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Design and Development of Domestic Solar Box Cooker with Reflecting Mirror

Kamlesh C Patel[1]

[1]*Lecturer,Mechanical Engineering Department, Government Polytechnic Waghai*

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Abstract - This paper presents design and development of a domestic solar box cooker which works on principle of solar energy concentrate, absorb and retention within box to achieve suitable temperature for cooking various types of meals. Solar box cooker is a sustainable cooking alternatives in area where abundant solar energy available.

Design process involved selecting material for box, insulation, reflecting mirror and choosing dimension for proper heat collection and absorption.

Main aim of development of a domestic solar cooker is simple to operate and maintain. It is a sustainable, economical, and socially beneficial solution for cooking food.

Testing was carried out to record ambient temperature and different temperature of parts in solar box cooker at hot sunny day. Results show device capacity to rise and sustain temperature within box during day time.

Overall developed solar cooker is alternative solution to fire wood and gas cooking in hot sunny time. Consequently it reduces carbon. Finally one can say it is environment friendly.

Key Words: solar cooker, solar oven, solar box cooker, renewable energy cooking.

1.INTRODUCTION

Solar cookers are devices that use direct sunlight as heating energy to cook food and enable important processes such as sterilization and pasteurization. The principle of the solar cookers is to catch UV light rays and convert them to longer infrared light rays while not allowing them to escape. The sun rays are this way converted into heat energy.[11]

Solar cookers can be generally categorized into three types and schematic drawings are shown in figure.

1.1 Solar panel cooker

It may be considered the simplest type available due to their ease of construction and low-cost material. In solar panel cookers, sunlight is concentrated from above. Panel cookers have a flat panel which reflects and focuses sunlight for cooking and heating. This method of solar cooking is not very desirable since it provides a limited cooking power.[8]

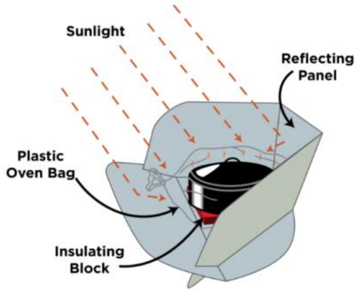

Fig -1: Solar Panel Cooker.

1.2 Solar parabolic cooker

It can reach extremely high temperatures in a very short time and unlike the panel cookers or box cookers; they do not need a special cooking vessel. However, a parabolic cooker includes risk of burning the food if left unattended for any length of time because of the concentrated power. A solar parabolic cooker simply consists of a parabolic reflector with a cooking pot which is located on the focus point of the cooker and a stand to support the cooking system.[8]

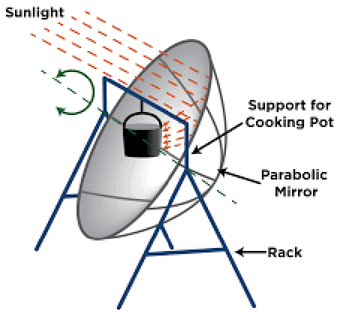

Fig -2: Solar Parabolic Cooker.

1.3 Box type solar cooker

These are the most common and inexpensive type of solar cookers. These box cookers have a very simple construction and they are made of low cost materials, which essentially consist of a black painted metallic trapezoidal tray (cooking tray) and is usually covered with a double glass window. It is kept in a metal or fibre-glass outer casing and the space between the cooking tray and outer casing is filled with the insulation like glass wool. The incoming solar radiation falls onto the double glass lid and passes through it to strike the blackened cooking pots and the cooking tray. The glass covers, while transmitting radiation of short wavelength which form major part of solar spectrum, is almost opaque to low temperature radiation emitted within the box. Thus, the temperature of the box rises until a balance is reached between the heat received through glazing and heat lost by exposed surface (greenhouse effect). In addition, a plane reflecting mirror (booster

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mirror) of about equal size as that the aperture area is used for augmentation of solar radiation on the aperture. The cooking tray is insulated on the sides and bottom. The heat is absorbed by the blackened surface and gets transferred to the food inside the pots to facilitate cooking.[8]

