جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

Spring 2020-21

Senior Design Project Report

Design and development of a mechanism for solar-heating of plastic sheets for thermoforming application

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Name	ID #	Personal photo
Abdulaziz Hamoud Alharbi	201700427	
Fahad AlQahtani	201700075	
Rayan Albelaihed	201001316	
Abdulaziz Almarri	201500710	
Amer Saleh Alqahtani	201602975	

Abstract

Thermoforming is a manufacturing procedure that involves heating a plastic sheet to a pliable forming temperature, shaping it in a mold, and trimming it to make a functional product. Thin-gauge thermoforming (a method of thermoforming process) is mainly used in the food, medical, and general retail industries to produce disposable cups, tubes, lids, and other items. Vehicle door and dash covers, refrigerator liners, recreational vehicle beds, and plastic pallets are also examples of thick-gauge thermoforming. The use of electric heaters (the most widely used) to soften the plastic sheets to thermoforming temperatures is an essential part of the thermoforming operation, which necessitates a significant amount of electricity (depending on thickness and material of sheet). The aim of the current project is to design and build a tabletop thin-gauge thermoforming system that uses solar-heating to heat plastic sheets and produces miniature disposable food items. In a broad scale, the solar-heating technology will not only help to lower production costs, but it will also help to reduce reliance on traditional thermal power generation methods. In Saudi Arabia, this industry has enormous commercial potential.

Acknowledgment Letter

First of all, we would like to recognize Dr. Asad for his contained support and understanding as well as his endless gaudiness though out the process. Also, we would like to extend our recognition to the Mechanical Engineering Department for their support to the part time students where they show a reasonable corporation and understanding of our daily work load and university load. Moreover, special thanks to the mechanical engineering lab technician Mr. Stephan and Dr. Elmhadi for the support which make the progress of our project is feasible.

Table of Contents

Chapter 1: Introduction

Project Defination

To achieve our goal, the project makes use of the sun's heat. First and foremost, creating the various parts and equipment used for the project. The aim is to complete the process using green energies. To clarify, thermoforming is the method of transforming plastic sheets into a desired three-dimensional shape, such as a cup holder, a liquid glass, or even a plain mobile phone cover, by combining three key factors (heat source, vacuum and pressure). Whereas the aim of the heat source is to heat the plastic sheets, the vacuum and pressure goal is to suck out the air between the mold and the sheets in order to form a negative shape of the given mold in the vacuum box. After the plastic sheets have been heated, the next step is to position the sheets over the necessary mold in the vacuum box. We must wait until the sheets are cold before modifying the exterior portion of the sheets to suit the required object after turning the vacuum to sucking the air out.

Project Objectives

Following are the objectives of this project:

- The target of this project is to plan and create a mechanism for solar warming of plastic sheets on parabolic concentrator for thermoforming application.
- To design a renewable thermoforming process use a clean energy and typical sources of energy to produce products.

Project Specification

Part	Dimensions
Bearing	width 4-mm, deep Groove Ball
Plastic sheet	Thickness: 1-30 mm Working temperature: (-50C to +70). Size: 6*15 cm,
Plastic sheet holder	Length: 8 cm 2- width 17 cm 3- Thickness 2 cm
slider track	Length: 32 cm 2- width 1cm 3- Depth of the tacks 3.5 mm
brace	Size is 40*10 cm, thickness is 1 cm
Stand	Length: 40 cm 2- width 30cm 3- high 10 cm
coupling	Diameter 8 mm outer and 4 mm inner, Length: 10 mm
swivel mechanism	Diameter 30 mm, thickness 5 mm
bolts	Length: 25 mm 2- Diameter 3 mm 3- 3- Diameter of the head hex: 8
Parabolic trough	Diameter: 34cm Thickness: 4cm

Project Application

The main object of the thermoforming process is to shape the needed shape those shapes could be used in food, sports, home and office utilities. Also, it can be used in the kitchens.

Chapter 2: Literature Review

Project Background

Creating plastic plates and plastic cups go through a well-known process called thermoforming. It is a process that involves heating a thermoplastic sheet to its melting point. Then stretching the sheet on one side of a mold, and then we let the sheet cools down to the desired shape. Depending on our desired final project we can choose the right polymer for us, there is a verity and each with specific properties. Many methods are applied to thermoform plastics into our desired shapes, for example; vacuum forming, pressure forming, twin sheet forming and more. Thermoforming has numerous applications that serve different industries and fields. Many corporations nowadays are switching to the renewable energy sources that are beneficial to our environment, and with new technology coming up every day renewable and clean energy can produce enough energy, as much as fossil fuels.

Vacuum Forming

Thermoforming is one of eldest and most common ways of processing thermoplastics. Vacuum made plastics are all over the place and play a vital part in our day-to-day lives. It's a process that includes heating a plastic sheet and stretching it across a desired mold. A vacuum box is placed under mold that provides vacuum pressure when the plastic sheet is placed on top of it, it will suck all the air in between the sheet and the mold in which the desired shape is obtained instantly with low energy. It is hard to find a process that can match the low cost, efficiency, pace of replication for prototyping a small sequence of certain shapes is and that is easy to operate. One of main advantages of vacuum forming is the speed at which products can be produced and the cost is much cheaper when comparing to injection molding. (Taylor, 1992)

Pressure Forming

Pressure Forming is a combination of vacuum shaping and downward pressure applied to the heated thermoplastic layer created by a Pressure Box on the non-mold side. The highest air pressure in normal vacuum formation is 14.7 PSI in theory. On the non-mold side, the added air pressure can reach 60 PSI, which can raise the total thermoforming pressure by up to four times that of a conventional vacuum forming operation. This increased pressure enables the production of products and parts with finer details. The mold side can resemble an injection mold component, but it will need much less tooling and cost up to 20% – 30% less. Pressure Forming is a less expensive alternative to RIM (Reaction Injection Molding) and can provide significant benefits where textured finishes are desired. When using female molds, Pressure Forming is an ideal method for moderate production volumes on medium to large products and components. (Wang, 2004)

Twin Sheet Forming

Twin sheet thermoforming is a process that is not very well known, it has always been hidden in the shadows of vacuum forming and pressure forming in thermoforming industry. Pressure forming and vacuum forming have been around for years and are widely accepted. Nonetheless, the challenging process in this twin sheet thermoforming process is that it is both vacuum and pressure forming. The two plastic sheets in twin sheet forming must be in complete aligned with each another. This is to make sure that the plastic can be synced with their pressed points. Pressed points are the areas where the two desired molds are pressured together. There is no place for mistakes during the fusion of the two sheets. They have to be perfectly synced in order to join together correctly.

