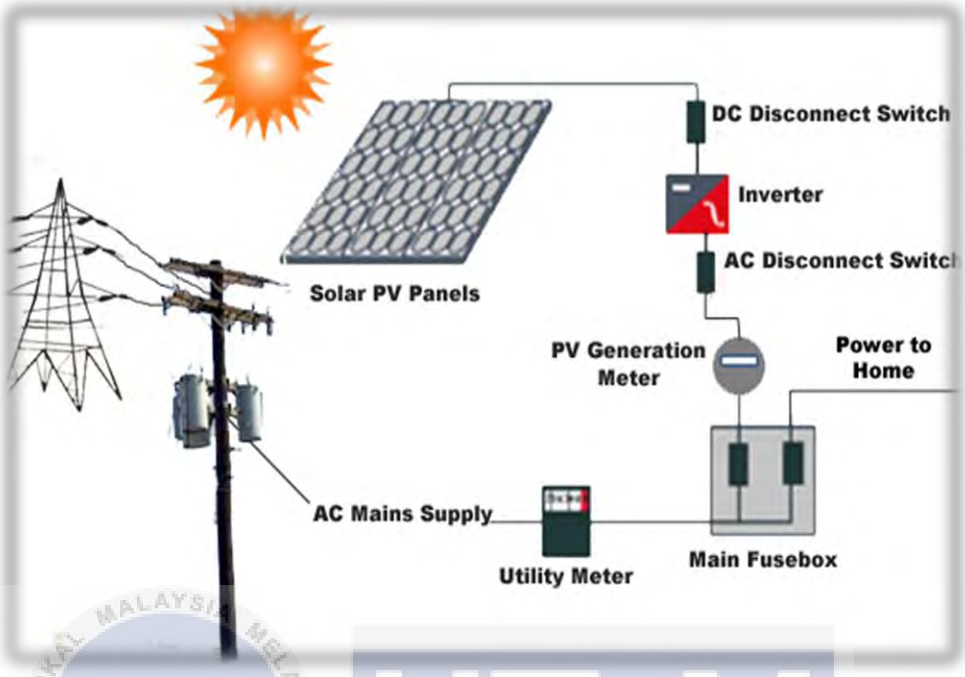


Figure 2.12: The residential photovoltaic schematic diagram

(www.mapawatt.com, 2009)

Heat or thermal energy that been generated from sunlight is called as solar thermal energy. This can be done by transferring energy from solar radiation into thermal by using thermodynamic system. Solar thermal energy can be stored in a storage or in terms of steam cycle (Ruwa, 2016).

The common use of this system is in domestic water heating. Solar energy from sunlight is been collected by a flat solar plate which transfer the heat into the flowing water via tubes (Musunuri, 2007).

The mechanism of solar thermal energy is shown in the Figure 2.13 below:

Figure 2.13(a): Domestic water heating mechanism, Diagram (Without reservoir)

(www.cherrymortgages.com, 2012)

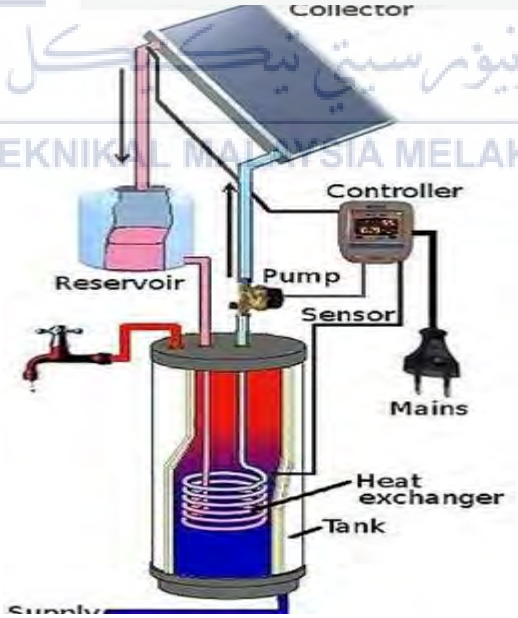


Figure 2.13(b): Domestic water heating mechanism, Diagram (With reservoir)

(www.cherrymortgages.com, 2012)

The Photovoltaic solar shown in the Figure 2.14 below is patented on 31 Jan 2012 by Leo Francis Casey, Mark George Prestero and Janos Rajda the inventor of the system. The patent no of this system US8106537 B2 with No. of patented recorded is US 12/495,840. This system has a few characteristic on it such as it has a power converter for use with photovoltaic cells is disclosed.

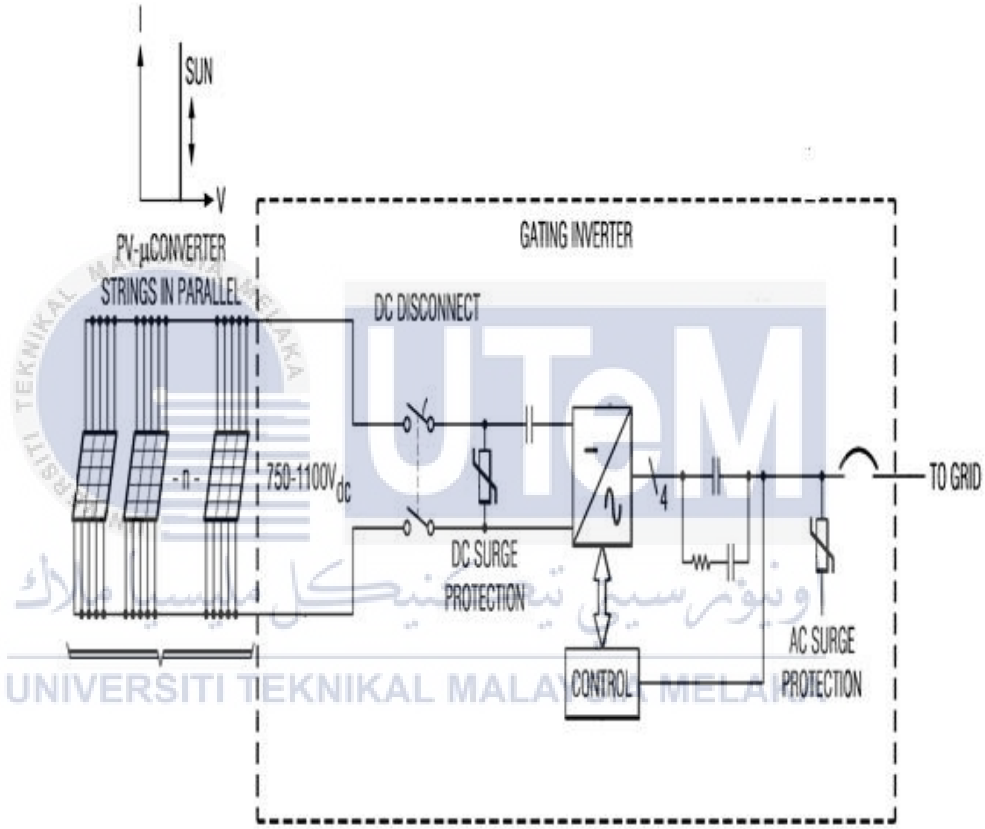


Figure 2.14 : Photovoltaic solar patent

(patents.google.com)

The solar thermal shown in the Figure 2.15 below is patented on 8 April 1975 by Matthew William Frank the inventor of the system. The patent no of this system US 3875926 A with No. of patented recorded is US 3875926 A. This system has a few characteristic on it such as it has a collector of solar energy reflects solar energy to a heat pipe which transmits vapour.

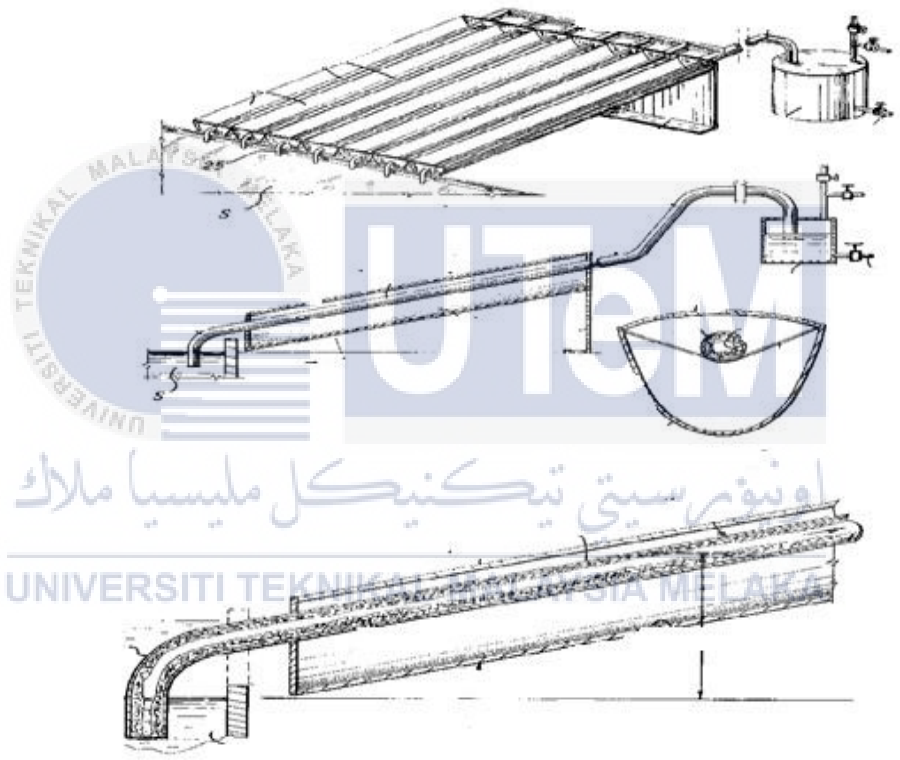


Figure 2.15: Solar thermal energy patent

(patents.google.com)

The solar energy system shown in the Figure 2.16 below is patented on 3 Nov 1992 by William E. Horne the inventor of the system. The patent no of this system US5269851 A with No. of patented recorded is US 07/970,948. This system has a few characteristic on it such as it has a solar energy system that includes a primary concentrator, a receiver having a plurality of photovoltaic cells, and a prefilter surrounding the receiver.

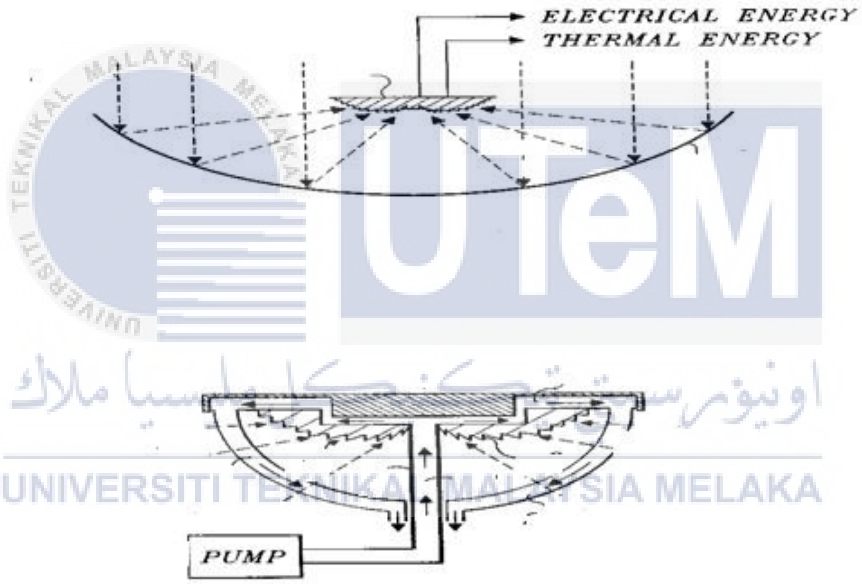


Figure 2.16: Solar Energy System

(Source: Author).

2.6 Summary of Chapter 2

The literature review relating to the solar toaster helps the better understanding on the project. The study on the patent of the solar system and toaster helps in generating idea for concept design. Hence, at the end of this chapter the implementation of the project could be carried on.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology can be defined as a process where the project are been implemented structurally. The process describes the procedures as well as the implementation of the project. This project basically three parts which is design process, analysis process and fabrication process.

All these three parts have been carried out so that the objectives of the project can be achieved. Through methodology the problem and missing parts of the project could be able to improve and identify as it analyze and review the structure of the process. Besides, the purpose of the methodology to get a better understanding about the project by have a look on the flow chart of the project outline as it more organized. The flow chart and procedures of the project is shown in the Figure 3.1 .

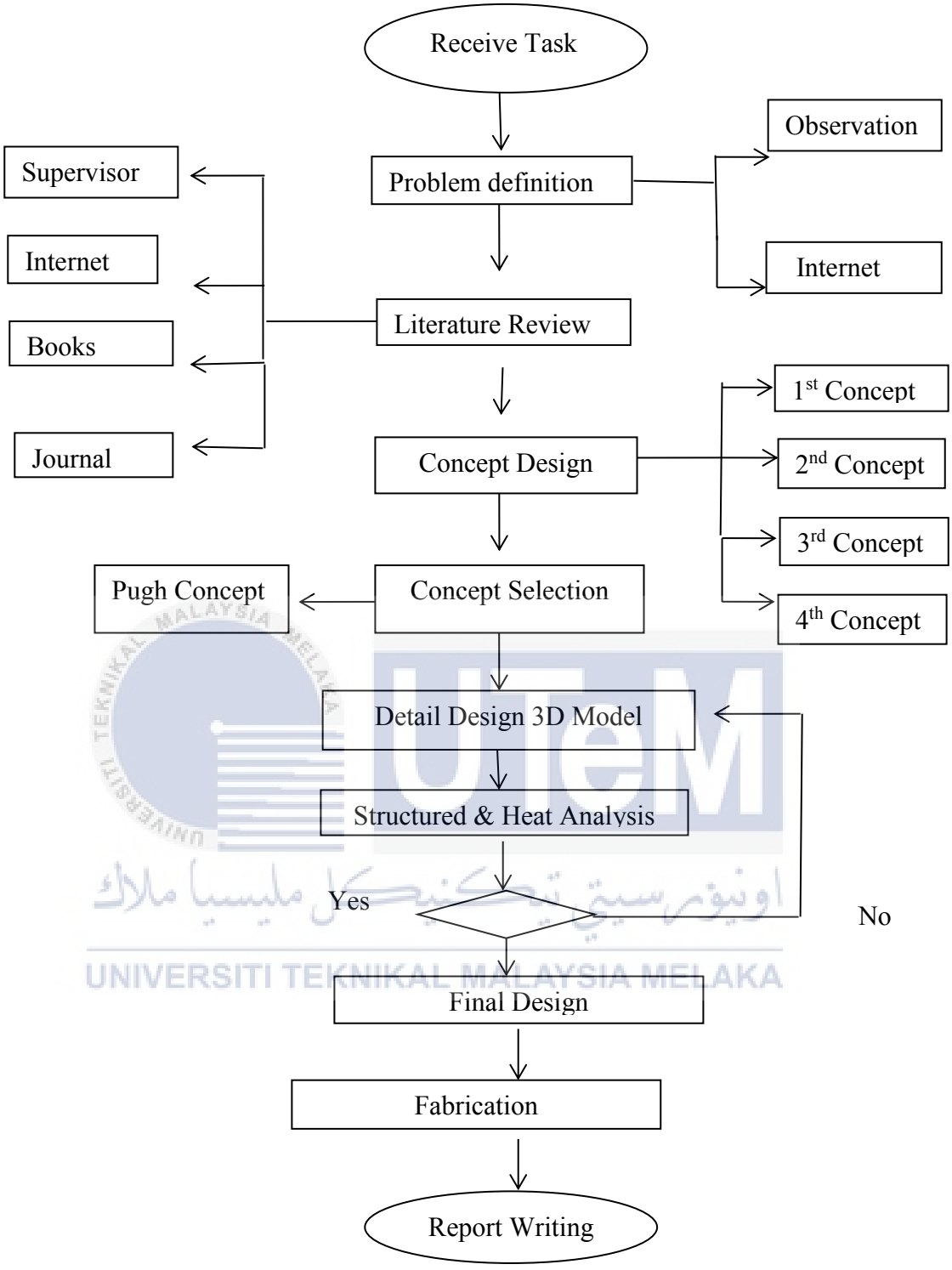


Figure 3.1: Flowchart of project outline

(Source: Author)

3.2 Problem Definition

Problem definition is a stage where author identifying the problem of the project. It is important to identifying the problem prior to start of the project so that the problem can be avoid in the future. Besides that it also will enhance and improve the project as better understanding about the project implementation obtained via problem definition. Problem definition can be obtained by many ways such as by surfing internet and observation. Information can be obtained by surfing internet and observations on related topic or studies before further continue on literature review. Opinion and guidelines from supervisor also important so that progress work is keep on track.

