Design and Construction of Solar Box Cooker System

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Abstract- A composite solar box cooker was successfully constructed with locally available material. The use of solar energy to meet the important need of energy apart from being a viable alternative is also accomplished without the environmental and health problem associated with most other fuels. This development is unique in terms of its simplicity and very light weight. It is the result of this paper that was carried out by designing and constructing solar cooker using locally available material. In building a solar cooker, the consideration of heat principles are heat gain, heat storage and heat loss. After constructing, according to the testing of solar box, The average cooking time for eggs is about 1.5 hr, for rice about 2.25 hr and 4 hr for prawn. Solar cooking is simple, safe and it is convenient to cook food without consuming fuel or heating up the kitchen and cook at moderate temperature and this helps to preserve nutrients.

Indexed Terms- Solar radiation, Drawing, Construction, Temperature and Time Testing

I. INTRODUCTION

Solar cooking is reckoned as a technically and commercially viable option for cooking, especially in areas with abundant solar radiation. Solar cooking offers an effective method of utilizing solar energy for meeting a considerable demand of cooking energy and hence, protecting environments. A solar cooker has also been developed using a flat plate collector as an energy collection unit. The box type solar cooker, however, is still the preferred option for individual family needs, mainly because of its small size and simple handling and operational requirements. Daily or seasonal adjustment of the reflector is required to maximize reflected irradiance onto the aperture. Here, cooking is a slow process and limited to boiling-based cooking only. In view of the above constraints, it is relevant to design a box-type solar cooker using an appropriate concentrator configuration, which can enhance the collection of solar energy without requiring daily adjustment. The design must be simple and convenient to use. Non-tracking concentrator can be used to take advantage of box type cookers by concentrating the solar radiation onto the aperture of the cooker. [4]

II. DETERMINATION AND CALCULATION OF SOLAR RADIATION

Solar radiation incident on the atmosphere from the direction of the Sun is the solar extra-terrestrial beam radiation. Fig. 6 shows the angle of incident on surface. [5]

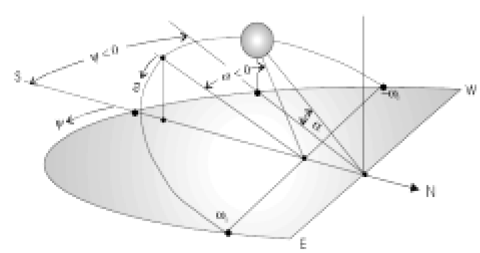


Fig.6. Sun Angles, Altitude, Azimuth and Hour Angle

1. Hour angle (ω)

ω is the sun's hour angle, which are the angular displacements degrees of the sun east or west of the local meridian due to rotation of the earth on its axis at 15˚ per hour.

$\omega = 15(12 - T)^{\circ}$, (T=0 to 24 hours) (1)

2. Latitude (Φ)

The angular location north or south of the equator, north positive; $-90^{\circ} \leq \Phi \leq 90^{\circ}$

3. Slope (β)

β is the angular between the plane of the surface in question and the horizontal; $0 \leq \beta \leq 180$*/°. ($\beta > 90^{\circ}$

means that the surface has a downward facing component)

4. Equation –of –time correction (E)
Minutes of time, E is needed because of the earth's elliptical orbit and axis tilt.
E= 229.2(0.000075+ 0.001868cosB - 0.032077sinB - 0.014615cos2B - 0.04089sin2B) (2)
B= (n-1)360/365, (n= day of the year) (3)

5. Angle of incidence (θ)
θ is the angle between the beam radiation a surface and the normal to that surface.
$\cos\theta = \cos\theta_z \cos\beta + \sin\theta_z \sin\beta \cos(\gamma_s - \gamma)$ (4)

6. Zenith angle (θ_z)
$\theta_z$is the angle between the vertical and the line to the sun, i.e., the angle of incidence of beam radiation on a horizontal surface.
$\cos\theta_z = \cos\Phi \cos\delta \cos\omega + \sin\Phi \sin\delta$ (5)

7. Declination (δ)
δis the angular position of the sun at solar noon(i.e., When the sun is on the local meridian) with respect to the plane of the equator, north positive;
-23.45˚≤ δ ≤ 23.45˚

$$\delta = 23.45 \sin\left(360 \times \frac{(284 + n)}{365}\right) \quad (6)$$

8. Solar azimuth angle (γs)
γ_s is the angular displacement from south of the projection of the beam radiation on the horizontal plane. (Displacement east of south are negative and west of south are positive)

$$\tan\gamma_s = \frac{\sin\omega}{\sin\Phi \sin\omega - \cos\Phi \tan\delta} \quad (7)$$