The Twin sheet process allows the hot air to be trapped inside. This may cause the board to collapse. To fix this, holes are placed along the one side of the board that acts as a ventilation system. Cool air is comes in and the holes are designed in a way that conceals the presence. Painted or unpainted, surface finishing is important when thermoforming. Shadowing, a phrase used that mean noticeable deviation in surface finish, can happen on edges near where the twin sheets are pressed together. To erase shadowing, the mold can be bead blasted which will give the board a textured finish. (Araghi, 2011)

Previous Work

The supplementary need of a solar water heating system is an indicator of the end-expense user's and, therefore, the system's likelihood. The effect of using a compound parabolic collector (CPC) on the annual assisting energy savings of a solar water heating system was numerically examined and associated to the energy output of a standard flat plate collector in several locations around the world with high and low solar radiation and electricity prices in latitudes of 0, 15, 30, 45, and 60N were selected for this analysis, and the effect of using a compound parabolic collector (CPC) on the annual auxiliary energy savings of a solar water heating system was numerical The annual solar radiation ranges between 2509 and 852 kWh/m2 depending on the region. The cost of electricity varies between 0.04 and 0.28 USD per kWh. The benefit of CPC becomes more important as solar radiation rises. Extreme net present values are all reached in regions with the peak energy levels and not too high discount rates, in terms of costs and economic viability of CPC. With gross NPV values of 1,981 and 1,811 UDS, in that order, selected sites in Japan and Italy have the highest electricity prices of 0.28 and 0.27 USD/kWh, respectively. In both nations, the discount rate is about 0.3 percent. It may be inferred that investments in CPC would yield the best returns in areas with high energy costs and low discount rates, even though solar radiation is low. (Gilani, 2021)

The aim of this paper is to look at different potential reflector configurations for the compound parabolic collector (CPC) and choose the best one for the job. CPC is made up of two parabolic segments, and its simple structure allows for a wide variety of design possibilities. This structure is dependent on design criteria such as approval angle, parabolic parts, truncation of parabolas, and focus point position, and it is finished for a suitable end use. For each architecture choice, a graphical ray tracing simulation is used to analyze the arrangement of solar ray concentration. The numerous reflector arrangements are created from the scheme-morphological chart and associated based on ray concentration density and area. The study underlines a new approach to building a CPC with various architecture arrangements, which has a lot of potential for future studies. Engineers may use the different settings to choose and build a CPC that meets their needs. (Waghmare, 2019)

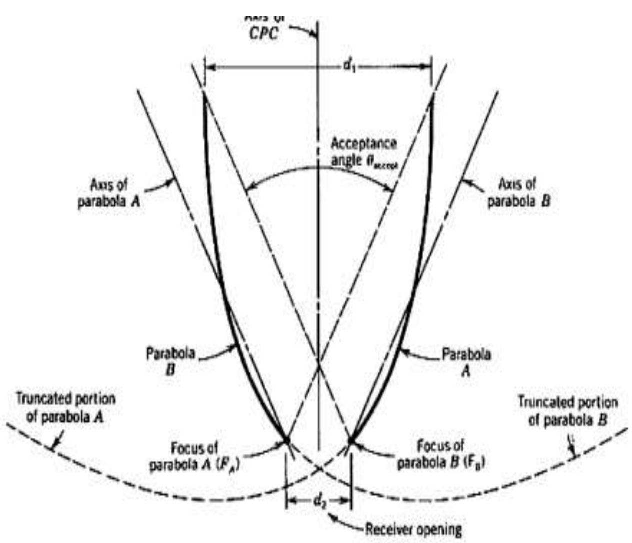


Figure: Basic construction of Compound Parabolic Collector (Waghmare, 2019)

Solar thermal applications have been mentioned as a potential source of heat for industrial processes. In this paper, the presentation of an individual solar collector under laboratory environments was compared to the performance of the collector range under field environments. A compound parabolic concentrator has been utilized as a solar collector for preheating boiler feed water. Under normal test conditions, the CPC's optical performance is calculated to be 64.8 percent. A total of 200 CPCs were deployed in the sector, each with a 3 m2 area. Over the course of ten months, the success of the final installation was monitored and evaluated. On average, the system was expected to produce 448,500 kWh of thermal energy per year, saving the equal quantity of fossil fuel. With a median difference of 14.7 percent, the average production variance was about 9%. The key causes for the poorer presentation output than predictable are heat losses through the collector manifold and piping, fouling of the CPC reflector, absorber, instrument uncertainties, and other unaccounted damages such as displacement of the evacuated tubes from their real position, loss of vacuum through evacuated tubes, and shaking of the evacuated tubes. (Kurhe, 2020)