3.3 Literature Review

Generally, literature review is a phase where all related and previous study are been discussed. The main idea is to gather all information and knowledge about the project so that the reader are able to understand the whole project easily. By putting citation on related and previous study about the project, it will strengthen the explanation process as the related case had been studied before. Basically the complete literature review comes from main sources such as article from internet, books and journals.

3.4 Concept Design and Selection

Generating a concept or an idea into a drawing or pattern is called as concept design. Before generating a concept into a drawing, the are a few criteria, needs, or requirement regarding the project has to be meet or considered so that the design process will be ease.

For example customer requirement and design requirement should be considered before draw a concept design. Concept design are drawn between three to six depend on the situation, needs and requirement. All these design and drawing will be filtered to identify the best concept design by using Pugh concept.

Pugh concept was invented by Stuart Pugh in 1981 is the decision-matrix technique that helps design engineer to select the best concept design. Example of Pugh Concept is shown in the Figure 3.2:

	Overall Concept Comparison				
Selection Criteria	A	B	C	D (Reference)	E
Cost	-	-	0	0	0
Complexity	-	-	-	0	+
Life-span	+	+	+	0	+
Durability	+	+	+	0	+
Safety	+	+	+	0	+
Packagability	-	0	+	0	+
Efficiency/Power Consumption	+	+	+	0	+
Functionality	+	+	+	0	+
Controllability	+	+	+	0	-
Sum + 's	6	6	7	0	7
Sum 0's	0	1	1	9	1
Sum -'s	3	2	1	0	1
Net Score	3	4	6	0	6
Rank	3	2	1	4	1
Continue?	No	Yes	Yes		Yes

Figure 3.2: Example of Pugh Concept

(www.edge.rit.edu, 2011)

In the Figure 3.2, the example of the Pugh concept is to compare the overall concept of the project from selection criteria. Among concept A,B,C,D and E the highest rank of the concept design is concept C & E as its obtain the highest sum +'s then followed by B, A and D.

3.5 Detail design and analysis

The best design that was selected from Pugh method will be drawn into detail design and 3D model. This design is drawn by using Computer Aided Design software (CATIA). Beside helps to draw the design in 3D model, CATIA V5 capable in completing the development process of the product drawn from it. In addition, CATIA V5 has many widely users because of the capability of the software. Besides, this software can be apply in many sectors such as in industries, aerospace,

automotive and many more. CATIA capable in realizing the design as the parts and dimensions of the product are more details and specific. This helps design engineer to improve and develop the product.

On top of that, CATIA has many special features such as analysis, simulation and synthesis that able to helps the user to experience high technology of 3D system which ensure the quality of the product and market acceptance.

3.6 Finite Element Analysis (FEA)

Finite Element Analysis or known as FEA is a technology where the product and the system are modelled in a virtual environment. Usually FEA is used by mathematician, scientist and engineer to solve any complex structure or multiphysics problem. FEA also been used to analysed the structure of a product to identify the stiffness and strength (Dolbow, 2016).

FEA enable the user to identify construction frame or the product structure weak point, which helps the user to improve the design before construction and fabrication to avoid any mechanical failure in the future (DePalma, 2011). The Figure 3.3 shows an example of the finite element analysis (FEA) results.

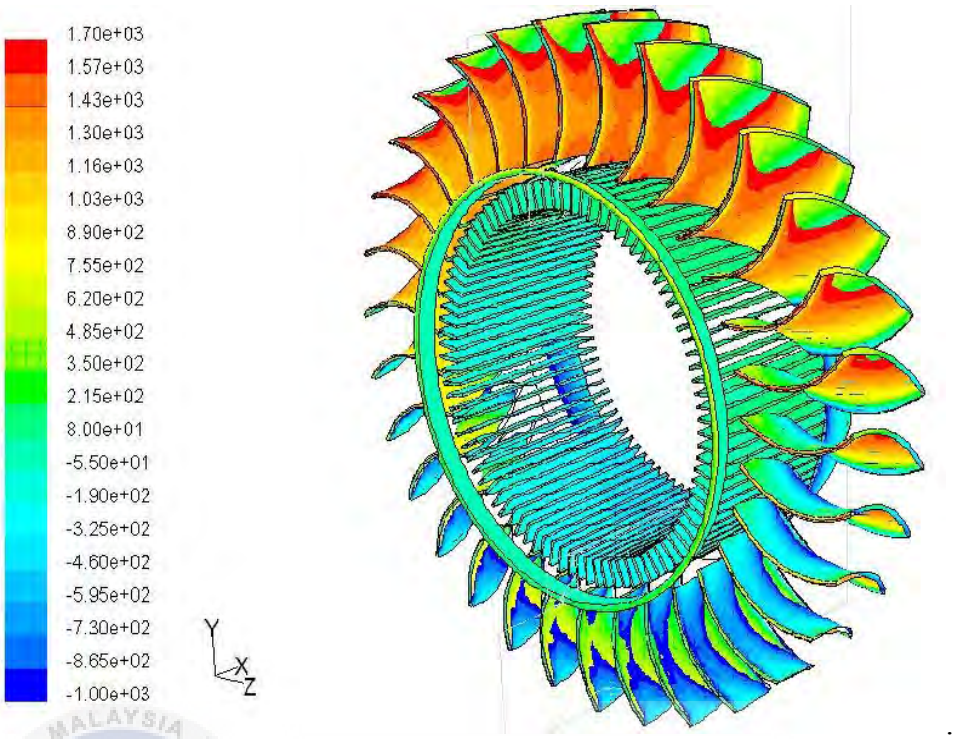


Figure 3.3: An example the result of finite element analysis (FEA)

(www.tensquareintl.com, 2013)

On the Figure 3.3 is an example of the finite element analysis. It shows the minimum and maximum von mises obtain on the design. From this figure minimum von mises obtain is -1.00 e + $10^3 \frac{N}{M^2}$ while maximum von mises obtain is 1.70e + $10^3 \frac{N}{M^2}$.

3.7 Thermal analysis

Heat analysis on the design of the solar toaster was conducted by using ANSYS software. ANSYS software helps engineer in solving the most complex design challenges and product in an efficient way. Author use ANSYS thermal analysis to solve heat analysis problem on the design of the solar toaster.

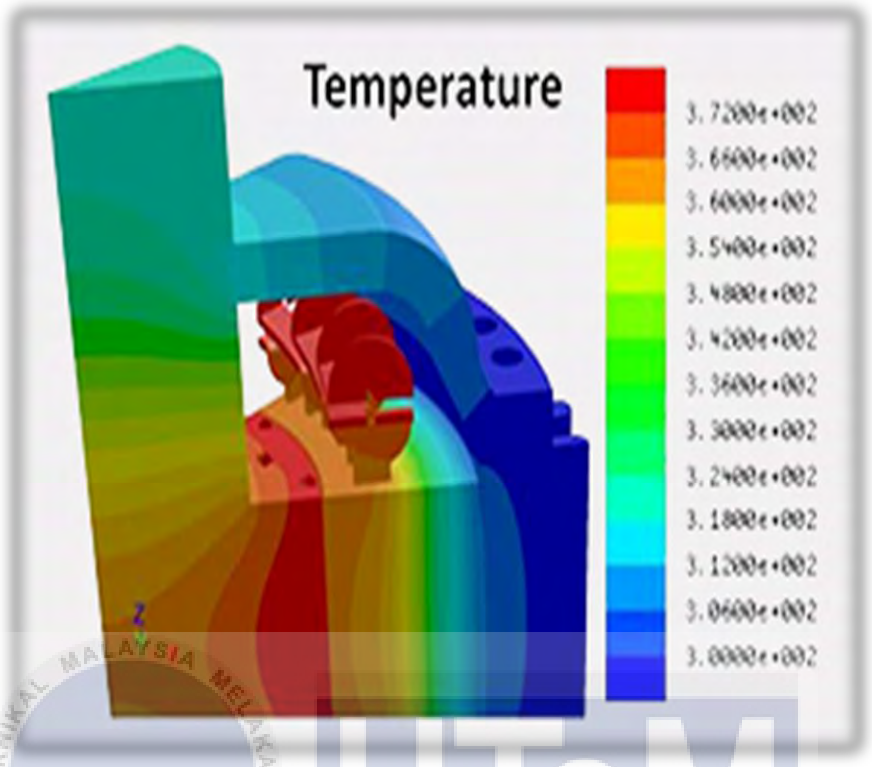


Figure 3.4: Example of thermal analysis conducted on product (www.ansys.com, 2017)

In the Figure 3.4 is an example of thermal analysis conducted on the product. It shows the minimum and maximum temperature recorded on the product. From this figure the maximum temperature recorded is 3.7200e + 10^2 °C while the minimum temperature recorded is 3.0 e + 10^2 °C.

Thermal or heat analysis on ANSYS software could be done in three form which is heat convection, heat conduction and heat radiation. Heat convection is a situation when heat is transfer from one medium to another medium via fluid movements. Heat conduction is a situation when heat is transfer from one solid to another one after been touch. Lastly, heat radiation is a situation when internal energy is been transfer in the form of electromagnetic spectrum (Cengel, 1998).

3.8 Factor of Safety

Factor of safety or known as safety factor is a theoretical calculation to obtain the ratio of allowable working stress (Burdekin, 2007). It determined the ability of the structure to withstand the load of any unexpected force. Different material or structure has different factor of safety. But generally, if the value of the ratio obtain is less than one then it is poor and lack of strength to withstand the load.

$$FS = \frac{Syt}{\sigma\, Von\ mises} \quad \text{(Equation 3.1)}$$

Where,

FS = Factor of safety

Syt = Yield tensile strength

$\sigma\, Von\ mises$ = Maximum of material stress

As soon as the value of the ratio is acceptable and able to withstand the load then the final design process can be proceed. Then fabrication process will took place by producing the prototype of the solar toaster. This is to prove that the project is successfully done and the last phase is completing the final report of the project.

3.9 Summary of Chapter 3

This chapter is describing the method used to complete the project such as literature review, concept design and selection, detail design and analysis, finite element analysis, thermal analysis, factor of safety and fabrication process. The analysis is used to prove theoretically whether the project works or not while the fabrication process is to prove it practically.

CHAPTER 4

DESIGN PROCESS

4.1 Concept design

Generally, design process is a process designating a product where the product design need to meet a certain criteria and requirement such as engineering requirement. After gathering all information and data about the project, four design were drawn. The four design were called or known as concept design. The first concept design as shown in the Figure 4.1 below use one mirror to toast a bread. It have a good safety features which comforts the user. Besides, it can be lift easily as it in a medium size.

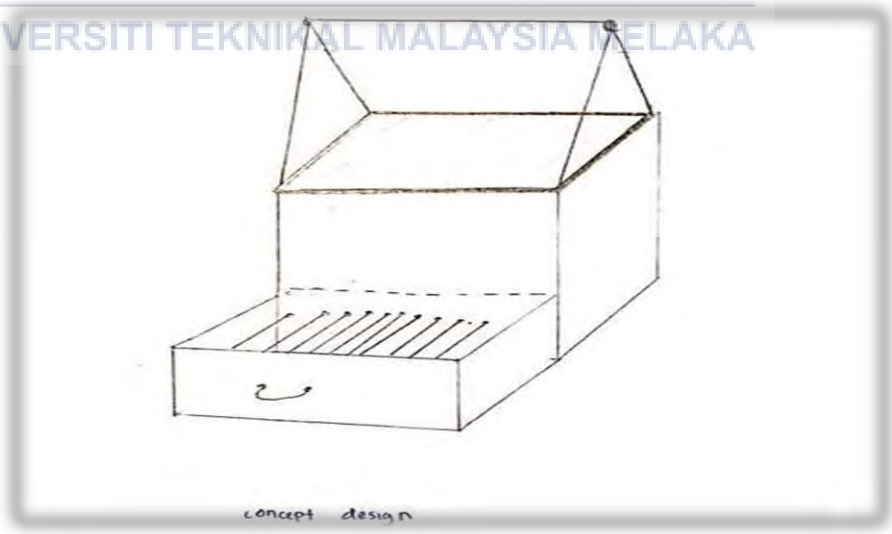


Figure 4.1: First concept design (One-mirror)

(Source: Author)

Second concept design as shown in the Figure 4.2 below is using a wide mirror as it special features. This wide mirror features enhance the efficiency of the solar toaster to bread which reduce the time taken to toasting. In addition, it also able to be use easily by the user as it has a simple mechanism.