9. Solar altitude angle (α_s)
α_s is the angle between the horizontal and the line to the sun i.e., The component of the zenith angle.
$\alpha_s = 90 - (\Phi - \delta)$ (8)

10. Surface azimuth angle (γ)
γ is the deviation of the projection on a horizontal plane of the normal to the surface from the local meridian, with zero due south, east negative, and west positive; -180˚ ≤ γ ≤ 180˚

If the intensity of the direct solar radiation incident on a surface normal to the rays of the sun is 1 kWm-2, then the component of this intensity in any direction can be easily calculated.[5]

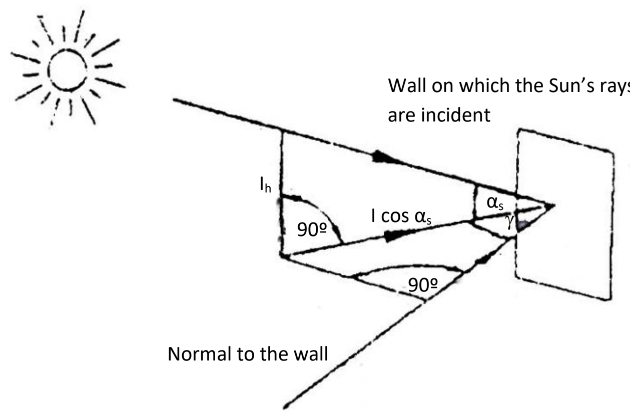


Fig. 7. The Intensity of Solar Radiation

If the angle of altitude of the sun is a, then simple trigonometry shows that the component is I_h=I sin α_s. The component of direct radiation normal to a vertical surface (I_v), as illustrated in Fig. 7. It then follows that the resolution of I cos α_s normally to the wall is I cos α_s cos γ.[5]

This paper includes the design calculation of focusing solar collector for Technological University (Hpa-An) Campus under study is geographically located at latitude 16º 52' North and longitude is 97º 30' East. Testing is on September 25and the day of the year is 268 days.

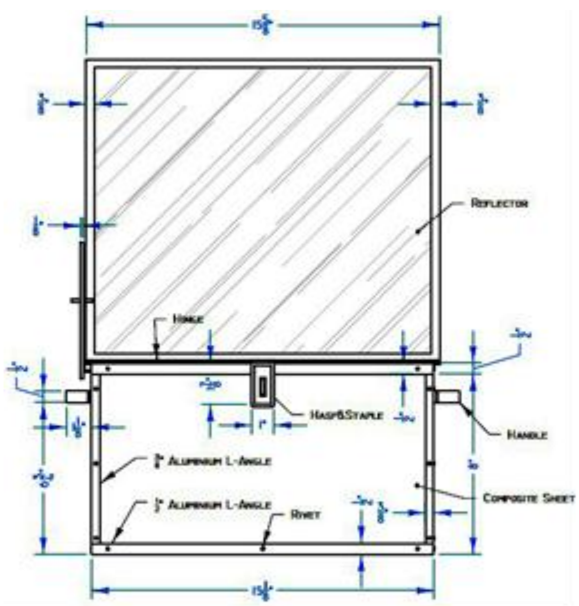
Table 1.Design calculated data

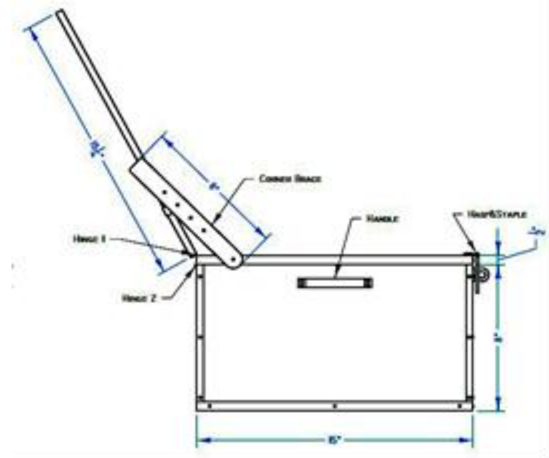
PARAMETERS	SYMBOLS	VALUES	UNIT
Declination	δ	- 1.815	deg
Solar altitude angle	α_s	71.315	deg
Time correction	E	8.37	-
Hour angle	ω	30	deg