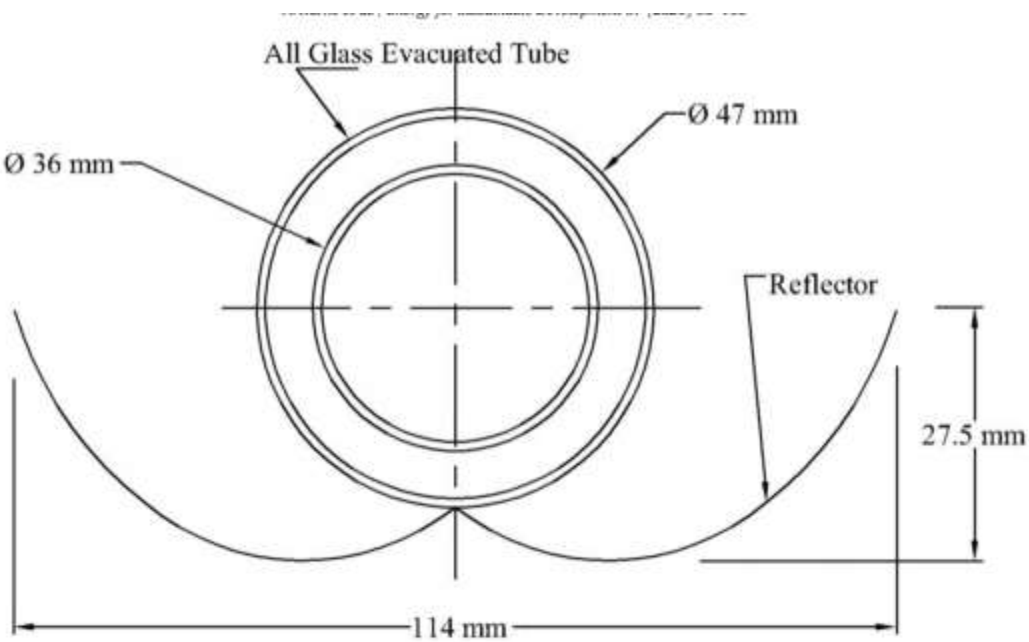


Figure: Actual CPC Construction (Kurhe, 2020)

Comparative Study

Using a detailed radiative Monte Carlo model, this paper provides a comprehensive and measureable analysis of the visual and photon absorption efficiency of the solar compound parabolic collector photo reactor. To present various experimental settings and examine their effect on the CPCP's radiation absorption, device parameters such as receiver wall properties, collector reflectivity, solar irradiation conditions, and optical thickness were varied. The findings revealed that the receiver wall's function in determining an optimum CPCP configuration and modeling its energy absorption field must be adequately defined. Finally, using an Energy Absorption Distribution Index, a new approach for optimizing solar CPCP was suggested (EADI). This index takes into account the expense of rising the overall degree of energy absorption on the radiation spread in the photo reactor length, making it a more systematic approach than the extended formula used in the literature, which calculates the optimum photocatalyst concentration solely by maximization of the TREA. To run CPCPs effectively, the app should be at least 2.20 0.20, with a further improvement based on the process's inherent kinetics and hydrodynamics, but not exceeding app = 3.58 0.20. (Acosta-Herazo, 2020)

Direct absorption nano fluid is attracting a lot of attention as a good way to harness solar energy since of its amplified fluid absorption and lower heat loss. For the first time, this research will look at the use of DANF in parabolic trough collectors, a promising collector for solar thermal systems. The simple energy equation and radiative transfer equations are mathematically solved to obtain the fluid temperature distribution and energy conversion efficiency after a illustrative flow and heat transfer analysis of many liquids in a straight tube is performed. Both previous research have ignored the impact of photons on the direct solar absorption trough collector, which is the subject of this study. When using direct solar absorption nanofluids for concentrated solar collectors, this paper investigates the performance of both absorptance and transmittance quality considerations. To demonstrate the potential of the new paradigm, a theoretical model based on energy balance is developed, and two case studies are performed. (Kasaeian, 2020)

The aim of this paper is to present experimental results related to the efficiency of a altered cavity-type receiver in a parabolic dish concentrator configuration. Isothermal receiver surface and non-isothermal receiver surface boundary conditions were used to develop the numerical models. Three mathematical concepts were used to validate the computational models with experimental results: mean of absolute variance, R2, and root mean square error. The thermal efficiency of the receiver values calculated using a numerical model with a non-isothermal receiver surface were found to be in good agreement with experimental findings. In comparison to the numerical model with isothermal surface boundary condition, the numerical model with non-isothermal surface boundary condition produced more reliable results. To approximate the contributions of different types of heat transfer, a receiver heat loss study based on the experimental results is also performed. Radiation, convection, and conduction losses account for about 27.47 percent, 70.89 percent, and 1.83 percent of overall receiver damage, respectively. In order to predict the influence of studied parameters on receiver selection performance, an empirical correlation based on experimental results is also provided. The developed models would help with the design and estimation of dish concentrator system performance with a modified cavity receiver for applications like power generation, water heating, air conditioning, solar cooking, solar drying, energy storage, and so on. The differential-mathematical analysis and modeling of a hemispherical-shaped modified cavity receiver with a non-uniform surface temperature boundary condition presented in this manuscript is exceptional. It can quantify the heat transfer fluid's temperature differential as a function of receiver height, accounting for receiver cavity losses due to radiation and convection modes. (Bopche, 2021)

While in our project, To achieve our goal, the project makes use of the sun's heat. First and foremost, creating the various parts and equipment used for the project. The aim is to complete the process using green energies. To clarify, thermoforming is the method of transforming plastic sheets into a desired three-dimensional shape, such as a cup holder, a liquid glass, or even a plain mobile phone cover, by combining three key factors (heat source, vacuum and pressure). Whereas the aim of the heat source is to heat the plastic sheets, the vacuum and pressure goal is to suck out the air between the mold and the sheets in order to form a negative shape of the given mold in the vacuum box. After the plastic sheets have been heated, the next step is to position the sheets over the necessary mold in the vacuum box. We must wait until the sheets are cold before modifying the exterior portion of the sheets to suit the required object after turning the vacuum to sucking the air out.