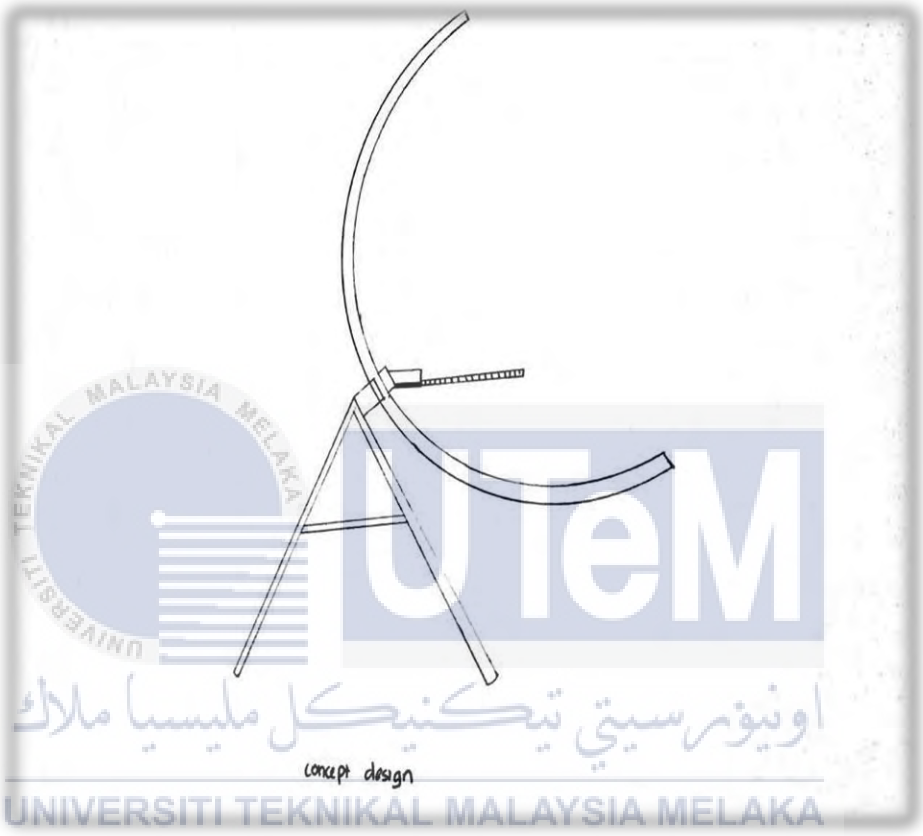


Figure 4.2: Second Concept Design (Wide mirror)

(Source: Author)

The third concept design as shown in the Figure 4.3 below has three mirrors as it special feature to enhance the efficiency of toasting process. Besides, it also comes in medium size which enables the user to lift it easily. In addition, the design also has a good safety feature.

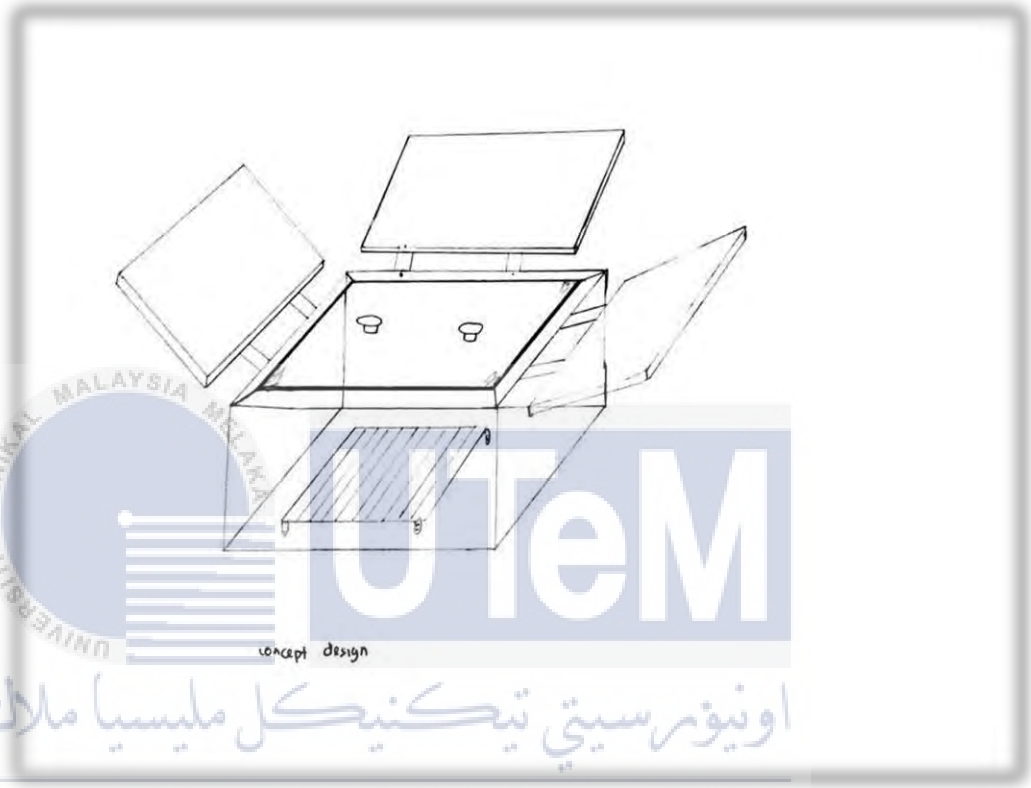


Figure 4.3: Third concept design (Three-mirror)

(Source: Author)

The fourth concept design as shown in the Figure 4.4 below has a modern looks as it comes in small size which enables the user to lift it easily. It also has the ability to toast two breads at one time.

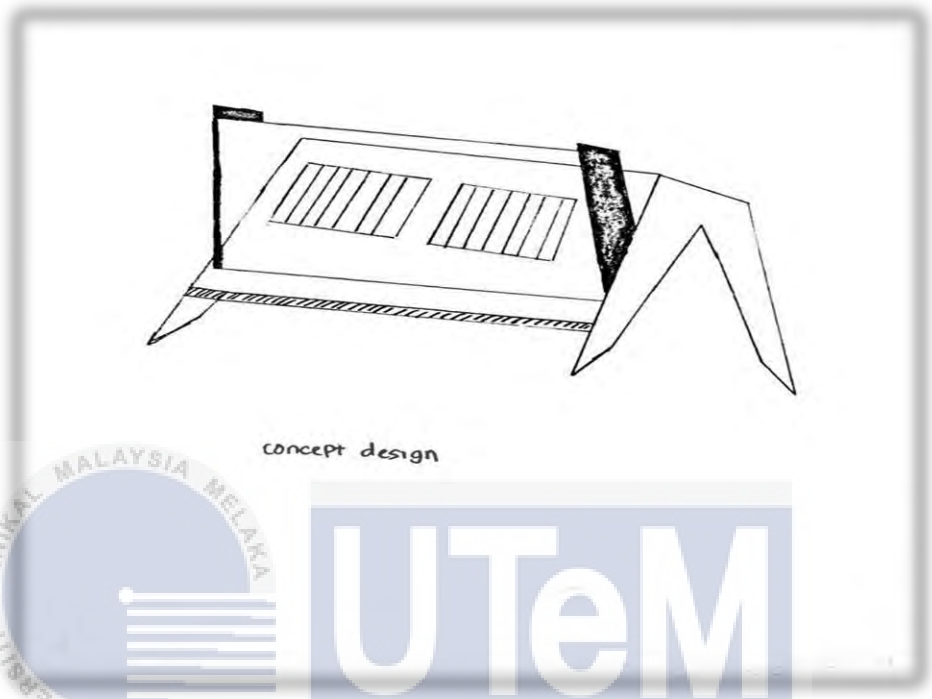


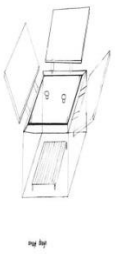
Figure 4.4: Fourth concept design (Two toasters)

(Source: Author)

All these concept design is the suggested design for this project after undergoes customer and engineering requirement selection. These designs are obtain during brainstorming and research as it met all criteria of the project. After that Pugh concept method as shown in the Table 4.1 is used to filter all these design and select one best design among these four as a final design. The Pugh concept method is shown on the Table 4.1:

Table 4.1: Pugh concept selection

(Source: Author)

Description	One-mirror	Wide-mirror	Three-mirror	Two-toaster
Sketch				
Criteria	Design 1	Design 2	Design 3	Design 4
Efficiency	–	+	+	–
Time to toast	–	+	+	–
Cost	–	–	–	+
Size	+	–	+	+
Able to manufactured	+	–	+	+
Safety	+	–	+	+
Sum of (+)	3	2	5	4
Sum of (-)	3	4	1	2
Overall total	3	2	5	4
Ranked	3	4	1	2

+ represents = 1

- represents = 0

From the Pugh concept selection among four concept design, design 3 is selected as the best design among these four as it is ranked in number one by collecting the highest sum of (+) from the criteria given. This design was drawn more detail in 3D model using Computer Aided Design CAD software (CATIA). The 3D model of the product are shown in the Figure 4.5 below:

Figure 4.5 : Final design of solar toaster in 3D model

(Source: Author)

4.2 Fabrication

The fabrication process takes about 3 weeks to be completed. The purpose of the fabrication process is to prove that the solar toaster is really works. After the fabrication process, the solar toaster is been tested multiple times to find the best time range of the toasting process.

Table 4.2: Material Used

(Source: Author)

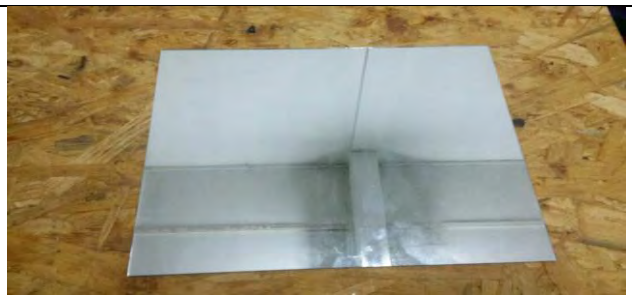
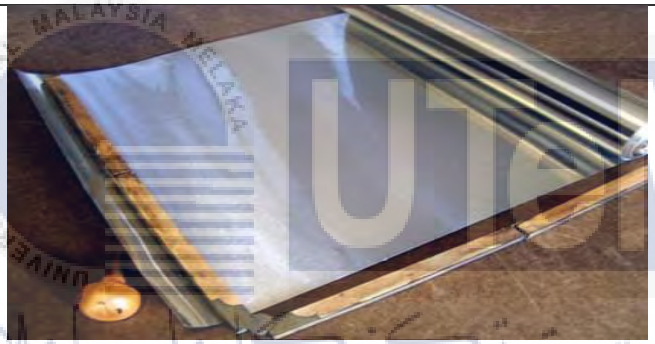
Materials	Function
 I. Mirror	.-To reflect the heat from the sun towards the bread.
 II. Aluminium Sheet	-Act as a platform where heat are collected and concentrated.
 III. Plywood	-Act as a main frame or structure for the body of the prototype.

Table 4.3: Equipment and tools used

(Source: Author)

Equipment & Tools	Function
 I. Hacksaw	-To cut plywood into a desire shape.
 II. Small Hacksaw	-Cut small plywood with difficult angle into a desire shape.
 III. Hammer	-To delivers a nails into the plywood.
 IV. Drilling machine	-To cut holes and give room for bolt and nut. -To fastening the screw. -

 V. Super Glue	-To stick the mirror with plywood.
 VI. Carpenter Glue	-To stick between plywood and plywood.
 VII. Wood Toner	- To decorate the plywood so that it looks more attractive.
 VIII. Sand Paper	-To smoothing the rough plywood surfaces.

 IX. Bolt and Nut	-To bind between aluminium sheet and plywood.
 X. Screw	-To fastening between the edges of plywood and plywood.
 XI. Nail	-To fastening between plywood and plywood.

The solar toaster prototype was fabricated to complete the final task of developing a solar toaster. Overall the fabrication process took almost three weeks to be completed. Plywood has been used as a basis part of the main body. Then, aluminium sheet is attached on it. Finally, mirror that act as sunlight reflecting component was attached on the top of the body.

Bolt and nut was used to bind between aluminium sheet and plywood so that it can strongly attach. Screw and wood glue were used to bind between plywood and plywood. Meanwhile to attach mirror and plywood together super glue was used because it can attached together quickly.

For surface finishing, sand paper was used to smoothing the plywood rough surface. Wood toner was used to decorate to the plywood so that it looks more attractive. Prototype of the solar toaster is shown in the Figure 4.6 below.

Figure 4.6 : Solar toaster prototype

(Source: Author)

4.3 Summary of Chapter 4

Chapter 4 is generally about a design process starting from concept design until the fabrication process. Four concept design are drawn before the best final design been selected. The best final design is selected by using Pugh concept method. Then, based on the final design the fabrication process took place.

CHAPTER 5

RESULTS

5.1 Prototype Experiment

The prototype of the solar toaster has been tested to identify whether it could work in real situation. It was placed under the blazing sun where the temperature recorded was 35°C as shown in the Figure 5.1 below.

Figure 5.1 : Solar toaster prototype was placed under sunlight.

(Source: Author)

The prototype was placed under the sunlight around 10 minute to obtain ideal temperature. After that bread was placed on top of aluminium sheet as shown in the Figure 5.2 below.

Figure 5.2 : Prototype of solar toaster been tested.

(Source: Author)

After 20 minutes under the sunlight the prototype of the solar toaster showing the positive result as the bread successfully toasted as shown in the Figure 5.3 below. This proved that the mechanism of the solar toaster is working.

Figure 5.3 : The bread successfully toasted.

(Source: Author)

5.2 Structural Analysis

Structural analysis has been done using finite element analysis on the solar toaster structure to find max stress on von misses, translational displacement, deformation, stress principal and factor of safety (FS) of the structure. The results of analysis is shown on the figure below after 500N ideal force was applied on the solar toaster.

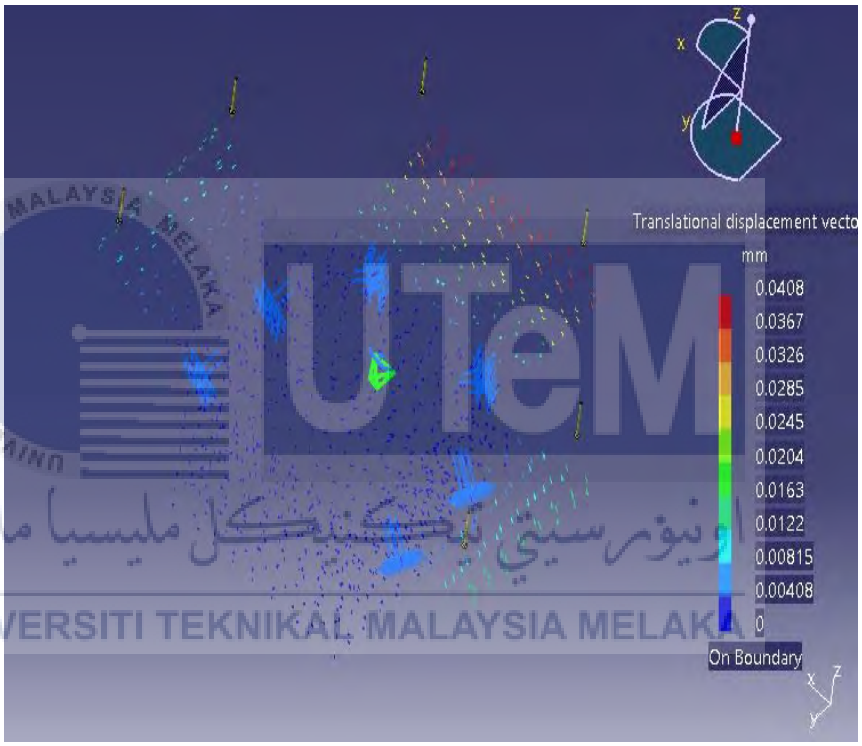


Figure 5.4: Translational displacement of the solar toaster

(Source: Author)

In the Figure 5.4 is a translational displacement of the solar toaster. The figure shows the minimum and maximum value of the translational displacement. The minimum value obtain is 0 mm while maximum value obtain is 0.0408mm.

