Design and Analysis of Parabolic Solar Cooker

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ABSTRACT

The parabolic solar cooker concentrates solar radiation and uses reflective materials to transform it produces heat energy. The correct selection of reflective things significantly affects the efficiency regarding the parabolic solar cooker. There are three distinct types of reflective materials that are significantly compared in this research. These are Mylar tape, aluminium foil, and stainless steel. These three types of cookers were put to the test in a variety of weather conditions and produced a wide range of temperatures. The use of reflective Mylar tape allowed for the maximum temperature of 91.6 ˚C to be reached. Moreover, the greatest temperatures of 78.4 °C and 71.1 °C were attained using stainless steel and aluminium foil, respectively. It has been determined via testing and analysis of various reflective materials that Mylar tape has the ability to reflect the most heat in the shortest length of time.

Keywords: Mylar tape, Stainless steel, Aluminium foil, Parabolic solar cooker

1 Introduction

Fossil fuels, oil, natural gas, and other natural energy sources are depleting in nature and may run out soon. Solar energy is now the finest alternative option for meeting both the present and future energy needs. Today, a parabolic solar cooker provides a suitable option for cooking. Conventional wood for fires and other fossil fuels are substituted with this stove. It is readily usable in both regular and urgent circumstances, such as those that arise in rural homes, refugee camps, places impacted by hurricanes, and so forth.

Purpose of using this cooker prepare food containing the fewest calories possible, preserving energy, nutrition, and food, and gustatory characteristics, in addition protecting the environment by reducing CO_2 and other hazardous emissions produced by all types of stoves or cookers. The parabolic solar cooker operates on the idea of solar ray concentration. For this reason, selecting reflective materials wisely is crucial to obtaining the best performance. This report detailed the whole three designs and constructions cookers, their performance analyses, and their financial stability.

2 Block Diagram

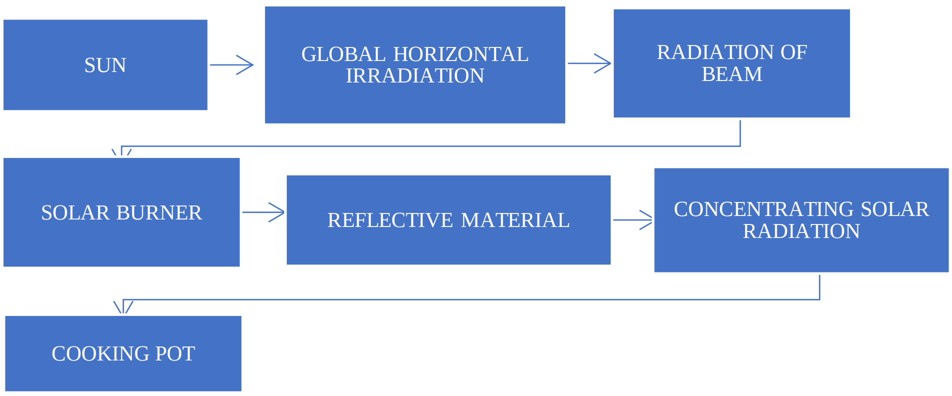

Figure 1: *Parabolic Solar Cooker Block Diagram*

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3 Calculation

We employed a variety of equations to carry out our simulation, including:

Provides the equation expressing the focal distance (f) as follows:

$$f = \frac{h^2}{4R} \quad (1)$$

The surface of the parabola is:

$$A = \frac{8\pi f^2}{3}\left[\left\{\left(\frac{d}{4f}\right)^2 + 1\right\}^{\frac{3}{2}} - 1\right] \quad (2)$$

Half Aperture of the Parabola is:

$$\tan \emptyset = \frac{1}{\frac{d}{8h} - \frac{2h}{d}} \quad (3)$$

The permanent rate solar concentrator's heat balance is given by

$$P_a = P_u + P_e \quad (4)$$

Calculations for the radiation absorptive power include:

$$P_a = E\ C_g\ A\ \rho\ \gamma\ \tau\ \alpha \quad (5)$$

The following equation gives the intercept coefficient:

$$\gamma = 1 - exp\left[-820\left(0{,}7\frac{r}{f}\right)^2 (1 + \cos(\emptyset_0))\right] \quad (6)$$