Chapter 3: System Design

3.1 Design Constraints and Design Methodology

3.1.1 Geometrical Constraints

Initially the project plan was very clear, and we start planning and when went throw the details then the challenges started to show on the surface. Our first struggle was the design of mechanism using Solid work which is needed to move the plastic sheet on linear motion to make sure the heat is distributed around the whole surface. The second challenge for us was the needed dimension to create enough heat to warm up the plastics sheet.

3.1.2 Sustainability

As for sustainability our project may not have any issue sine all the parts which used in the project are easy to find except for the plastics sheet which need to be communicated earlier with the right buyer.

3.1.3 Environmental

Since our project depends on the solar energy as the heating source we are considered as pro-environment project which will not generate any type of waste that may harm our environment.

3.1.4 Social Constraints

Using the sun as heating source as we are doing in our project is not usual in the local community. Hopefully this type of project will encourage the community to start thinking of solar energy as the new oil and shift our minds from sing oil or coal as heating sources.

3.1.5 Economic Constraints

Our project in term of economy it is not costly as we are using clean energy which doesn’t need to pay for it.

3.1.6 Safety

Safety is one of the most important requirements in any project. Based on the tools and the elements that we used to assemble our project, none of them can create a huge danger on the workers and the environment. Except when the material is hot caution must be considered, even thou as we side we don’t want to melt the material, so we will not reach the melting temperature hence the material will not be that hot to create severe damage.

3.1.7 Ethical Concerns

They are similar project been done and we try to create our own by using different mechanism and we also embrace of the aspects in these projects.

3.2 Design Methodology

3.2.1 Thermoforming Theory

Thermoforming could be a process utilizing warm and either vacuum or high gas weight to create a mollified thermoplastic film onto a mandrel of wanted shape and measure. The film is set on the tooling plate, transported into the chamber that's at that point heated. The vacuum or gas weight pushes the softened film down onto the tooling embed to require the shape. Although it may be a broadly utilized innovation in shaping thermoplastics for bundling, white products, and customer items, the integration of printed hardware into the thermoforming prepare is moderately recent. The effect of the thermoforming process on the execution and confinements of printed hardware circuitry and the item and prepare plan rules are not completely understood**.**

3.2.2 Finding the Focal Point for the parabolic trough

The focal point for the parabolic through is calculated using the equation below.

f = x/4a is the formula for a parabola.

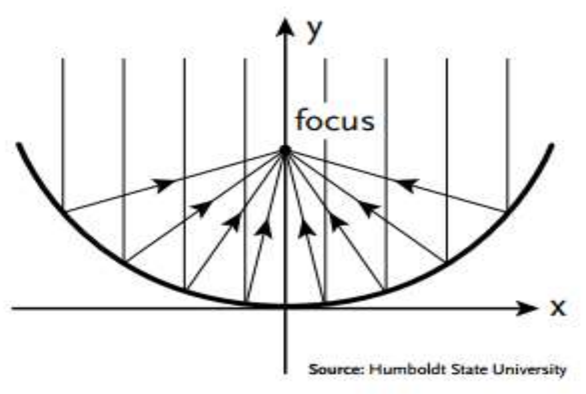
Follow these steps to locate a parabola's focal point:

Step 1: Find the parabola's largest diameter (width) at the rim.

Step 2: To find the circumference (x), divide the diameter by two and square the result (x).

Step 3: Multiply the depth of the parabola (a) at its vertex by four (4a).

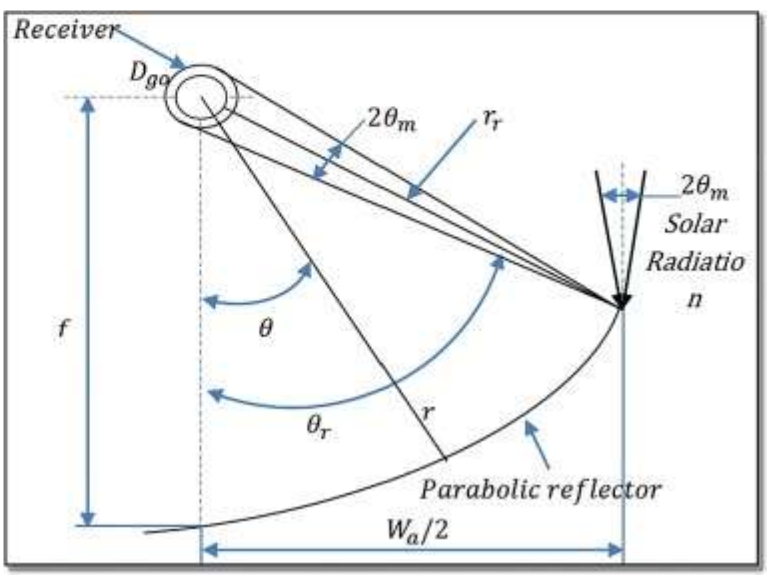
Step 4: Multiply the result of Step 2 by the result of Step 3 (x/4a). The distance between the parabola's vertex and its focal point is the response.



The focal point is the point at which light waves traveling parallel to the axis of the parabola meet after reflecting off its surface.

3.2.3 Radiation Analysis

To determine the radiation districts and where they are viable, we must consider areas where sun-oriented radiation is readily available to collect vitality and form the environment. It is called basic to verify achievability by looking at the preferences and environment to see if they are sufficient. The proposal will be evaluated based on the feasibility analysis of sun-oriented control plants. In addition, industrialized countries have long-term calculated data of solar-powered radiation that can be used to assess the region's solar energy accessibility. In either case, in places where long-term data is not accessible, various techniques and material science are used to assess data on solar vitality. To explain, sun-based vitality takes the form of electromagnetic radiation with wavelengths ranging from about 0.3 m (100.6 m) to over 3 m, as opposed to bright (less than 0.4 m), unmistakable (0.4 m to 0.7 m), and infrared (over 0.7 m); the majority of this vitality is contained within the obvious and near-infrared wavelength ranges. Irradiance, or the energy per unit time per unit area (kW/m2), is a measurement of incident solar radiation, also known as insolation. The solar constant, Io, is the total amount of solar radiation falling on a surface normal to the sun's rays beyond the earth's atmosphere, extra-terrestrial insolation, at a mean earth-sun distance Do. New calculations recently revealed the magnitude of the solar constant to be 1366.1 W/m2.