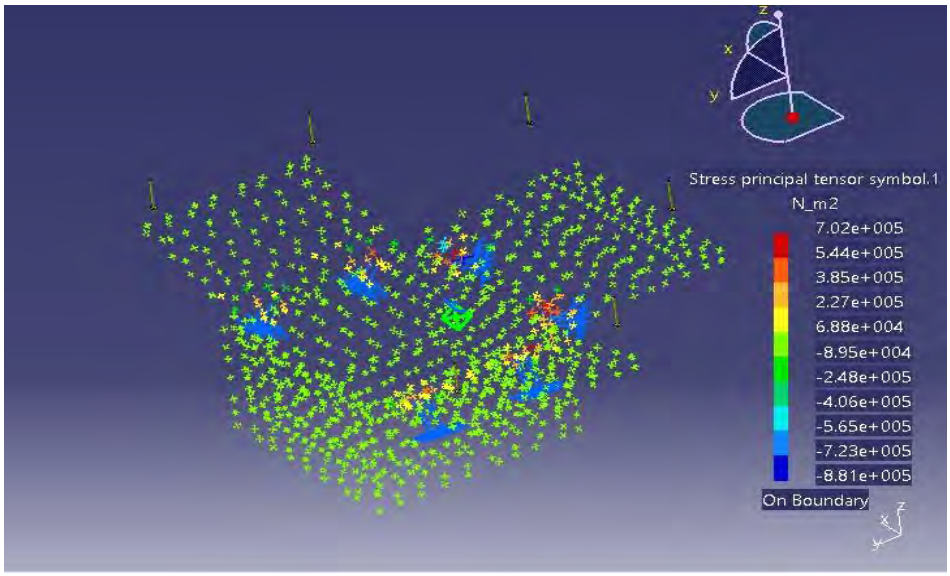


Figure 5.5 : Stress principal of the solar toaster

(Source: Author)

In the Figure 5.5 is a stress principal tensor of the solar toaster. The figure shows the minimum and maximum value of the stress principal tensor. The minimum value obtain is -8.81e + 10^5 $\frac{N}{m^2}$ while maximum value obtain is 7.02e + 10^5 $\frac{N}{m^2}$.

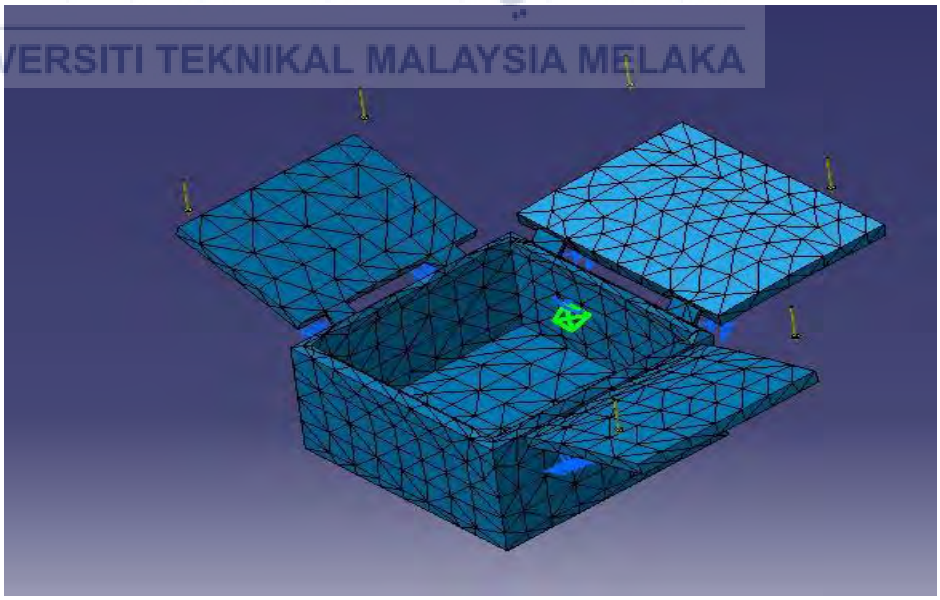


Figure 5.6 : Deformation of the solar toaster

(Source: Author)

Figure 5.6 are shown the deformation that occurs on the solar toaster. Every point that has deformation process is shown.

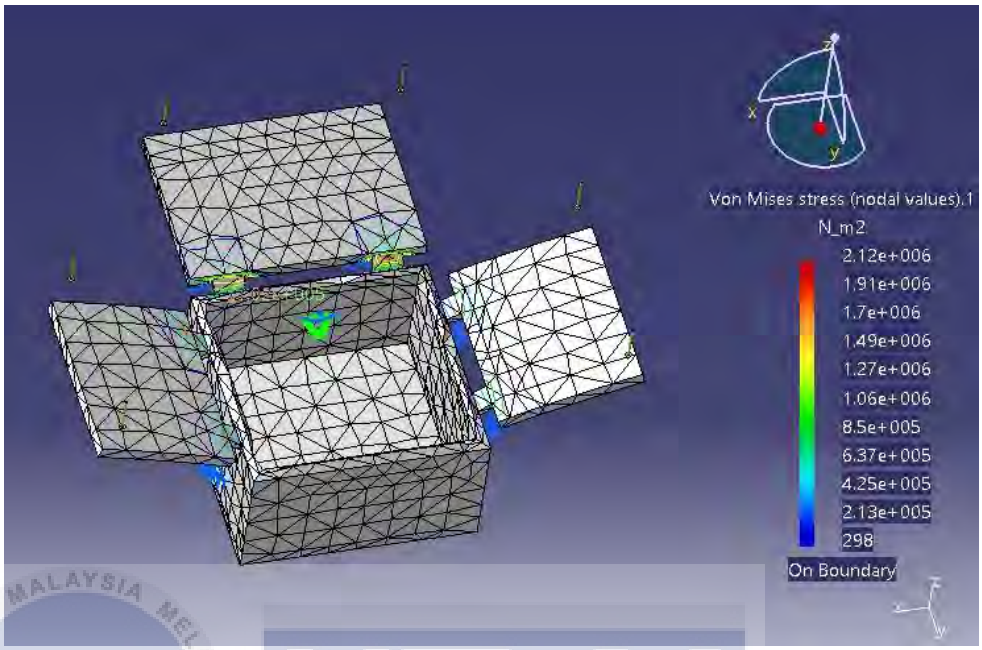


Figure 5.7: Von mises stress of the solar toaster

(Source: Author)

In the Figure 5.7 is a Von mises stress of the solar toaster. The figure shows the minimum and maximum value of the Von mises. The minimum value obtain is 298 $\frac{N}{m^2}$while maximum value obtain is 2.12e + 10^6 $\frac{N}{m^2}$.

Table 5.1: Material Properties (Aluminium)

(Source: Author)

Material	Pure Aluminum
Young Modulus	7e+010N_m2
Poisson Ratio	0.346
Density	2710kg_m3
Thermal Expansion	2.36e-005_Kdeg
Yield Strength	9.5e+007N_m2

Table 5.1 shows the material properties of the aluminium. Aluminium is used as a main material for the solar toaster. Every value for each of the material properties are shown on the table.

From equation 3.1: Factor of Safety (F.S) $= \frac{Syt}{\sigma\, Von\ mises}$

$$= \frac{9.5\ X\ 10^7}{2.12\ X\ 10^6}$$

$$= 44.81$$

The factor of safety record by using pure aluminium as a material is 44.81 which is good. Pure aluminium are the ideals material as their properties are superior to other. It is reasonably affordable, light and very advantageous in terms of materials weight. However, aluminium is very hard to work as it requires high skilled expertise to use it because of a soft metal. In addition to improves the factor of safety, the edges of the solar toaster been chamfer. This is to avoid the user from having an injury in the future. Besides, the holder which made from wood also been fabricated on the both side of the solar toaster. This is to ease the user during lifting the solar toaster and avoiding their hand from scalded due to high heat temperature.

5.3 Heat Analysis

Malaysia is located on an equatorial region and deal with tropical rainforest climate, because of that Malaysia receive high amount of sunlight compared to other country. These amount of sunlight are benefited as it can be use to generate solar energy. Author is focusing this research in Malacca, Malaysia as it is the location

where this research took place. The Figure 5.8 below shows the sunlight schedule and data in Malacca.

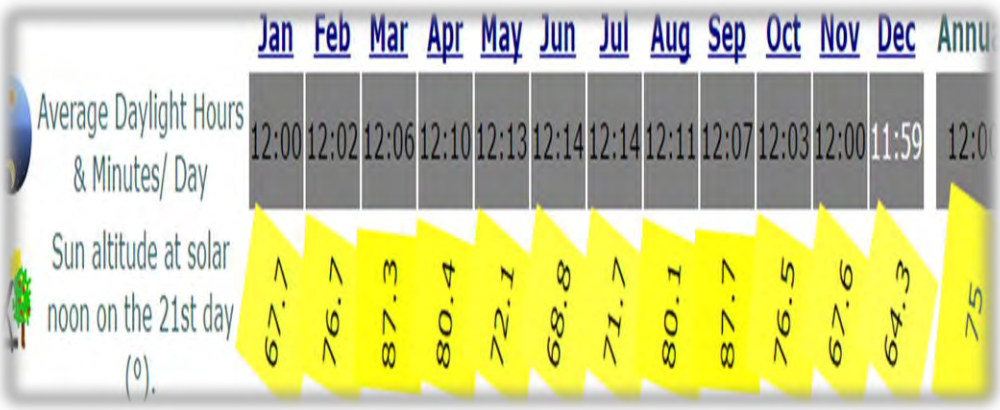


Figure 5.8 : Average daylight hours in Malacca

(www.climatemps.com, 2016)

Figure 5.8 shows the average daylight hours in Malacca, Malaysia. It can be conclude that Malacca is having average 12 hours daylight.

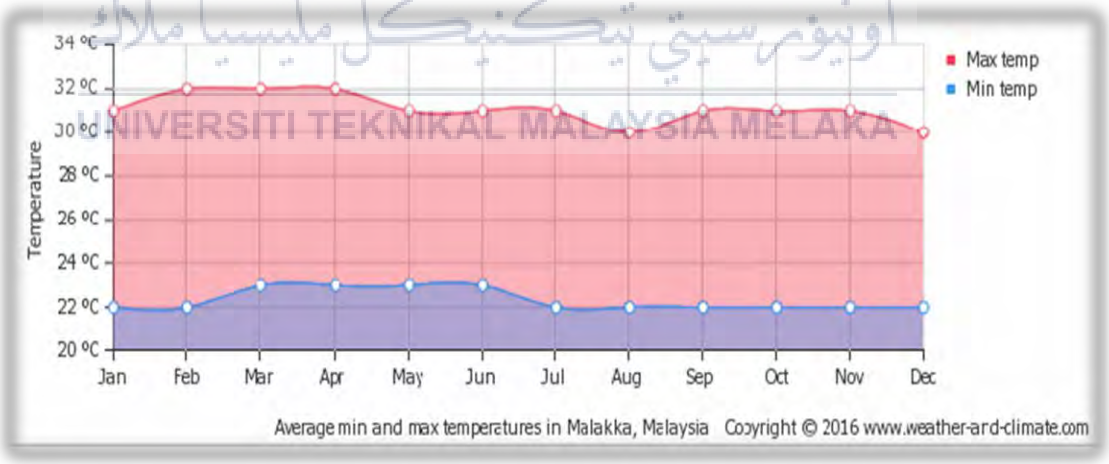


Figure 5.9 : Average temperature in Malacca

(www.wheather-ard-climate.com, 2016)

Figure 5.9 shows the average temperature in Malacca, Malaysia. It can be conclude that average temperature in Malacca is around 31°C.

Figure 5.10 : Monthly sun hours in Malacca

(www.wheather-ard-climate.com, 2016)

Figure 5.10 shows the monthly sun hours in Malacca, Malaysia. In can be conclude that Malacca is having around 230 sunhours.

Average toaster will use around 1200 watts to toasted a bread. Thus, the solar toaster need sufficient amount of heat energy so that it can function and operated well. The energy emitted from the surface in kilowatts is :

$Q = \varepsilon_s \sigma T^4 A_s$ - Equation 5.1

Where,

The area of the surface A_s = L x W

ε_s = Surface emissivity of the material

σ = Stefan-Boltzmann constant (5.67 x 10^{-8} W. m^{-2}/ K^{-4})

T = Temperature

Figure 5.11 shows the thermal or heat analysis of the solar toaster which was conducted using ANSYS software. The software was been used as the medium to solve heat analysis because of it ability was proved able to helps many similar case study before. The result of the study was show on the Figure 5.11 below:

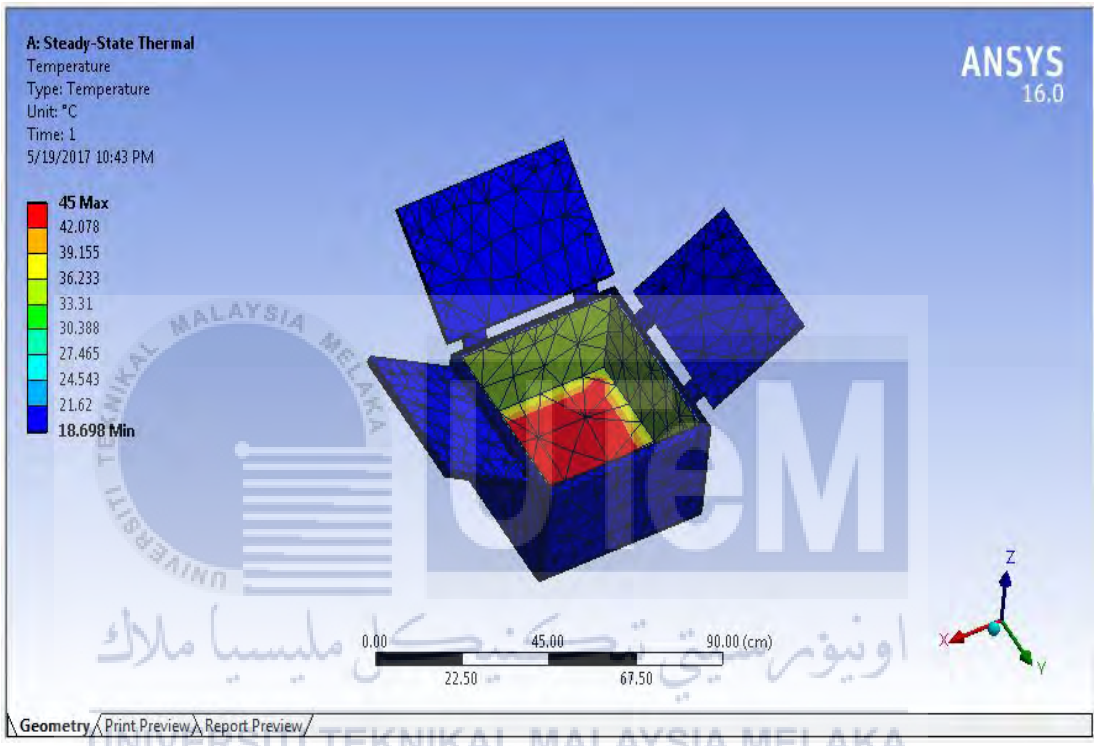


Figure 5.11: Thermal analysis on the solar toaster

(Source: Author)

The heat transfer radiation features is been selected as element for analysis. This is because the solar toaster receive large amount of heat energy from the sun. Heat energy from the sun can be categorized as heat radiation. The solar toaster is analysed at 31 °C temperature condition which is an ideal and average temperature in Malacca.