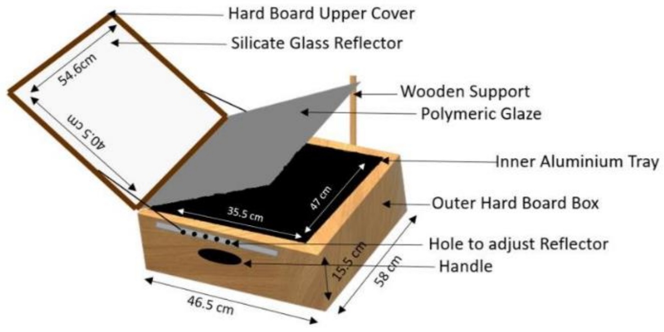


Fig -3: Solar Box Cooker [19].

2. DESIGN OF SOLAR BOX COOKER

2.1 Outer Box: Outer box is made of wood size of 10 mm thick plywood having thermal conductivity of 0.13w/m2. Box size from outside is 620mm X 620 mm X 250 mm dimensions with glass cover and reflecting mirror. Black colour painted is applied on plywood which absorbs heat on outer surface which minimize difference between inside and outside, resulting negligible heat leakage from inner vicinity. Main criteria for selecting plywood are cheap and low thermal conductivity. It is also weather resistant due to colour coating applied on it. Height of cooker is chosen low to reduce gap between cooking pot and cover glass.

2.2 Inner Box: Inner box is made of 1 mm aluminium sheet with black painted inner surface to maximize heat absorption. It acts as cooking chamber. Depth of inner box is 190 mm. Surface area of inner box is 550 mm X 550 mm. Surface area is enough for 4 cooking pot placement.

2.3 Insulation: Thermocol insulation is placed between the outer and inner boxes to minimize heat loss. Materials like fiberglass, rock wool, or expanded polystyrene can be used but selection for thermocol is cheap as well as well suited to fix plywood and aluminium sheet.

2.4 Glass Cover: It is made of 4 mm glass with wooden frame protection around. It allows maximum intensity of sun rays to enter and heating absorber and cooking pot. It is hinged to make the cover easy to open and close. The box is well-sealed with the glass cover.

2.5 Reflector: It is made of mirror, size of 500mm X 500mm. It is fixed to box at one side end with the help of hinges. The mirror is positioned so as to allow the reflected sunlight to fall on the glass cover of the box.

2.6 Cooking Pot: 4 set of cooking pot which is made of high heat conducting aluminium, size of 200 mm diameter and 75 mm height with lid. It is black-painted from outside to absorb heat efficiently.

2.7 Handle and latches: 1 handle each side is fixed to easy carrying and latches to secure lid while transporting.

3. CONSTRUCTION OF SOLAR BOX COOKER

3.1 Procedure

Measure and cut the plywood pieces for the base, sides, and top of the box as per dimensions. Ensure all pieces fit together tightly. Use wood glue, nails and screws to secure the sides to the base. Cut a glass sheet to fit the top of the box. Construct a glass cover lid for the box using the same plywood. Ensure it fits air tight. Apply insulation material thermocol to the inside of the box. Place aluminium sheet for inside box and paint it with black matte paint. Attach reflective surface to the lid of the box using hinges to allow adjustment for optimal sunlight capture. Fix handle and latches to box to carry easily as per suitable dimension.

Table -1: Dimensions of solar cooker

Parameter	Dimension and Description
Type	Domestic solar cooker with 4 pots
Weight	9 kg
Shape	Box type
External dimension	L x B x H 620 mm x 620 mm x 250 mm
internal dimension	L x B x H 550 mm x 550 mm x 190 mm
Inside volume	0.057 m^3
No of glass cover.	01 No. L x B x H 450 mm x 450 mm x 4 mm
Pot dimension	D x H 200 mm x 75 mm
Absorber Plate	L x B x H 450 mm x 450 mm x 1 mm
Reflecting mirror	L x B x H 450 mm x 450 mm x 1 mm

3.2 3D modeling.