3.2.4 Solar Angles Analysis

The seasonal variation in solar radiation availability at the earth's surface is explained by the geometry of the planet's relative rotation around the sun. The earth's distance from the sun varies during the year, with the minimum distance being 1.4711011 m at the winter solstice (December 21) and the maximum distance being 1.5211011 m at the summer solstice (June 21). (21st of June) Year-round, the average diameter of the earth's sun is 1.496 1011 m. As a result, the amount of solar radiation intercepted by the earth varies over the year, peaking on December 21 and falling on June 21. The earth's normal rotation axis intersects the axis of its ecliptic orbital plane around the sun at a 23.45-degree angle. Seasonal changes in the amount of solar radiation available at any given location on the earth are mostly caused by this tilt. The angle created by the earth-sun line (which passes through their center) and the plane going through the equator is known as the solar declination angle, or s. The declination angle is -23.45° on December 21 and +23.45° on June 21.

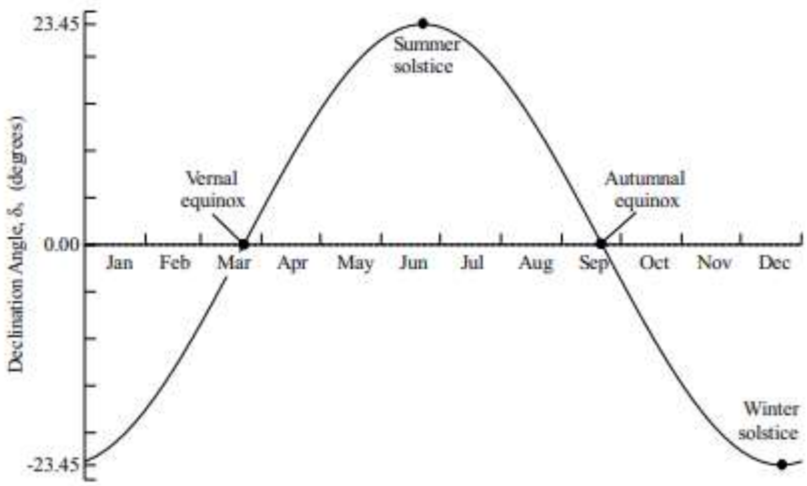


Figure: Variation of declination angle, throughout year

$$\delta_s = 23.45^\circ \sin\left[\frac{360\,(284+n)}{365}\right]$$

Figure: Illustrating angle analysis for solar system

3.3 Project Subsystems and Components

3.3.1 Screw

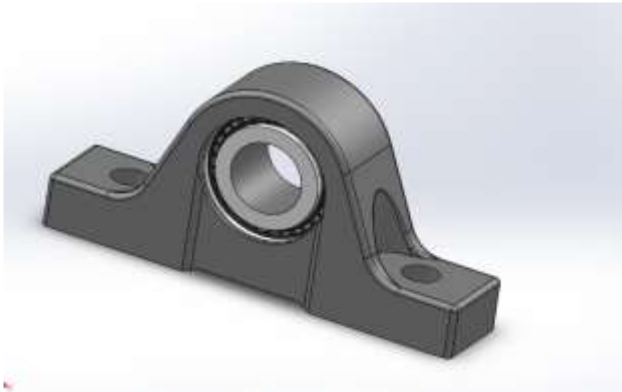
The screw has been chosen from the toolbox from the Solid-Works® software.

1- Length: 34 cm

2- Thickness of the head: 4 mm

3.3.2 Bearing

Roller Bearings width 4-mm the standard of the bearing is: Deep Groove Ball



3.3.3 Plastic Sheet

Thickness: 1-30 mm

Working temperature: (-50C to +70).

Size: 6*15 cm

3.3.4 Plastic Sheet Holder

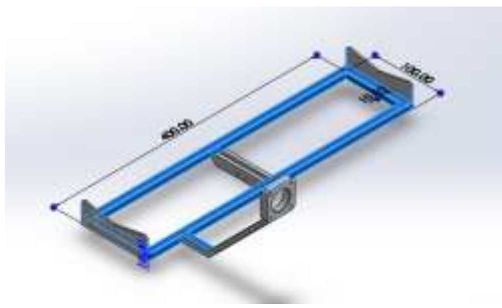
1. Length: 8 cm
2. width 17 cm
3. Thickness 2 cm

3.3.5 Slider Track

1. Length: 32 cm
2. width 1cm
3. Depth of the tacks 3.5 mm

3.3.6 Brace

1. Size is 40*10 cm
2. Thickness is 1 cm



3.3.7 Stand

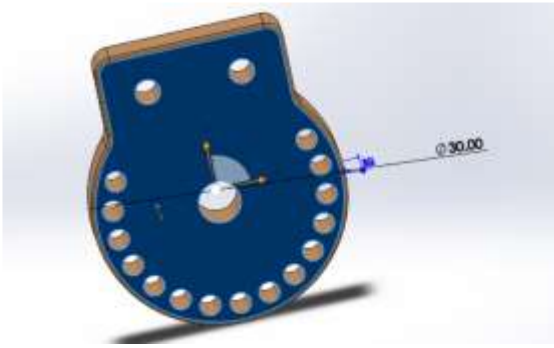
1. Length: 40 cm
2. width 30cm
3. high 10 cm
4. Size of the squires 1*1 cm