From the Figure 5.11 it can be seen that the minimum temperature recorded on the solar toaster is 18.698°C while the maximum temperature recorded is 45°C. The maximum temperature recorded is on the toasting area. This is because of the heat are consistently been concentrated on the toasting area from the mirror installed. This analysis theoretically proved that the mirror works on the solar toaster.

5.4 Mechanism on the Design

A mechanical system or mechanism was added on this design. This is to improve the function or studies done during PSM 1. This mechanical system also improves the heat efficiency of the toaster to toasting. Basically, the functions of the mechanical system are stated below:

a) Able to toast high amount of bread.

b) The bread can receive a high amount of heat from the sun, hence making the toasting process more faster.

c) The system design makes every each of toast is able to receive a heat from the sun equally.

d) It has better safety compared to previous studies of the solar cooking.

The detail design of the mechanical system or mechanism is drawn by using CATIA software. The figure below shows every each part or component of the new toaster mechanism:

a) The bread holder

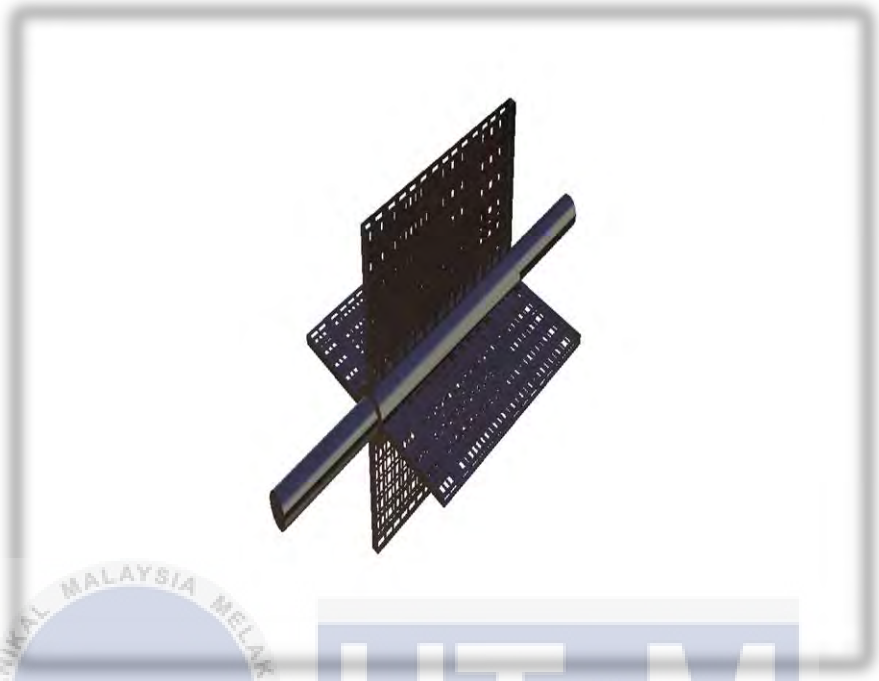


Figure 5.12 : The detail design of the bread holder

(Source: Author)

This component has four main slots which are attached on the roller. The material of this component is completely made up of aluminium this is because it has low melting point. Therefore, it can easily absorb the heat which will speed up the toasting process.

The bread holder is big enough to placed 4-6 bread on each one of it. After the bread was toasted. It can be removed by using spatula after the toaster cover was slide. This will prevent the user from experience hand burns.

b) Chain

Figure 5.13: Detail design of chain
(Source: Author)

Figure 5.13 shows detail design of chain. Chain works exactly like belt drive mechanism which is the key of the motion. It transmit motion from one wheeled axis to another. This finally will lead the rotation of the toaster system. Chain was used because of its characteristic which is able to withstand at high temperature. As solar toaster involved in heat energy it is important that the component of the solar toaster able to withstand high temperature.

c) Motor

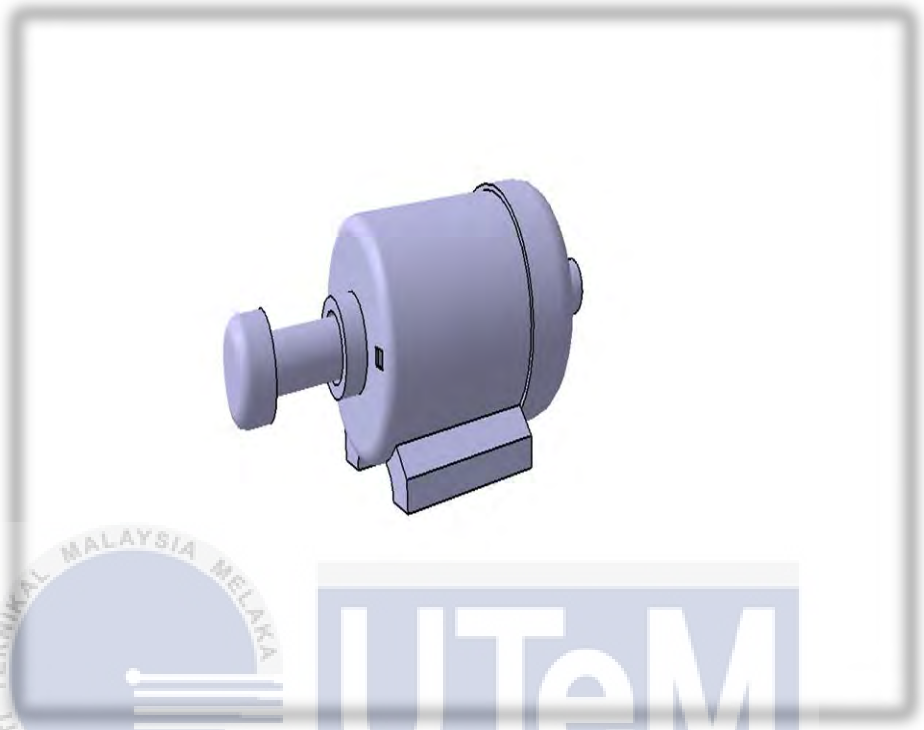


Figure 5.14: Detail design of motor

(Source: Author)

Motor as shown in the Figure 5.14 is the source of the rotation. It is connected to smaller sprocket to transmit the rotation to another sprocket which finally will rotate the toaster. Motor that will be used has a high number of torque so that it capable enough to provide the rotation to the whole system.

d) Power source

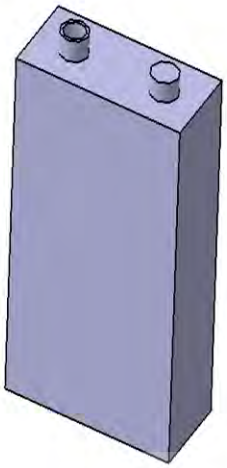


Figure 5.15: Battery
(Source: Author)

Battery 9V as shown in the Figure 5.15 is used as power source of the system. This is because it has sufficient amount of voltage to support the rotation of the system. It was located at the below of the solar toaster. This is to protect it from experience high heat energy because it can be damage. Besides by putting it on the below also make it looks more better and more tidy.

e) Locking-Nut

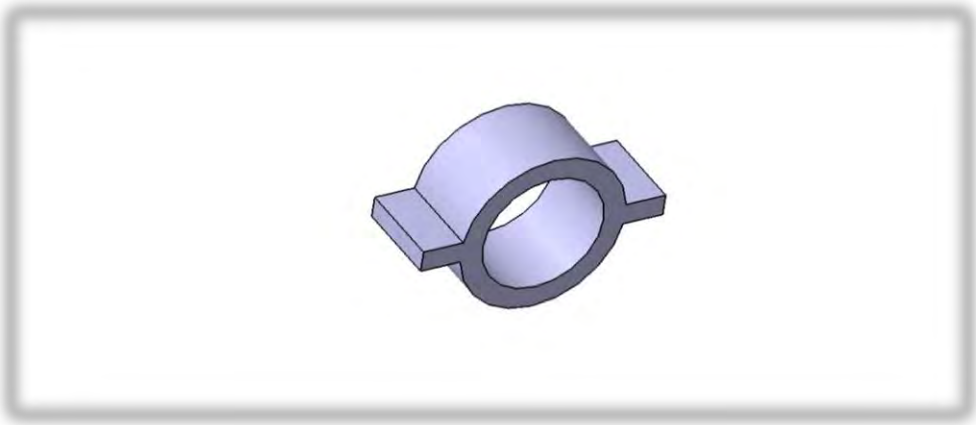


Figure 5.16: Design of locking-nut

(Source: Author)

The locking-nut shown in the Figure 5.16 is used to tight or lock the connection between the roller and the sprocket and between the motor and the sprocket so that it can rotate properly without a risk of been removed accidentally.

f) Switch

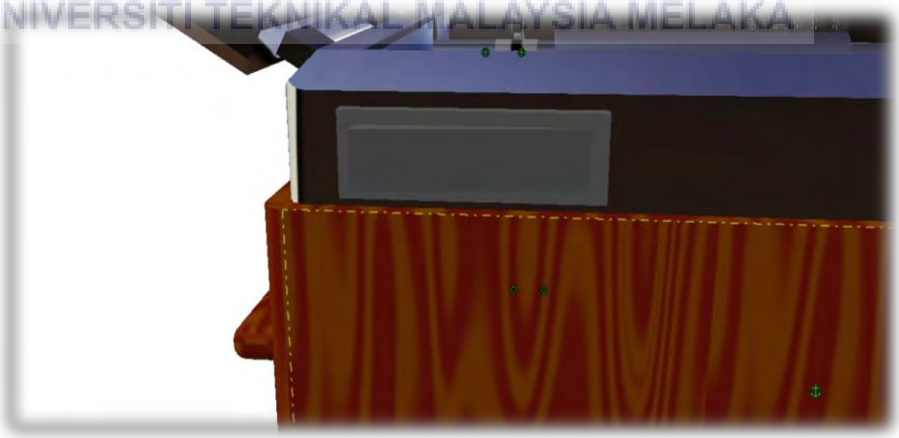


Figure 5.17: Design of switch

(Source: Author)

Figure 5.17 shows the design of the switch. The switch will enable the user to turn on or off the operation when need it.

A final design of the solar toaster is shown on the Figure 5.18 below:

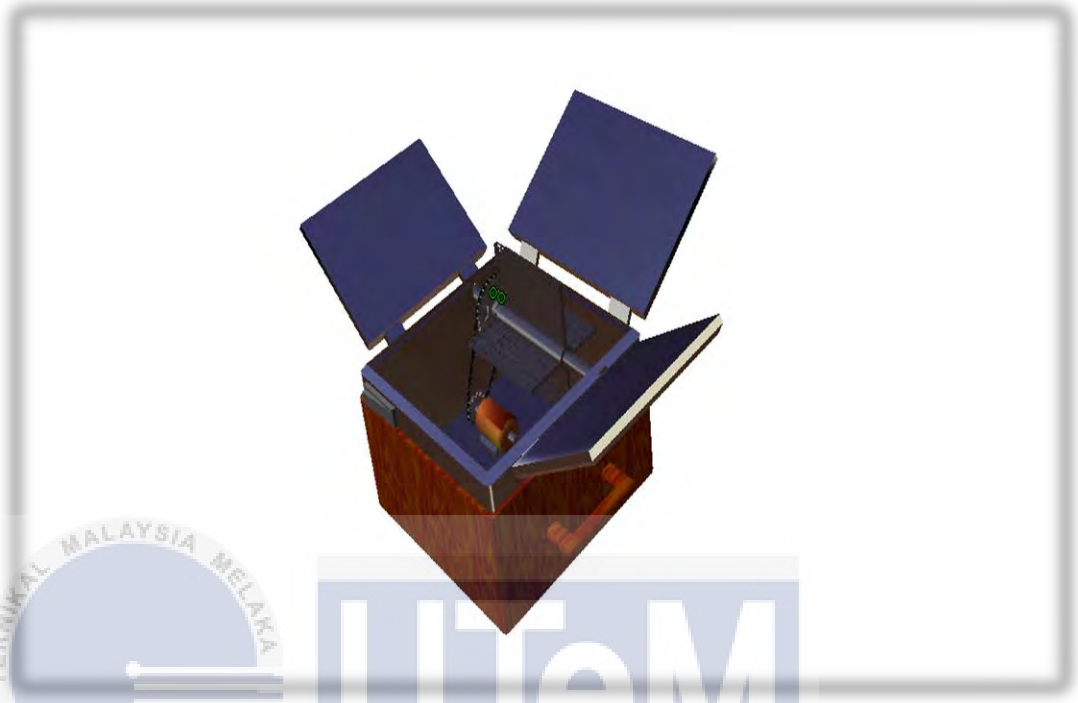


Figure 5.18 : Final design with complete mechanical system.

(Source: Author)

This mechanical system or mechanism works by using a battery as it power source. This will rotate a motor which will also rotate a gear. By using gear and belting mechanism, this finally will lead the rotation of the toaster. As the toaster rotate, the bread will receive a sufficient amount of heat from the sun. Hence making the toaster works efficiently.

5.5 Summary of Chapter 5

This chapter generally is about the result of the solar toaster on this chapter. Theoretically, the structural and thermal analysis has proven that the project is going to work. In addition, the fabrication process also verified this analysis by showing that the solar toaster is working.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

As a conclusion, the objective which is to design, perform analysis and fabricated solar toaster have been achieved. The analysis performed were structural analysis and heat analysis which were performed using CATIA software and ANSYS software.

Methodology was developed from a flowchart as discussed previously in chapter 3. Firstly, the method begin with problem definition as soon after receiving task to identify the problem so that the problem can be avoided in the future by using internet, book and journal as a reference. Then the next method is to generate concept design by producing four concept design and finally the best design was selected to solve the problem on the previous study of solar toaster.

Besides that these studies also investigate the von misses stress, translational displacement, deformation and principal stress by using finite element analysis in CATIA software. It also can locate the stress concentration on the structure frame to give some improvement in designing the structure. After the analysis, based on the value obtained, factor of safety of the design was determined. Any possible structure or design which lack of safety and may harm the user was modified.

All the modifications performed in this study is to improve the quality of the structure frame of strength and life cycle. Then, the heat analysis on the solar toaster

was conducted to identify whether the solar toaster theoretically works under desire condition. Then, the fabrication process took place which the objective of it was to prove experimentally whether the project successful or not.

Lastly, it can be concluded that this project gives experience and benefits especially in identifying and solving the problem by practically engineering approach.

6.2 Recommendation

There are several things in this study which need an improvement and recommendation for future studies such as:

i. Various materials should be applied during analysis.
ii. An improvement on the mechanism of the solar toaster.
iii. Adding more mirror on the solar toaster.
iv. Adding solar cell on the toaster.