The heating power is listed as follows:

$$Q_{heat} = \frac{M_w C_w \Delta T_{\infty - 95}}{\Delta t} \quad (7)$$

The power of radiation is standardised to 700 W/m² in order to compare the various cookers in different nations and climates. The standard power is therefore represented as follows:

$$Ps = \frac{(Mw.Cw)(Twf - Twi)}{600} \times \frac{700}{Ib} \quad (8)$$

The measurement's time interval is shown as "600" in seconds.

The evaporation's power is given by

$$Q_{ev} = m_{ev} \times h_{fg} \quad (9)$$

The Centre for Energy Studies [1] provides the thermal losses factor:

$$(MC)_w = M_{pot} . C_{pot} + M_w . C_w \quad (10)$$

The cooker's output is determined by:

$$\eta = \frac{(M_w \times C_w \times M_{pot} \times C_{pot})(T_{wf} - T_{wi})}{A_{parabole} \times \int_0^t I_b\ dt} \quad (11)$$

The following expression for the normal sun irradiation and ambient air temperature for a region may be used to get the standard boiling time (in minutes) of the specified cooker:

$$t_{boiling} = \tau_0 \times ln\left[\frac{1}{\left(1-\left(\frac{F'U_L}{F'\eta_0}\right)\times\left(\frac{A_{pot}}{A_{parabole}}\right)\times\left(\frac{100-T_a}{I_b}\right)\right)}\right] \quad (12)$$

4 Parabolic Solar Cooker of Different Types

4.1 Making use of Stainless Steel as a Reflective Material

An alloy steel known as stainless steel has a minimum mass-based chromium concentration of 10.5% [2]. Five different varieties of stainless steel exist. They are precipitation hardening, duplex, austenitic, ferrite, martensitic, and five more types. Austenitic stainless steel had been employed for this design. Molybdenum, Nickel, Manganese, and Chromium alloys are primarily used in its production. It combines formability and weld ability to a great degree. These steels are susceptible to cracking from stress corrosion. Steel that is completely nonmagnetic.

First of all, mild steel square pipe and flat mild steel take were used to create the horizontal stand and parabolic dish throughout the building time. Cutting the stainless steel sheet allowed for the discovery of the proper parabolic form. The whole design of the parabolic solar cooker using stainless steel as a reflecting material is shown in Fig. 2. This steel's primary benefits are its resistance to corrosion and effectiveness as a reflector. Additionally, the electrical conductivity is low. Some issues with this framework exist. First off, the curve is not perfectly parabolic because of the intense hydraulic pressure. Second, this form prevented the precise focus point from being discovered. Finally, the price is too exorbitant. Finally, due to its size and weight, it is challenging to transport.

Figure 2: *Stainless Steel as a Reflective Material*

4.2 Utilizing Aluminium Foil as a Reflective Material

Over 100 years have passed since aluminium was first used commercially [3]. The thin metal leaves made of aluminium that are less than 0.2 mm thick are used to create aluminium foil paper. It goes by the name misnomer tin foil as well. Both the glossy and matte sides of aluminium foil are present [1]. Bright aluminium foil has a reflectance of about 84%. For heat exchangers and radiation shields, aluminium foil is frequently utilised. For this stove, a parabolic dish Concentrator was first required. The aluminium foil was then divided into tiny bits. After the aluminium foil had been cut to the proper size, it was attached to the parabolic dish concentrator with double-sided tape. The horizontal platform and parabolic dish were first constructed using mild steel square pipe and flat mild steel take during the construction period. With this Stand head, the parabolic dish was properly connected in the desired position. Comparatively speaking, this cooker's overall cost is lower than that of other parabolic solar cooker varieties. Locally, aluminium foil is readily available. This paper acts as a potent concentrator, delivering the most heat to the focus point. This aluminium foil's primary drawback is that it will be harmed or ruined after ninety days. The fact that this cooker's maximum temperature setting (in which the reflecting medium is aluminium foil) is insufficient to boil rice is another negative. Figure 3 depicts the general layout of the parabolic solar cooker that uses aluminium foil as a reflecting material.