3.3.8 Coupling

1. Diameter 8 mm outer
2. 4 mm inner Diameter
3. Length: 10 mm

3.3.9 Swivel Mechanism

1. Diameter 30 mm
2. Thickness 5 mm



3.3.10 Bolts

1. Length: 9 mm
2. Diameter 3 mm
3. Diameter of the head hex: 4

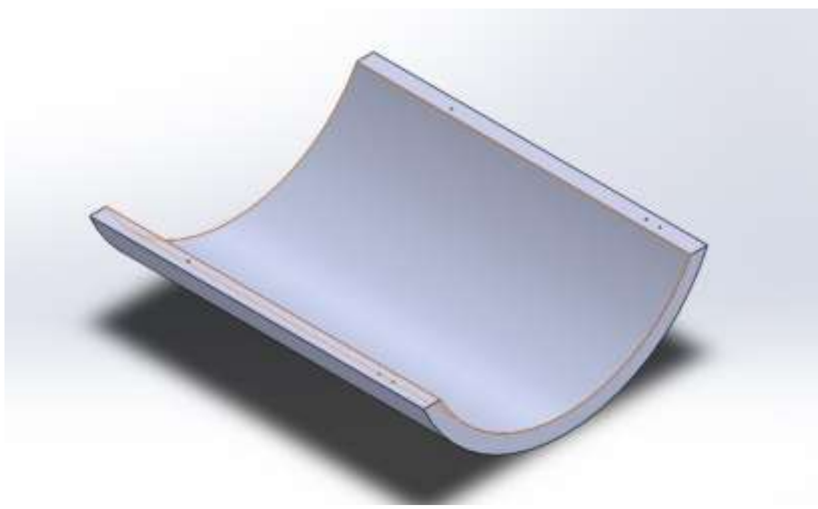
1. Length: 25 mm
2. Diameter 3 mm
3. Diameter of the head hex: 8

3.3.11 Nut

Inner diameter 4mm head hex nut

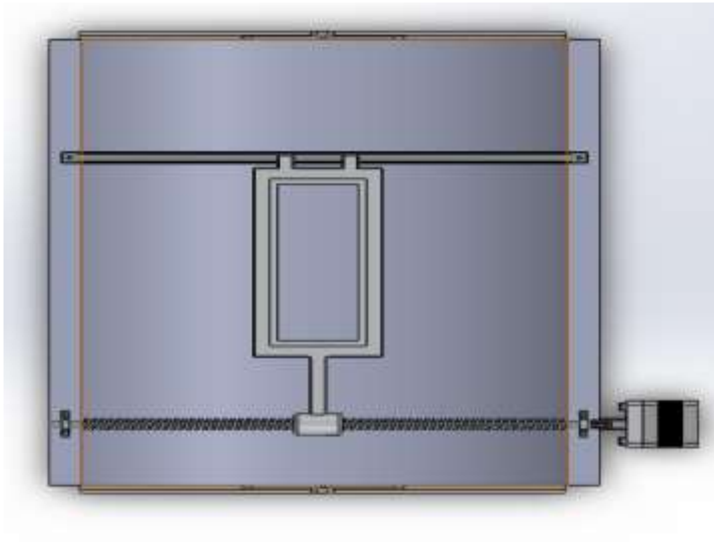
3.3.12 Parabolic Trough

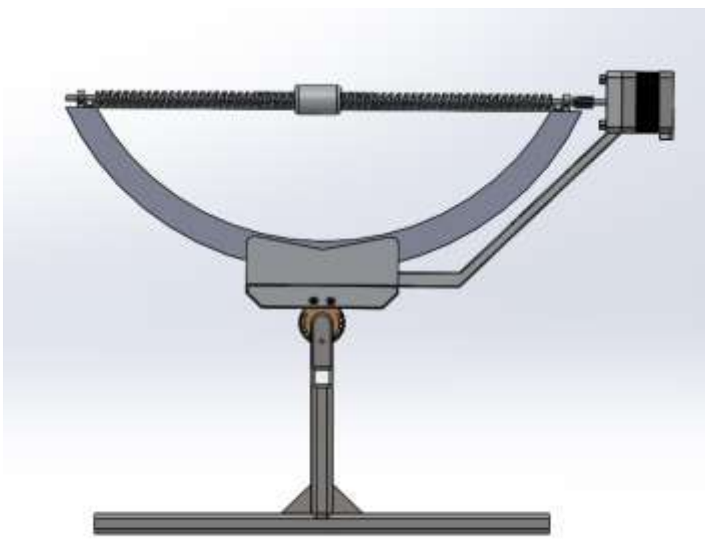
1. Diameter: 34cm
2. Thickness: 4cm



3.4 Implementation

Solar collector with a parabolic trough and three minor parts: a solar collector, a plastic sheet holder, and a frame that holds the collector and tilts it against the sun's radiation. A carbon steel sheet will be covered with an aluminum foil, which will reflect a large amount of solar rays back from the sheet's top. The aluminum sheet would be mounted on top of a parabolic surface, giving it the perfect shape and focal point for reflecting solar rays. A square metal frame the height of the plastic sheet would be used in the plastic sheet holder. It will be fitted with a linear motor to ensure that it remains stationary on the top of the Parabolic Trough for the duration required for the sheet to melt. By using this linear motion, we can ensure that the temperature is evenly spread over the plastic layer. The foundation, which will have a swivel function to ensure that the parabolic surface is angled against the solar radiation, will be the third component.





The project consists of multiple parts and components. To explain, the first to design a parabolic surface to collect the solar radiation to reach a certain point of heat and to make sure we can reach the needed heat point. In that point, the plastic sheets will be placed to absorb that heat and form to a workable material. And to make sure the heat is distrusted well enough across the sheet we must create a mechanism to reach specific focal point as you know, with increasing the temperature of the work piece, the plastic sheets will be more eligible to expand and give you more delicate designs. After reaching that step, the work piece will transfer to final station which is the vacuum box which will not be part of our project.