There are some 3D model images of constructed parts are shown in Fig.4, fig.5 and Fig.6. 3D model is drawn in Solid works. After construction, pictorial view of made solar box cooker is shown in Fig.7

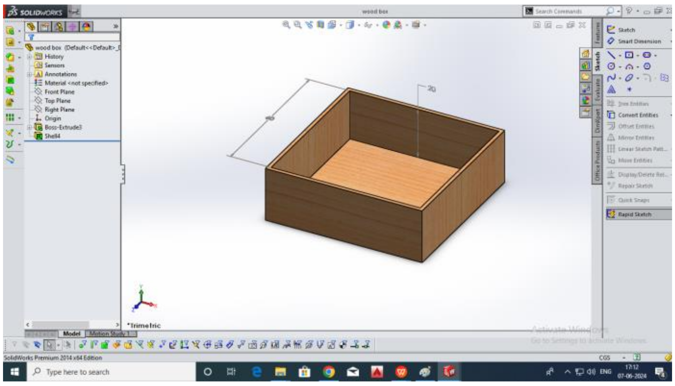


Fig.4 3D model of outer Box

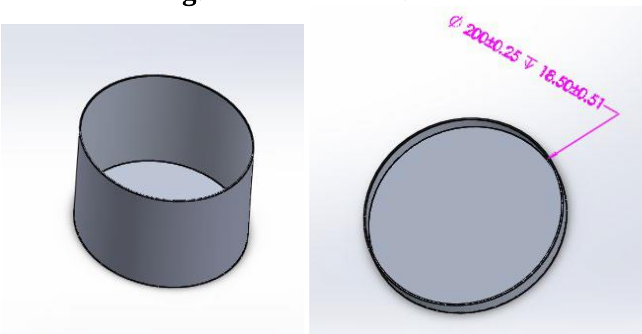


Fig.5 3D model of cooking pot and lid

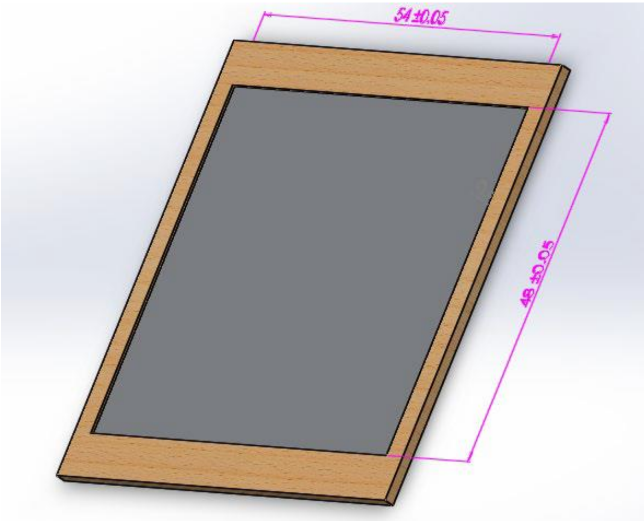


Fig.6 3D Modeling of reflector

Fig.7 Domestic solar box cooker.

4. COSTING OF SOLAR BOX COOKER

Costing of various parts of solar box cooker is shown in below table. Labour charges is neglected due to parts are made in workshop.

Table 2: Costing of solar cooker parts

Sr No.	Items	Cost in ₹
1.	Plywood	800
2.	Transparent glass	350
3.	alluminium sheet	1000
4.	Thermocol sheet	180
5.	Reflector mirror	400
6.	Container or Cooking Pot	400
7.	Screws, Nails. Hinges and Handle	190
	Total	₹ 3320

5. MEASURING INSTRUMENTS

For conducting trials, Temperature measuring instruments were used. Thermocouple (Fig.9) is sensing Temperature and indicator is displaying real time temperature (Fig. 8).