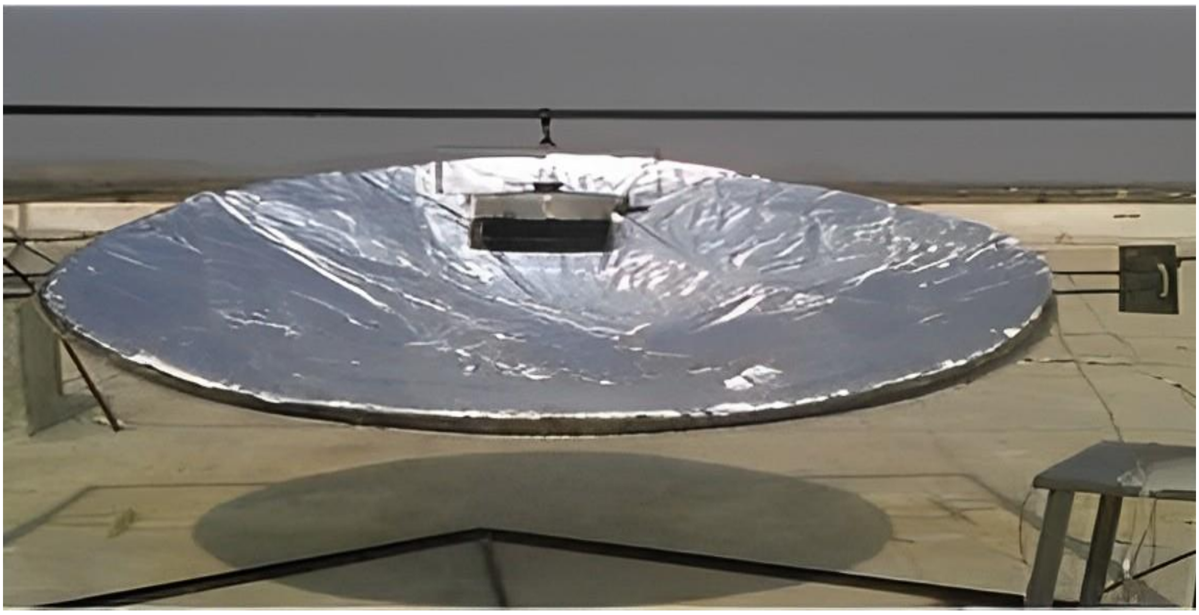


Figure 3: *Aluminium Foil as a Reflective Material*

4.3 Utilizing Mylar tape as a Reflective Material

Polyethylene Terephthalate Polyester film with a biaxial orientation and acrylic glue are the main components of mylar tape [4]. Mylar tape is best used as a radiation barrier and for sensing. The building process is very identical to that of the Parabolic Solar Cooker, except that Mylar tape was utilised as a reflecting substance in place of Aluminium foil in this cooker. The construction of a parabolic solar cooker utilising Mylar tape as a reflector is shown in Fig. 4. Corrosion resistance, high reflectivity, and low electrical conductivity are this tape's key benefits. This tape has a reflectivity of around 93%. For heat exchangers and other high-temperature applications, Mylar tape is frequently utilised. The biggest drawback of Mylar tape is that it cannot be purchased locally. Another drawback of Mylar tape is that it is more expensive than aluminium foil.