It is recommended that various materials other than pure aluminium should be applied during finite element analysis so that it can be compared the different between materials applied on the design. Secondly by making an improvement on the mechanism of the toaster as is to enable more bread can be placed besides to increase the efficiency of the toaster.

Another recommendation is adding more mirror on the toaster to enhance the efficiency of the toaster by reducing the time taken for toasting. Experimental results on the prototype of the solar toaster shows that it takes about 20 minutes to toast the bread. The time taken is much longer compared to electrical toaster. Hence, by adding more mirror so that the time taken for toasting could be reduced.

In addition, It is recommended for future studies the solar cell is added on the toaster for extra features. The solar cell will generate electric energy and save it while the toasting process took place. Then, if at the night or rainy day the solar toaster can be used by using energy generated from solar cell. This will improve the solar toaster and reduced the solar toaster weakness.

Lastly, if all suggestion and recommendation are follow on this case of study the solar toaster will function more better compared to electrical toaster. The solar toaster also able to achieve its objectives in reducing the usage electrical energy by implementing renewable energy in this project.

REFERENCES

Ament, P. (2007, April 27). *TOASTER*. Retrieved from Idea finder: http://www.ideafinder.com/history/inventions/toaster.htm

Bailey, R. L. (1980). Solar Electrics Research and Development. *MI: Ann Arbor Sciences*, 186.

Bessenbache, M. (2009). *great circle*. Retrieved from https://www.nationalgeographic.org/encyclopedia/great-circle/.

Burdekin, F. (2007). General principles of the use of safety factors in design and assessment. *Engineering Failure Analysis*, 420-423.

Cengel, Y. A. (1998). *Heat and mass transfer.* New York: Mc Graw Hill.

DePalma, A. (2011, October). *FEA: Only as Good* . Retrieved from https://www.asme.org/engineering-topics/articles/finite-element-analysis/fea-only-as-good-as-the-operator.

Deziel, C. (2017, April 25). *The Disadvantages of Solar Cooking*. Retrieved from http://sciencing.com/disadvantages-solar-cooking-21953.html.

Diffie Hellman, J. A. (1974). *solar energy Thermal processes.* USA,.

Dolbow, J. E. (2016). An International Journal for Innovations in Computational Methodology and Application. *Finite Elements in Analysis and Design*.

Ebieto, C. E. (2012). Construction of a Hybrid Solar Oven. *International Journal of Applied Engineering Research*.

Frances, W. J. (1960). Student Technology of Bread Making and Flour. *Food science and technology*.

Gale, T. (2006). *Solar Energy*. Retrieved from ENCYCLOPEDIA.COM: http://www.encyclopedia.com/environment/energy-government-and-defense-magazines/solar-energy

Gavin. (2007). Solar Energy Projects for the Evil Genius.

Goswami, Y. (2013). solar energy applications. *Solar Energy*.

Hottel. (1982). The performance of flat plate solar heat collectors.

Lomas, K. J. (1999). *Solar air collectors for buildings.* United Kingdom.

Lorraine Anderson, R. P. (2006). *Cooking with sunshine.* New York: Marlowe & Co.

MacEachern, D. (2016, May 5). *How to Improve the Energy Efficiency of Your Sunroom*. Retrieved from ttps://modernize.com/home-ideas/23908/how-to-improve-the-energy-efficiency-of-your-sunroom: https://modernize.com/home-ideas/23908/how-to-improve-the-energy-efficiency-of-your-sunroom

Maehlum, M. A. (2013, 8 14). *The History of Solar Energy*. Retrieved from http://energyinformative.org/the-history-of-solar-energy-timeline/.

Masson, V. (2014, June 4). *Solar panels reduce both global warming and urban heat island*. Retrieved from http://journal.frontiersin.org/article/10.3389/fenvs.2014.00014/full.

McLamb, E. (2011, September 10). *Earth's Beginnings: The Origins of Life*. Retrieved from http://www.ecology.com: http://www.ecology.com/2011/09/10/earths-beginnings-origins-life/

Miller, D. (2013). "Does the Toast make the Toaster?". *The Journal of Toaster Studies* .

Mongillo, J. F. (2011). Concentrating solar power. *A Student Guide to Energy*, 35.

Musunuri, R. K. (2007). *SOLAR THERMAL.*

Olmert, M. (2007). Kitchens. *The Colonial Williamsburg Foundation*.

Pedigo, S. (2010). *Solar Energy International*. Retrieved from https://www.solarenergy.org/.

Rinkesh. (2009). *How Do Solar Power Panels Work?* Retrieved from http://www.conserve-energy-future.com/howsolarpowerpanelswork.php.

Ruwa, T. L. (2016). Thermal energy storage for solar power plant.

Saxenaa, A. (2011). *Renewable and Sustainable Energy Reviews*.

Shahzad, A. (2013). Design and Development of Efficient Domestic Electric Cum Solar. *Journal of Basic & Applied Sciences*.

Thiele, T. (2017, 3 14). *Solar Power At Its Finest*. Retrieved from https://www.thespruce.com/g00/top-solar-energy-uses-1152263?i10c.referrer=https%3A%2F%2Fwww.google.com%2F.

W.Gruener. (2008, 8 18). *U.S. Scientists Claim World Record In Solar Cell Efficiency*. Retrieved from http://www.tomsguide.com/us/NREL-DoE-solar-cell-research,news-2374.html.

Willey, S. (n.d.). Solar Power—Is It theAnswer for YourElectric Needs? *A Backwoods Home Anthology*.

Woodford, C. (2016, September 16). *Electric toasters*. Retrieved from Explain That Stuff: http://www.explainthatstuff.com/electrictoasters.html

Zamostny, D. (2011). *Solar history: Alexandre Edmond Becquerellar*. Retrieved from Solar Energy Power: https://www.solarenergyworld.com/2011/06/17/solar-history-alexandre-edmond-becquerel/

Retrieved November 29, 2016 from https://www.timetoast.com/timelines/inventions-of-the-2nd-industrial-revolution--3 (Figure 2.1 & 2.2)

Retrieved November 29, 2016 from patents.google.com. (Figure 2.4 – 2.8)

Retrieved December 12, 2016 from http://www.cherrymortgages.com/sustainable_zero_carbon_housing/solar_water_heating_thermal_collectors_conservatory_integration.htm (Figure 2.13)

Retrieved December 12, 2016 from http://edge.rit.edu/edge/P11462/public/Select%20Product%20Concept%28s%29 (Figure 3.2)

Retrieved December 18, 2016 from http://www.tensquareintl.com/ppap.html (Figure 3.3)

Retrieved December 15, 2016 from http://www.best-reviews.co.uk/toaster/ (Figure 2.3)

Retrieved November 28, 2016 from http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/how_pv_system_works.htm. (Figure 2.11)

Retrieved November 21,2016 from www.traditionaloven.com/.

Retrieved December 19,2016 from http://www.malacca.climatemps.com/ (Figure 5.8)

Retrieved December 19, 2016 from https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,melaka,Malaysia (Figure 5.9)

Retrieved from December 18, 2016 from http://www.ideafinder.com/history/inventions/toaster.htm

Retrieved from December 18, 2016 from https://modernize.com/home-ideas/23908/how-to-improve-the-energy-efficiency-of-your-sunroom

Retrieved December 18, 2016 from http://www.ecology.com/2011/09/10/earths-beginnings-origins-life/

Retrieved December 15, 2016 from http://www.encyclopedia.com/environment/energy-government-and-defense-magazines/solar-energy

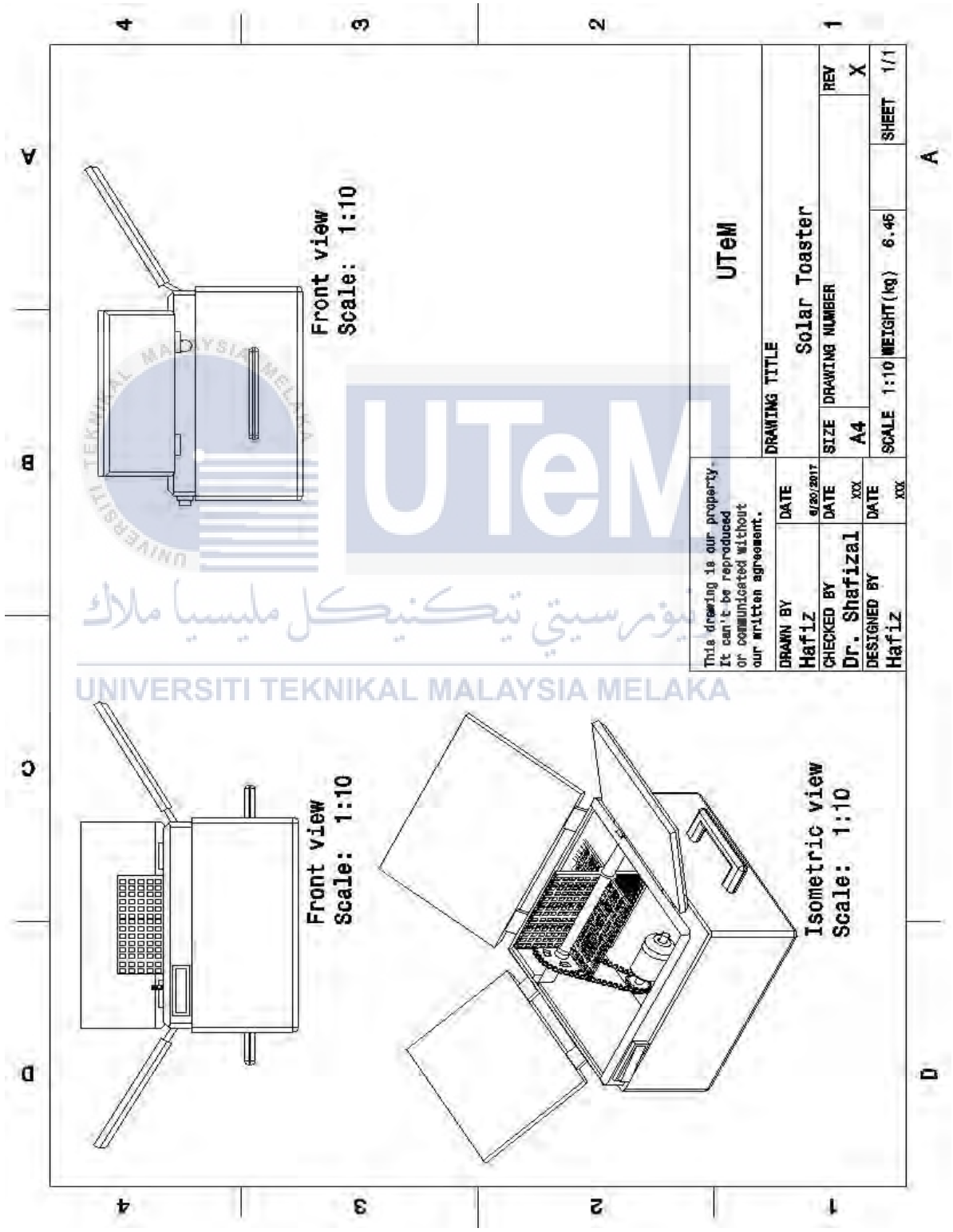
Retrieved May 21, 2017 from http://www.rowadventures.com/blog/2014/09/08/fun-facts-you-didnt-know-about-equator

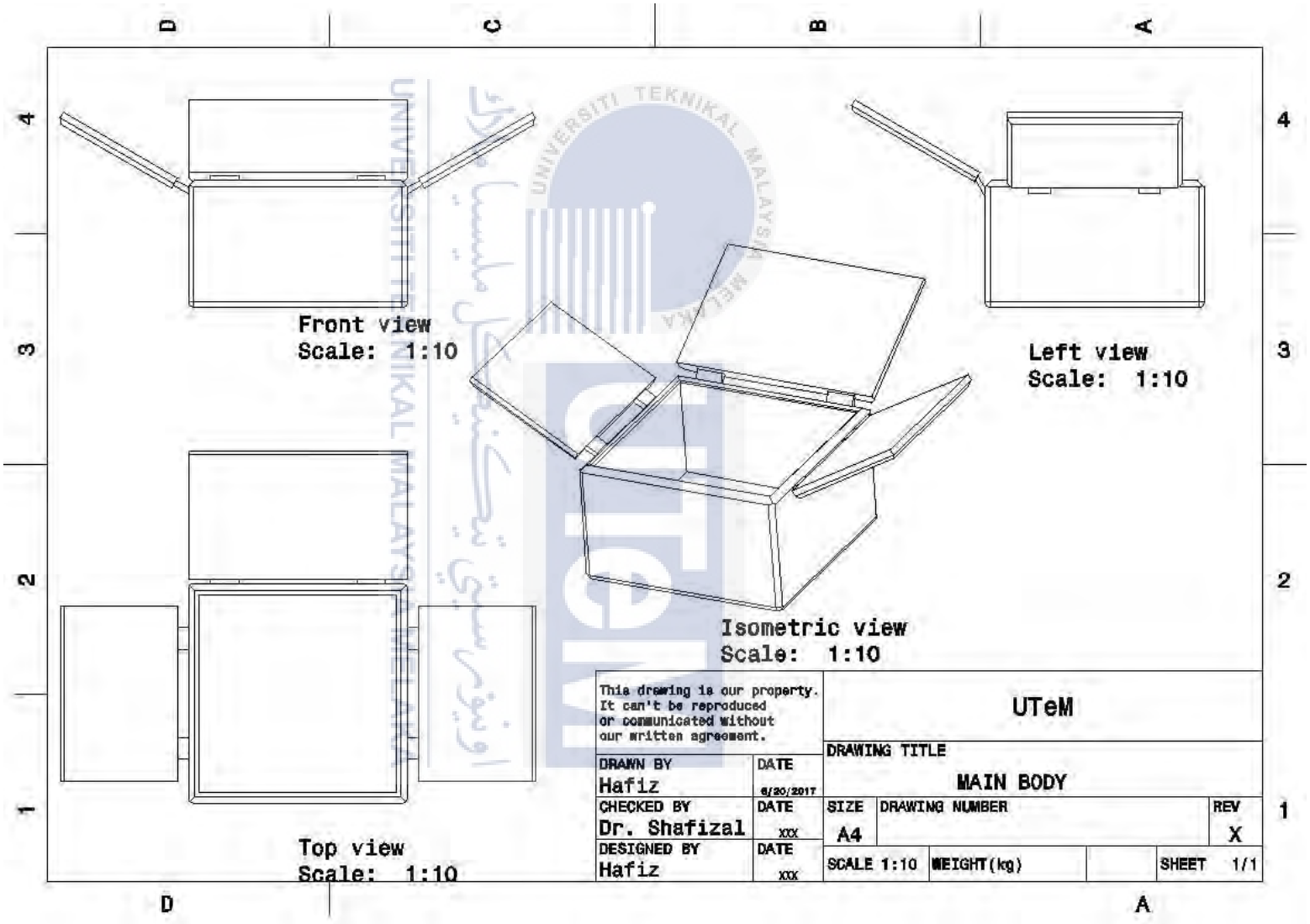
Retrieved May 21, 2017 from https://www.universetoday.com/73813/equator/