Fig.8 Temperature Indicator

Fig.9 Thermocouple

6. EXPERIMENTAL PROCEDURE

The experiments were conducted on the terrace of the Department of Mechanical Engineering, Government Polytechnic, Waghai. The performance of the system was continuously monitored during 18th to 20th April 2024. All the experiments were conducted from 10:00 am to 4:00 pm. basically; three types of temperature were measured for the box type solar cooker. Thermocouple and temperature indicator measuring devices were used to investigate the effects of the environmental and operating parameters on the performance of the solar box cooker. The ambient temperature, Chamber temperature, Cooking pot temperature and glass cover temperature were monitored using Thermocouple, accuracy ±0.1 °C. The thermocouples ware connected to the Temperature Indicator. It records the temperature at the required points every hour.

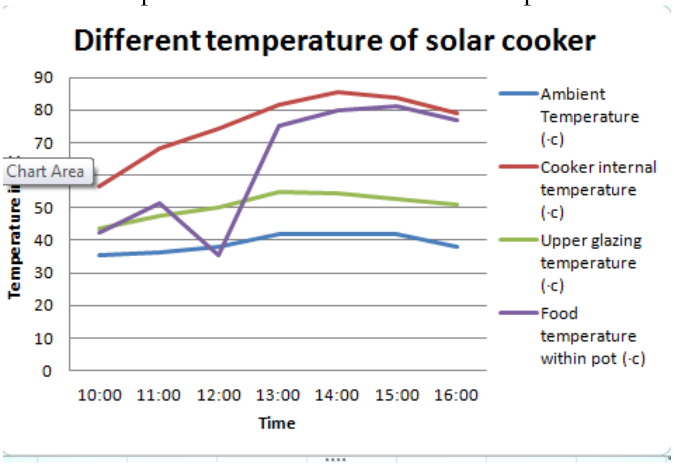
7. RESULT AND DISCUSSION

During Trial, temperature reading of different locations of solar box cooker with respect to time is recorded and it is formulated in below table.

Table 3: Temperature on 18 April 2024

Time (HH)	Ambient Temperature (·c)	Cooker internal temperature (·c)	Upper glazing temperature (·c)	Food temperature within pot (·c)
10:00	35.6	56.4	43.8	42.3
11:00	36.5	68.4	47.6	51.4
12:00	38.2	74.4	50.2	35.5
13:00	42	81.7	54.7	75.1
14:00	42	85.4	54.4	79.9
15:00	41.9	83.6	52.6	81.3
16:00	38	79.1	51.2	76.7

Chart: This chart showing variation of temperature and its comparison with other location temperature



The recorded ambient air temperatures range from 35.6°C to 42°C, indicating variations in the temperature over the experimental period. These fluctuations can be attributed to changes in weather conditions, time of day, and solar radiation intensity.
The highest recorded temperature is 85.4°C in inside chamber of cooker. This indicates that the solar cooker is able to efficiently absorb and convert solar radiation into heat energy, which is crucial for effective cooking.
The increase in temperature of food pot from 28.3°C to 59.3°C demonstrates the effectiveness of the glass cover in trapping and retaining solar radiation within the solar cooker.

8. CONCLUSIONS

The domestic solar box cooker was designed and constructed using readily available materials and incorporates reflecting mirror. The maximum temperature inside the cooking chamber was 84.5 °C at 14:00 hr. it was 29 °C more than 10:00 hr when it was first placed on terrace.
During cooking trials conducted, the rice and Toor dal were kept at 10:00 hr. Rice was cooked perfectly by 13:00 hr in solar cooker while Toor dal was not cooked in the solar cooker at time 13:00 hr. It needed more time up to 14:30 hr. So, the box type solar cooker with reflector will be a vital device for energy saving by solar cookers in India.
The use of this solar cooker would help in conservation of conventional fuels, such as firewood, animal dung cake and agricultural waste in rural areas and LPG, kerosene, electricity and coal in the urban districts.
Moreover, the use of the solar cooker would result in the reduction of the release of CO_2 to the environment.

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