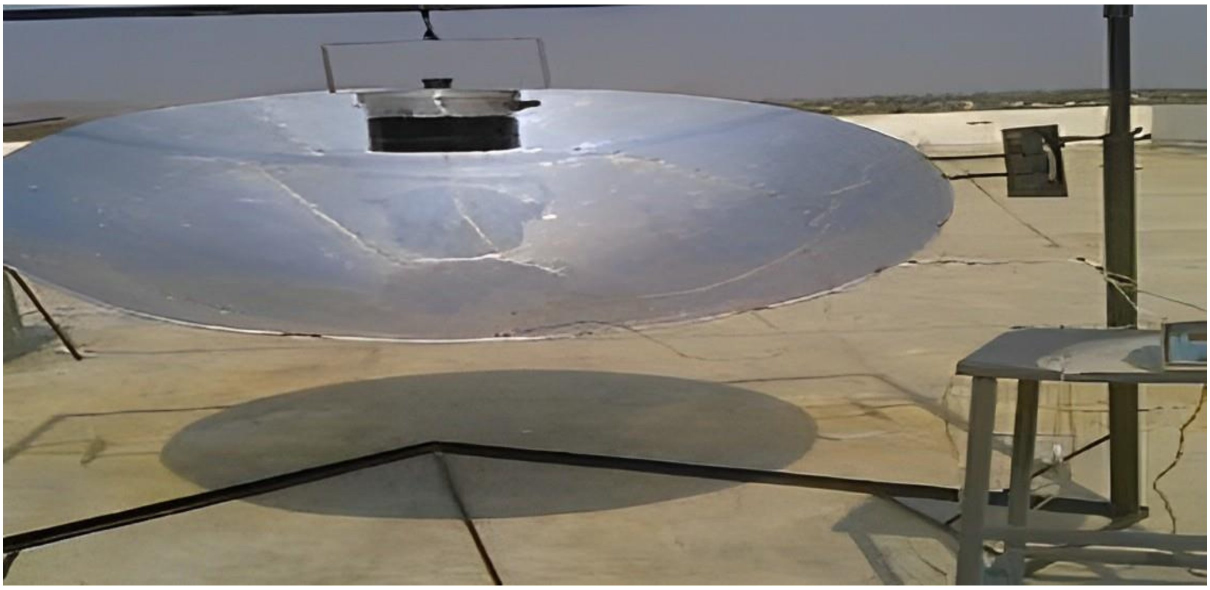


Figure 4: *Mylar Tape as a Reflective material*

5 Testing Site and Solar Irradiation Site

The effectiveness of the parabolic solar cookers was studied at the KIPM College of Engineering and Technology in Gorakhpur, Uttar Pradesh, India. The exact latitude and longitude of KIPM College are 25.9807308667 N and 80.7860068989 E.

The average annual Direct Normal Irradiation (DNI) ranges between 2 and 7.5 kilowatt-hours per square meter per day in most parts of the country.