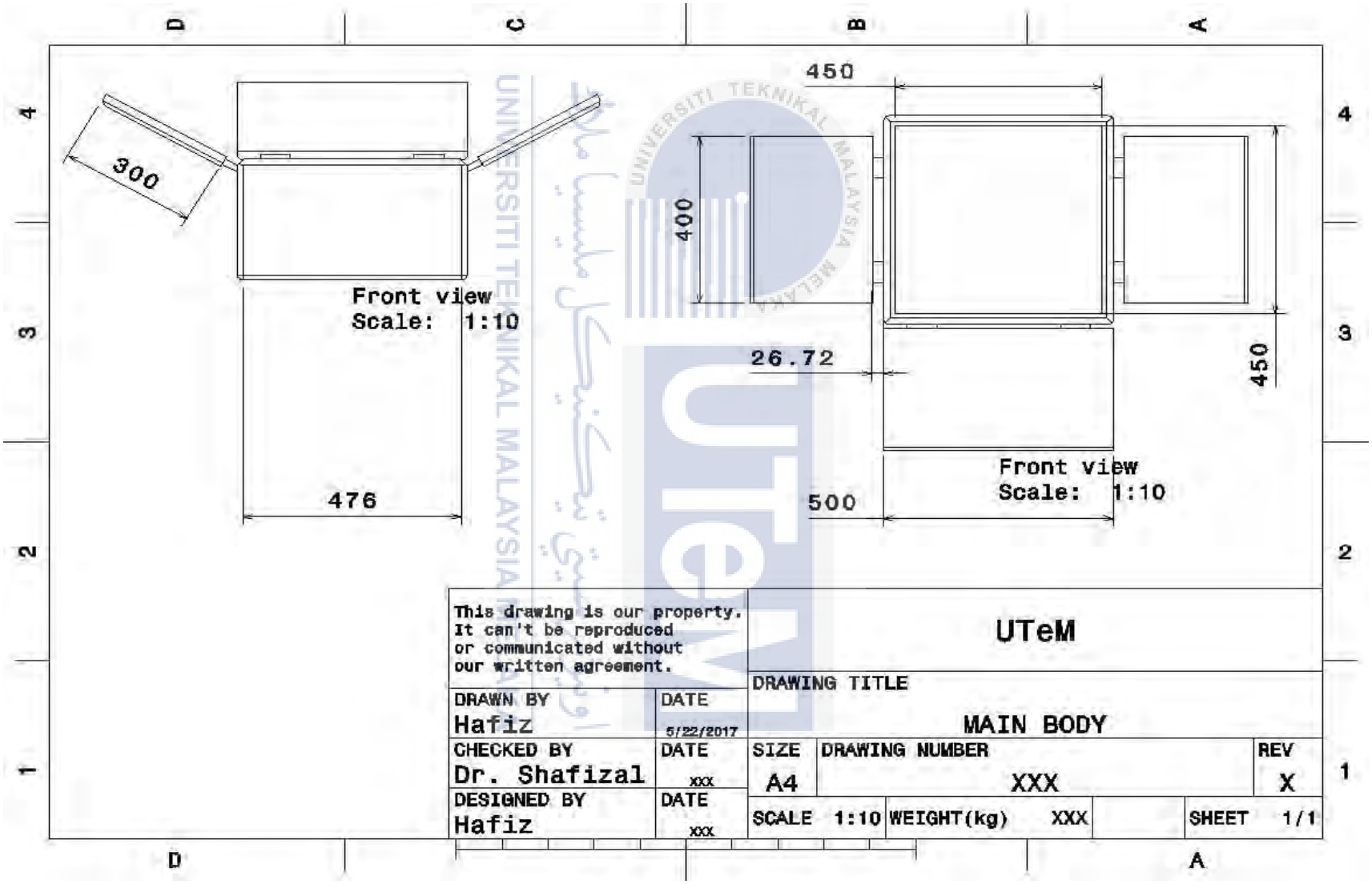
Retrieved May 21, 2017 from https://www.nasa.gov/vision/earth/lookingatearth/hurricane_record.html (Figure 2.10)

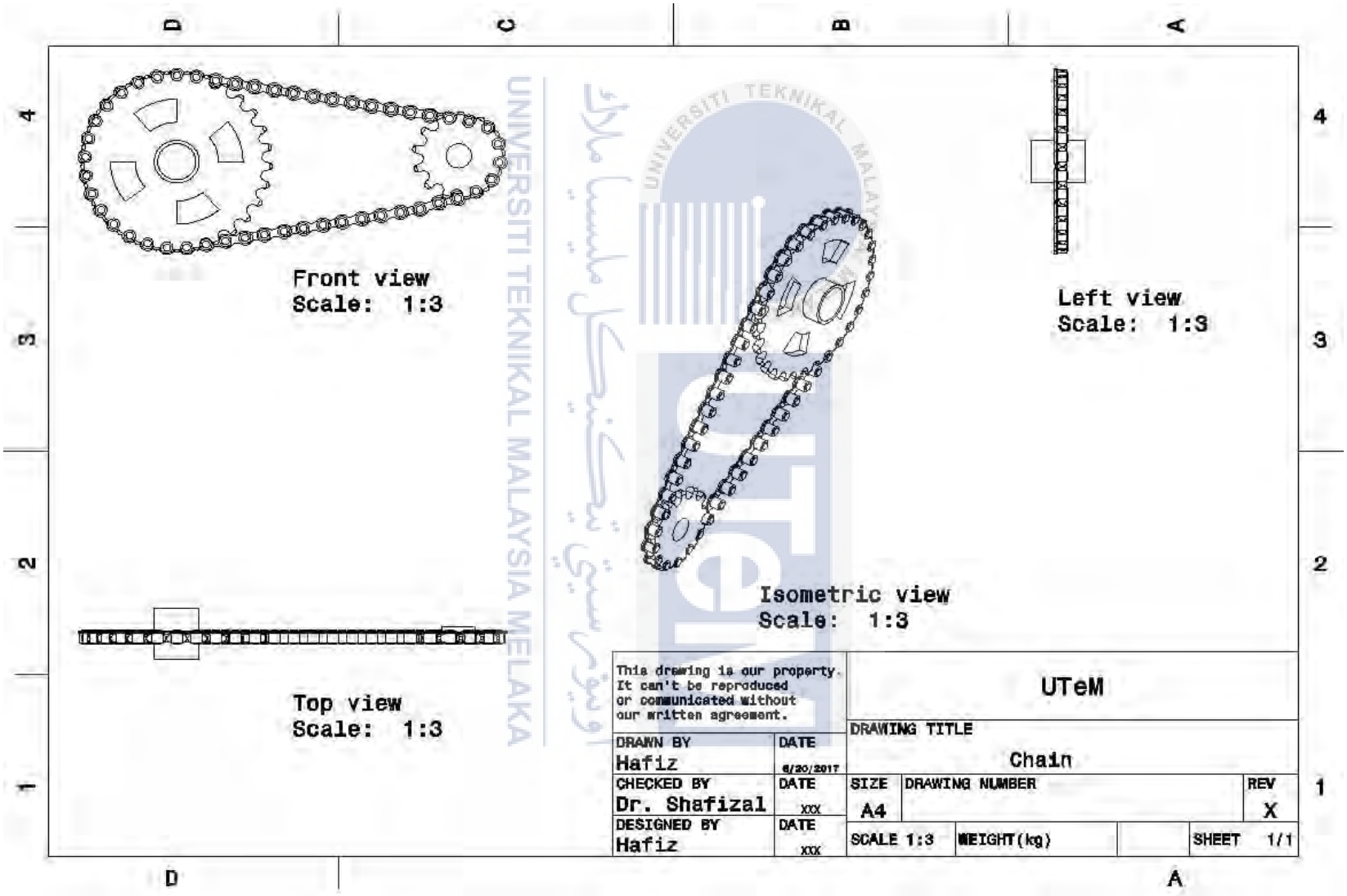
Retrieved May 21, 2017 http://www.worldatlas.com/aatlas/imagee.htm (Figure 2.9)