Chapter 4: System Testing and Analysis

4.1 Experimental Setup

4.1.1 Infrared Thermometer

For this section we had two setups. In the first setup we wanted to measure the temperature of the plastic sheet when we expose it to the heater. Thus we used an infrared thermometer to measure the temperature. Infrared Thermometer is a thermometer that measure temperature without contact from a specific distance by using radiation, plus leaser is used in this device to help aiming at the desired object. How did we used it? We simply wanted to measure the temperature of the plastic sheet when we expose it to the heater in order to know if the material reached it softening temperature.

Specifications	
Temperature Range	-30°C to 500°C (-22°F to 932°F)
Accuracy	±1.5°C or ±1.5% of reading, whichever is greater -10°C to 0°C: ±2.0 -30°C to -10°C: ±3.0
Response Time (95%)	< 500 ms (95% of reading)
Spectral Response	8 to 14 microns
Emissivity	0.10 to 1.00
Optical Resolution	10:1 (calculated at 90% energy)
Display Resolution	0.1°C (0.2°F)
Repeatability of readings	±0.8% of reading or < ±1.0°C (2°F), whichever is greater
Power	AA battery
Battery Life	10 hours with laser and backlight on

Physical Specifications		
Weight	255 g (8.99 oz)	
Size	175 x 85 x 75 mm (6.88 x 3.34 x 2.95 in)	
Operating Temperature	0°C to 50°C (32°F to 122°F)	
Storage Temperature	20°C to 60°C (-4°F to 140°F), (without battery)	
Operating Humidity	10% to 90% RH non-condensing at 30°C (86°F)	
Operating Altitude	2000 meters above mean sea level	
Storage Altitude	12,000 meters above mean sea level	
IP Rating	IP 54 per IEC 60529	
Drop Test	3 meters	
Vibration and Shock	IEC 68-2-6 2.5 g, 10 to 200 Hz, IEC 68-2-27, 50 g, 11 ms	
EMC	EN 61326-1:2006 EN 61326-2:2006	
Standards and agency approval	Compliance	EN/IEC 61010-1: 2001
	Laser Saftey	FDA and EN 60825-1 Class II

Testing Parameters	Objective
Infrared Thermometer	To measure the Temperature

4.2 Results, Analysis and Discussions

By knowing the specifications of our plastic sheet and applying the correct formulas, plus working with a solar energy harvesting mechanism.

We need only (12-14 s) to heat up the plastic then our project will start working.

Formulas:

Formula	Unit
$Q = mc\Delta T$	J
$t = Q \div P$	S

Chapter 5: Project Management

5.1 Project Plan and Contribution of Team Members

In our project, there are many tasks included. Each task is assigned to one or more members. The details about division of whole work is being presented below:

Task	Start Date	Days to complete	Responsible
Task 1: Plan			
Project Identification/Allocation	20/1/2021	4	Abdulaziz Hamoud Alharbi , Fahd Alqahtani
Objective Identification	25/1/2021	2	Rayan Albelaihed, Abdulaziz Almarri
Gannt Chart	29/1/2021	3	Amer Saleh Alqahtani
Task 2: Report Establishment			
Report Formatting, Table of Context & Acknowledgement.	2/2/2021	1	Abdulaziz Hamoud Alharbi
Chapter # 1: Introduction	4/2/2021	2	Fahd Alqahtani
Chapter # 1: Objectives	7/2/2021	1	Faisal Alqahtani
Chapter # 2: Background	9/2/2021	2	Rayan Albeilaihed
Chapter # 2: Previous Work	12/2/2021	2	Abdulaziz Almarri
Chapter # 2: Comparative Study	15/2/2021	2	Amer Saleh Alqahtani
Task 3: System Design			
Chapter #3: Design	20/2/2021	3	Abdulaziz Hamoud Alharbi , Fahd Alqahtani
Chapter #3: Calculations	24/2/2021	2	Everyone
Chapter #3: 3D Modelling	27/2/2021	2	Rayan Albelaihed , Abdulaziz Almarri
Material Selection / Machining	2/3/2021	14	Everyone
Gathering Parts	16/3/2021	2	Everyone

Task 4: Midterm Presentation			
1st Monthly Progress Report	TBA	1	Everyone
PP Presentation	19/3/2021	5	Everyone
Task 5: Testing & Data Collection			
Prototype Assembly / Completion	19/3/2021	4	Everyone
Pre-Testing Observation	23/3/2021	4	Amer Saleh Alqahtani
Chapter #4: System Testing	27/3/2021	5	Abdulaziz Hamoud Alharbi
Chapter #4: System Analysis	1/4/2021	5	Fahd Alqahtani
Chapter #5: Project Management	6/4/2021	4	Rayan Albelaihed
Chapter #6: Project Analysis	10/4/2021	4	Abdulaziz Almarri
Task 6: Deliverables & Final Presentation			
2nd Monthly Progress Report	13/5/2021	1	Everyone
Final Project Report	12/5/2021	3	Everyone
Final Presentation PP	19/5/2021	2	Everyone

Table: Plan of Work

5.2 Project Execution Monitoring

During our project, for the successful accomplishment of goals, regular meetings and sittings were arranged to ensure the continuous monitoring and meeting deadlines. Following is the list of events and meetings being conducted during this whole period of project formulation:

Time/ Date	Activities/ Events
Once time a week	Assessment class
Biweekly	Meeting with supervisor
Weekly	Meeting with group members

Table: List of activities being performed for monitoring project progress

5.3 Project Bill of Materials and Budget

The table below is showing the cost of parts that we purchased and the one we designed. Moreover, it also illustrates about the cost of material of which we designed this project.

Part	**Cost**
Parabolic trough	600
Swivel mechanism	220
Plastic sheet holder	200
Bearings	180
Screw	230
Slider track	220
Stand	250
Motor	815
Motor driver	60
Microcontroller	65

Table: Overall cost of project analysis

Chapter 6: Project Analysis

6.1 Life-long Learning

When we were working in our project, we gained diverse knowledge about different things, be it software skills, hardware skills, time management skills and project management skills. By working as a team we learnt that how to manage tasks by ensuring time management and good communication skills with members of team. In this part, we will explain the number of skills we gained since we worked on this project.