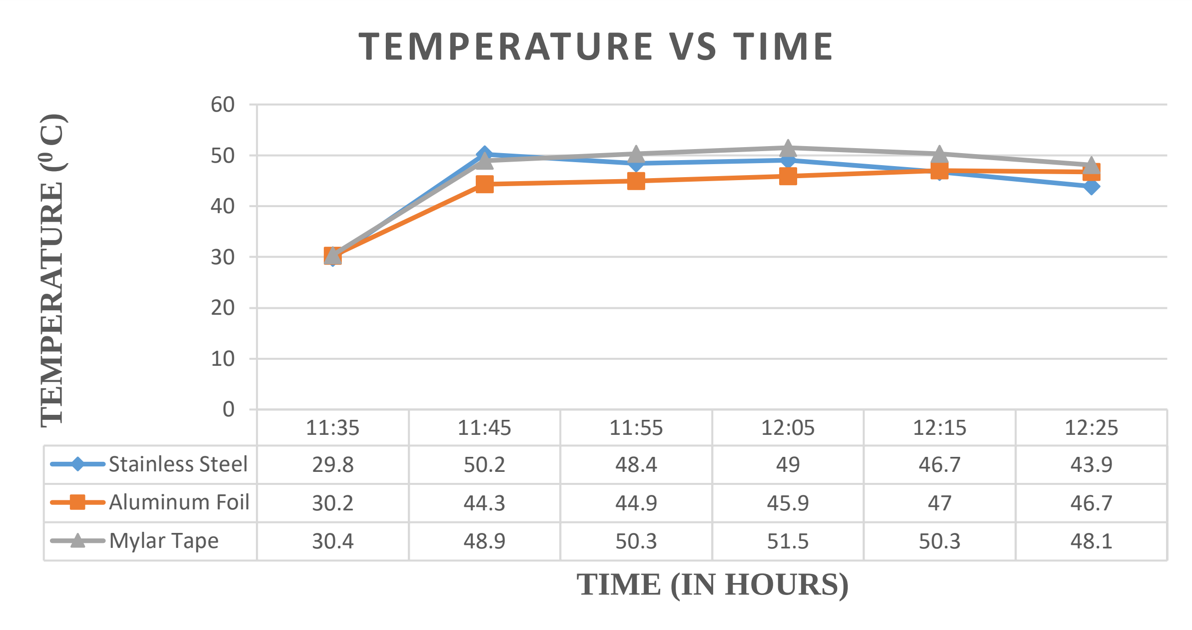
5.1 Performance Analysis

Table 1: *Performance Analysis of Different Reflective Material.*

Time	Temperature of Water Using Stainless Steel (°C)	Temperature of Water using Aluminum Foil (°C)	Temperature of Water Using Mylar Tape (°C)
11:35	29.8	30.2	30.4
11:45	50.2	44.3	48.9
11:55	48.4	44.9	50.3
12:05	49	45.9	51.5
12:15	46.7	47	50.3
12:25	43.9	46.7	48.1

Using various reflecting materials, the water's temperature change over time in a parabolic solar cooker.

a. The temperature range for Stainless Steel ranged from $21.8^{\circ}C$ to $50.2^{\circ}C$.
b. The temperature range for Aluminum Foil was from $30.2^{\circ}C$ to $47\ ^{\circ}C$.
c. The temperature range for Mylar Tape was $30.4^{\circ}C$ to $51.5^{\circ}C$.



	11:35	11:45	11:55	12:05	12:15	12:25
Stainless Steel	29.8	50.2	48.4	49	46.7	43.9
Aluminum Foil	30.2	44.3	44.9	45.9	47	46.7
Mylar Tape	30.4	48.9	50.3	51.5	50.3	48.1

Figure 5: *Water temperature variation over time for various reflective materials.*

6 Conclusions

The primary purpose of this parabolic dish solar cooker is to reduce the use of fossil fuels and firewood while maximizing the use of solar energy in rural communities, emergency circumstances and refugee rehabilitation initiatives. After testing the performance of three different types of cookers in a variety of weather circumstances, it can be said that the parabolic solar cooker that employs Mylar tape as a reflecting material is more effective than the other two types of cookers. The most heat energy is offered by Mylar tape in the shortest amount of time, making it ideal for cooking a dish.

7 Nomenclature

A_{pot} Area of the cooking pot, m^2

A_{par} Aperture area of the parabolic concentrator cooker, m^2

C Geometrical concentration

C_g Ideal concentration

C_w Specific heat of water, J/kg K

C_{pot} Specific heat of the matter of the pot of cooking, J/kg K

d the concentrator diameter, m

E Illumination on the level of The Concentrator, w/m^2

f Focal distance, m

F'UL Factor of losses thermal

h Depth of the parabola, m

h_{fg} Latent heat of vaporization, J/Kg

Ib Direct radiation intensity, W/m^2

M_w Mass of water, kg

M_{pot} Mass of empty pot with lid, Kg

$\dot{m}_{ev}$ Mass of evaporated water per unit of time, Kg/s

Pa absorptive radiation power, W

Pu Useful power, W

Pe Thermal losses power, W

R Radius of the parabola, m

r Exergy

8 Publisher's Note

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