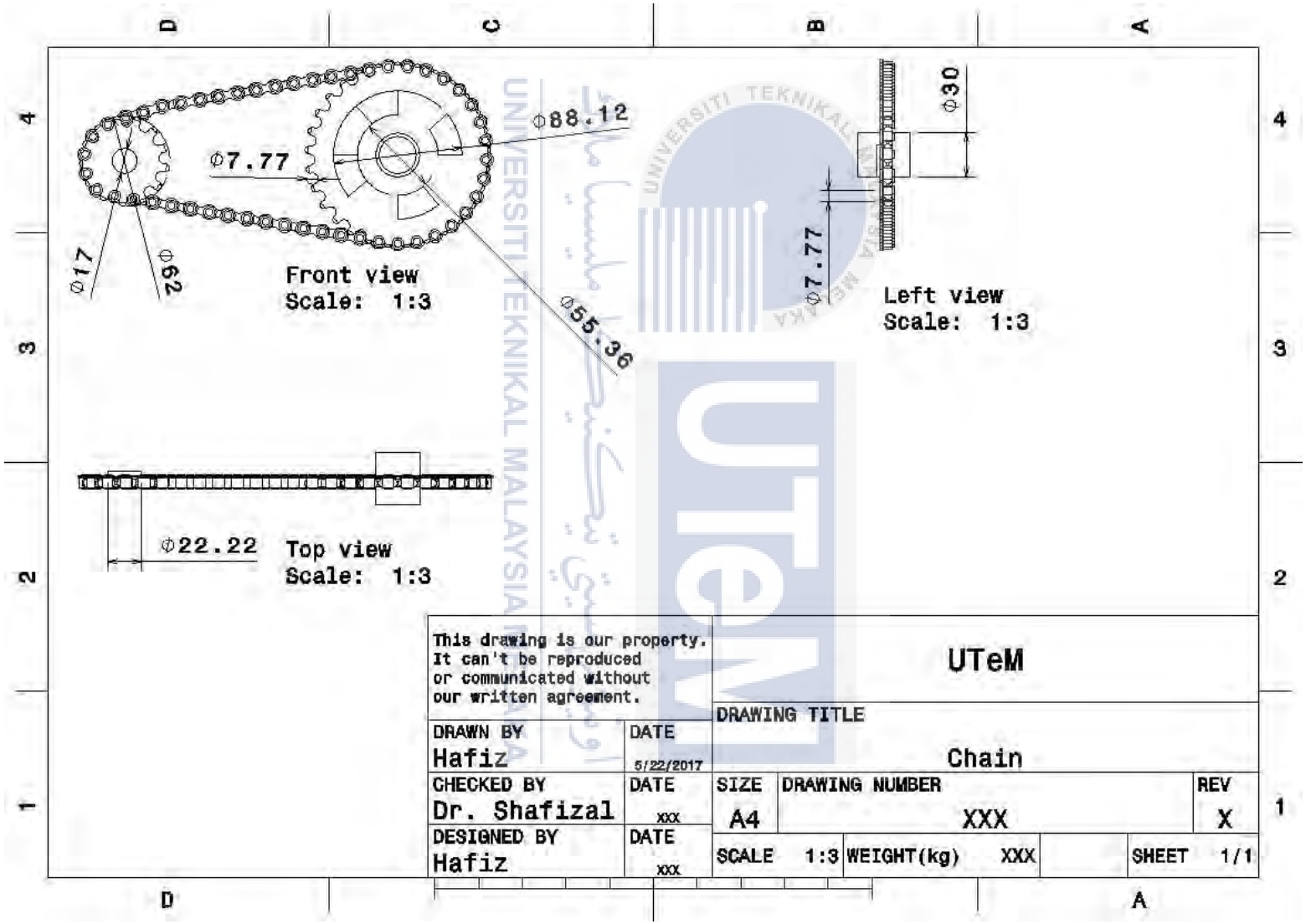
APPENDICES

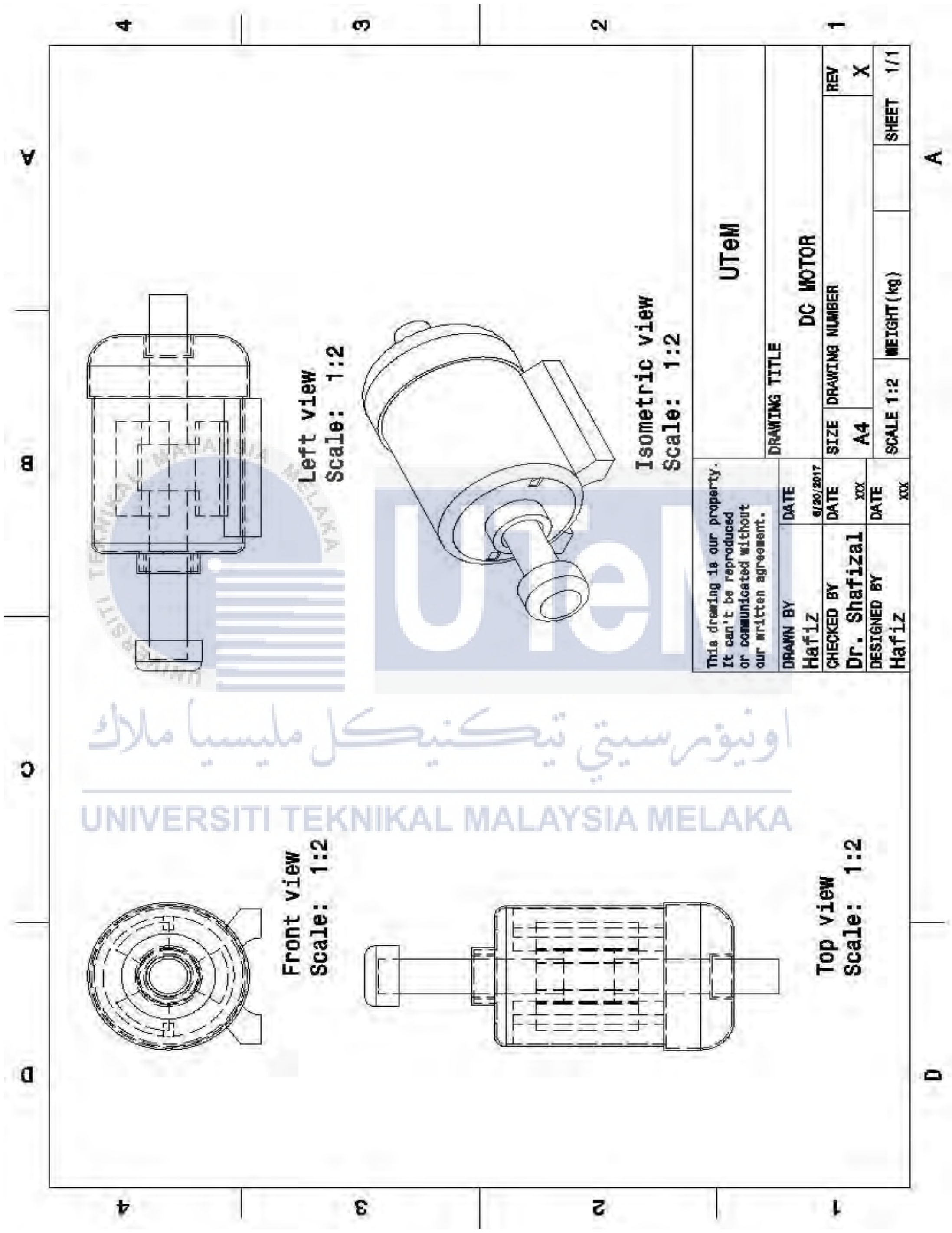


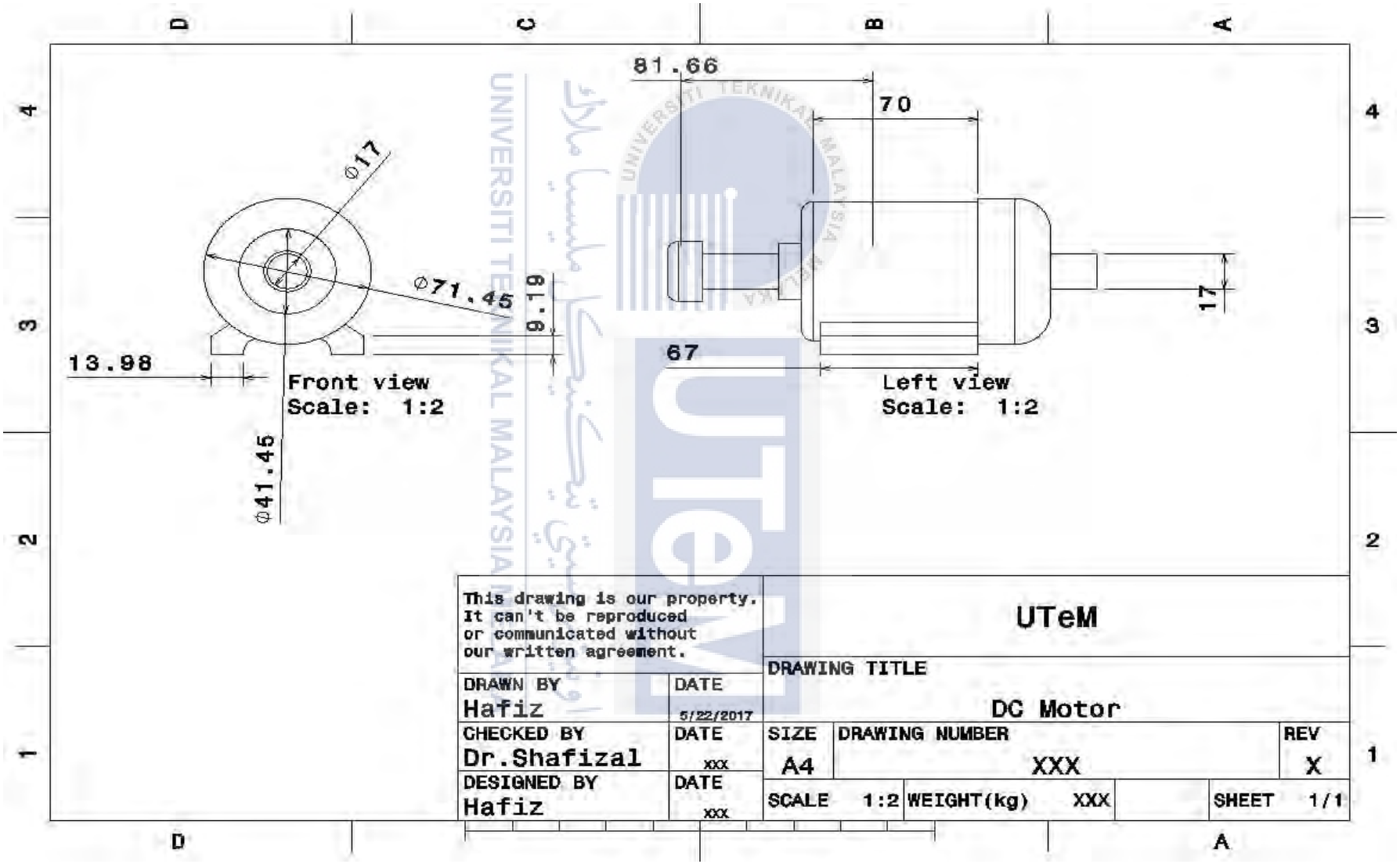

Front view
Scale: 1:10
Left view
Scale: 1:10
Isometric view
Scale: 1:10
Top view
Scale: 1:10
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
UTeM
DRAWING TITLE
MAIN BODY
DRAWN BY
Hafiz
DATE
6/20/2017
CHECKED BY
Dr. Shafizal
DATE
XXX
DESIGNED BY
Hafiz
DATE
XXX
SIZE
A4
DRAWING NUMBER
REV
X
SCALE 1:10
WEIGHT(kg)
SHEET 1/1

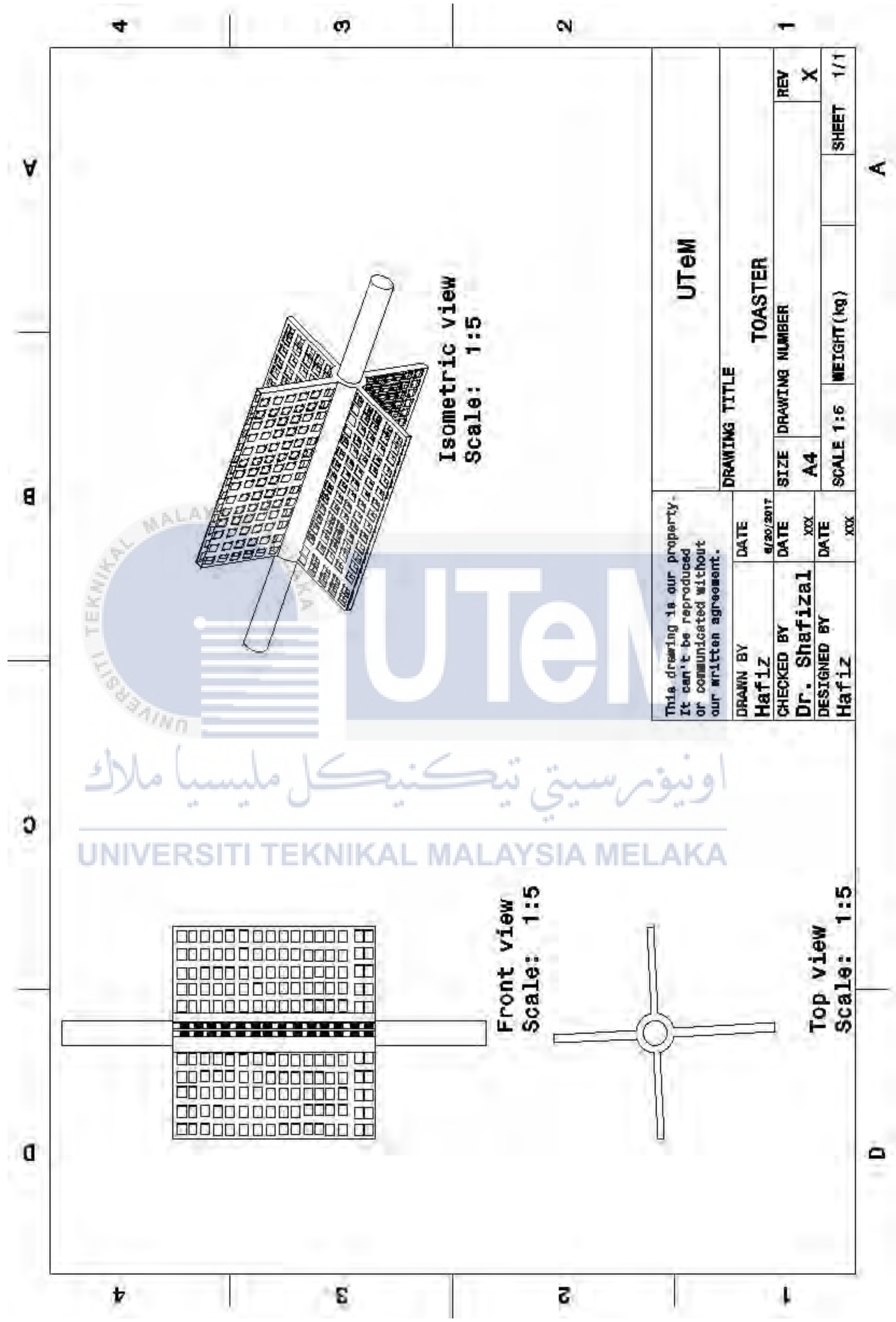

300
Front view
Scale: 1:10
476
450
400
26.72
450
500
Front view
Scale: 1:10
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
UTeM
DRAWING TITLE
MAIN BODY
DRAWN BY
Hafiz
DATE
5/22/2017
CHECKED BY
Dr. Shafizal
DATE
xxx
DESIGNED BY
Hafiz
DATE
xxx
SIZE
A4
DRAWING NUMBER
XXX
REV
X
SCALE 1:10
WEIGHT(kg) XXX
SHEET 1/1

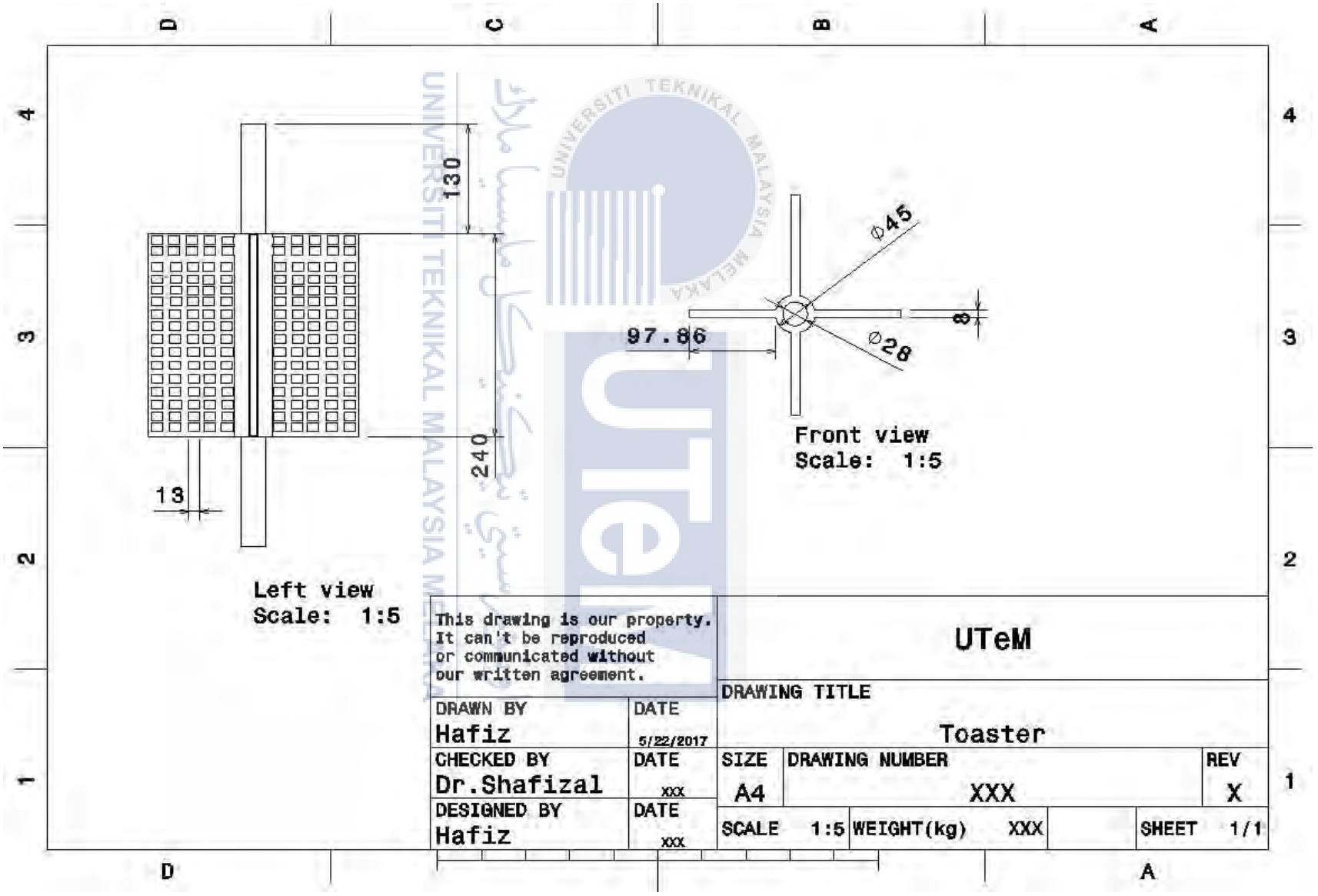

Front view
Scale: 1:3
Left view
Scale: 1:3
Isometric view
Scale: 1:3
Top view
Scale: 1:3
This drawing is our property. It can't be reproduced or communicated without our written agreement.
UTeM
DRAWING TITLE
Chain
DRAWN BY
Hafiz
DATE
6/20/2017
CHECKED BY
Dr. Shafizal
DATE
XXX
DESIGNED BY
Hafiz
DATE
XXX
SIZE
A4
DRAWING NUMBER
REV
X
SCALE 1:3
WEIGHT(kg)
SHEET 1/1


D
C
B
A
4
3
2
1
ϕ88.12
ϕ7.77
ϕ17
ϕ62
Front view
Scale: 1:3
ϕ55.36
ϕ30
ϕ7.77
Left view
Scale: 1:3
ϕ22.22
Top view
Scale: 1:3
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
UTeM
DRAWING TITLE
Chain
DRAWN BY
Hafiz
DATE
5/22/2017
CHECKED BY
Dr. Shafizal
DATE
xxx
SIZE
A4
DRAWING NUMBER
XXX
REV
X
DESIGNED BY
Hafiz
DATE
xxx
SCALE 1:3
WEIGHT(kg) XXX
SHEET 1/1




81.66
70
⌀17
⌀71.45
9.19
13.98
Front view
Scale: 1:2
⌀41.45
67
17
Left view
Scale: 1:2
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
UTeM
DRAWING TITLE
DC Motor
DRAWN BY
Hafiz
DATE
5/22/2017
CHECKED BY
Dr.Shafizal
DATE
xxx
DESIGNED BY
Hafiz
DATE
xxx
SIZE
A4
DRAWING NUMBER
XXX
REV
X
SCALE 1:2
WEIGHT(kg) XXX
SHEET 1/1




130
240
13
Left view
Scale: 1:5
Ø45
97.86
8
Ø28
Front view
Scale: 1:5
This drawing is our property.
It can't be reproduced
or communicated without
our written agreement.
UTeM
DRAWING TITLE
Toaster
DRAWN BY
Hafiz
DATE
5/22/2017
CHECKED BY
Dr.Shafizal
DATE
xxx
DESIGNED BY
Hafiz
DATE
xxx
SIZE
A4
DRAWING NUMBER
XXX
REV
X
SCALE 1:5
WEIGHT(kg) XXX
SHEET 1/1