6.1.1 Software Skills

In this project, we gained hand on experience of working on softwares like MS Word, MS Powerpoint and Solidworks. For designing of our project, we used the software of solidworks which helped us polishing our skills in this designing software. In addition to this, we learnt about using word and powerpoint while writing report and making presentation.

6.1.2 Hardware Skills

During our project, we learnt about assembling the designed parts to fabricate our desired project. We also have a hand on experience of the skill of welding. Moreover, I also learnt about doing sound calculations before moving towards fabrication part of project because a small difference in calculations can result into a huge difference while fabrication of project.

6.1.3 Management Skills

During project work, we learnt about time management that how deadlines can be met efficiently during the execution of project. Moreover, there are many skills like distribution of work, team work and leading the team in the right direction that I learnt during the completion of project.

6.2 Impact of Engineering Solutions

Following are the social, economic and environmental impacts of our project:

6.2.1 Social Impacts of project

Since most of the projects are carried out to develop product and contribute to making the industry better and efficient by using the minimum amount of resources as possible. In terms of society impact , we are honored to magnify awareness towards thermoforming process and how simple tools can achechve them . the project will help house holds who have an vacuum cleaner and other tools to make the exact mold that they wish to make. Moreover, cities residents must be aware of the different green resources that we can use such as the solar energy and Wind energy.

6.2.2 Economic Impacts of project

Thermoforming process may seem complicated or advanced process. However, with right tools and materials, everything is possible. In the beginning, we thought that we had order the parts from abroad but we researched for solutions and took our time to find the ultimate result which is to build it ourselves. After testing the materials, we concluded that we need more workable material. In the End the total money spent did not exceeded the 200 SAR and most of that goes to the fact that we used available recourses to our use.

6.2.3 Environmental Impacts of project

The major impact of our project does not focus in this side . Nonetheless, there is a minimal reduction of polluting the earth. Whereas users won’t need to use there fuel engine cars when they can produce their needs in home. Our ambition is to aware others about this process and its components.

6.3 Contemporary Issues Addressed

We can consider this part as an advantage for us because we do not have Contemporary Issues. Because we are depending heavily on clean energy, in other words our main source of energy is the sun, so we can say that our project is a environmental friendly project that uses small amount of electricity. In addition, all of our products can be recycled which consider as a huge advantage in this manner.

Chapter 7: Conclusion and Future Recommendations

7.1 Conclusion

In every work you do in your life you gain experience and new information that can benefit you in your normal life. During or project we went through a lot of challenges that made us improve our communication skills, critical thinking skills and we managed to work as a team. In addition, while working in the project we managed to achieve our main goals and results, which support and follow the 2030 vision. We proved that we can implement the concept of thermoplastic process by using limited sources of energy plus constructing simple designing plane and using simple parts that are in the hand of reach for everyone. Based on engineering science, we used many engineering aspects such as heat transfer, manufacturing, designing and computer aided design. Those areas of engineering supported us and helped us and improved our background. In this project, we learned how to use various devices that are essential in our lives such as sensors, vacuum and heaters. In addition, we managed to improve our skills in engineering software such as solidworks. This project like any other projects it must have some challenges and problems. We faced a problem with converting the solar energy to electrical energy, so we disregard the idea of using clean energy and deepened on electrical energy.

7.2 Future Recommendations

Below is a list of important points should be taken in consideration for whom going to continue in our project:

- Clean energy: for students that desire to enhance and improve our project we recommend them to utilize green energy to be their main source of energy. Due to the shortage of time and focusing on other aspects in our project we did not manage to use the solar energy. However, now we made the concept behind our project very clear plus we selected the right formulas and the specifications for the whole project. Thus the next group just have to focus on the green energy part to fulfill the main goal of this project and follow the 2030 vision.
- Heater with bigger surface area: at this part having a heater with a larger surface area will give the ability to heat and cover bigger area of the plastic sheet. By achieving that we can use larger and complicated geometries of molds. Our heater had a small surface area so the next group must have a bigger heater to be able to produce various shapes.

References

Acosta-Herazo, R. (2020). An optical and energy absorption analysis of the solar compound parabolic collector photoreactor (CPCP): The impact of the radiation distribution on its optimization. *Chemical Engineering Journal*, 12.

Araghi. (2011). Review on the development of a hybrid incremental sheet forming system for small batch sizes and individualized production. *Production Engineerin 5(4)*, 393-404.

Bopche, V. K. (2021). Thermal performance analysis of a Solar parabolic dish concentrator system with modified cavity receiver. *World Journal of Engineering*, 25.

Gilani, H. A. (2021). Techno-economic study of compound parabolic collector in solar water heating system in the northern hemisphere. *Applied Thermal Engineering*, 15.

Hsiao. (1999). Numerical analysis and optimal design of composite thermoforming process. *Computer methods in applied mechanics and engineering, 177(1-2)*, 1-34.

Kasaeian, A. (2020). Evaluation of MWCNT/ethylene glycol nanofluid flow in a parabolic trough collector with glass-glass absorber tube. *International Journal of Numerical Methods for Heat & Fluid Flow*, 30.

Kurhe, N. (2020). Compound parabolic solar collector – Performance evaluation as per standard test method and actual field conditions for industrial process heat application in Indian context. *Energy for Sustainable Development*, 11.

Taylor. (1992). Experimental and numerical investigations of the vacuum-forming process. *Polymer Engineering & Science*, 1163-1173.

Waghmare, S. A. (2019). Design configurations and possibilities of reflector shape for solar compound parabolic collector by ray tracing simulation. *Optik*, 9.

Wang. (2004). Viscous pressure forming (VPF): state-of-the-art and future trends. *Journal of Materials Processing Technology*, 80-87.