Solar azimuth angle	γ_s	60.603	deg
Zenith angle	θ_Z	35.015	deg
Radiation normal to horizontal surface	I_h	947.29	W/m^2
Radiation normal to vertical surface	I_v	320.37	W/m^2

III. DRAWING OF DESIRE MODEL

The basic shape of all solar cooking boxes is rectangular. A quadratic design minimizes heat losses through the joints and side walls, while a rectangular design has other advantages: the hinges are exposed to less wear and tear and the long reflecting lid makes solar positioning less critical. The drawings for construction of box type are shown in the following.





IV. CONSTRUCTION OF SOLAR BOX MODEL

The construction of solar box is described by the outer box, inner box, cooking pot Insulation material, cooking pot, two pane glasses with aluminium frame, reflector, rubber lining, hinges and handles.

a. Outer Box and Inner Box Metal case (aluminium) with wooden bracing offers the best finish and is adequately stable with regard to mechanical impact and the effect of weather. Put the aluminium pieces into a square to make a main frame and use of a drill with screw/rivet to hold each other. Next, we construct the outer box of composite material as shown in Fig. 10. Then two handle are fitted on side of the box to handle and a clamp in front for tightly closing the box.

Fig. 10. Outer Box

The inner box is usually made of blackened sheet metal. Firstly, the sheet metal is cut as required and bend the edge of the inner box as the trapezoidal or square section. Use a rivet to fasten the corners of the plate together. Then paint black to the inner part of the basin as shown in Fig. 11.

Fig. 11. Inner Box

b. Insulation

After making the inner and outer box, then put the insulation material between them. Then cover the insulation of the box with square wooden frame. It attaches with screw to the upper side of the inner box. The insulating material is rice husk as shown in Fig 12 because it can get easily. Its thermal conductivity is 0.05 $Wm^{-2o}C$, so it can keep well insulation. Rice husk is completely dried; if is not, latent heat of moisture will make lessen the efficiency of solar cooker.[3]

Fig. 12. Insulation Material

c. Glass Cover

The cover or aperture must consist of two panes of glass with a layer of air between them as shown in Fig 13. The pane to pane clearance usually amounts to 10 – 20 mm. Both panes may consist of normal window glass with a thickness of about 3 mm.

Fig. 13. Glass Cover

Aperture area is little different than outer box area with glass area and then the aluminium frame is set up side by side together to fasten the glass aperture. After that the cover is hinged with the outer box. The double pane mirrors must fit tightly around the top of the box in order to trap as much heat as possible, thus maximizing the cooker's efficiency and minimizing the required cooking time. Therefore solar box is well insulation of rice husk; very good heat absorption of black coating, air tight aperture and adjustable reflector can improve good effect to the cooker efficiency. So, the design and construction of cooker is portable and suitable for our region. Typical box type solar cooker with insulating material is shown in Fig. 14.

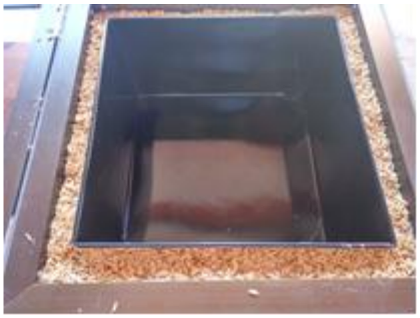


Fig. 14. Box with Insulating Material

d. Reflector

At the top of the box, the reflector is fastened with hinged on the cover frame and collects the sun radiation with adjustable rod as shown in Fig 15. It is rectangular in shape. Reflector keeps the lid in the proper reflection position and a latch is used to close it like a suitcase. Both the positioning mechanism and the latch must be fail-safe to the extent that they cannot get between the lid and the cover and break the glass. The closed lid with or without a layer of insulation behind the mirror- keeps the food warm. The hinges for the reflecting lid must be strong enough and carefully mounted to ensure that they stand up to everyday use; the hinges are a frequent weak point. Instead of metal hinges, strips of leather or textile can be used.

Fig. 15. Reflector

e. Cooking Pot

Cooking pot is thin-wall aluminium cylindrical vessel. Aluminium has very good thermal conductivity. According to the inner box, the size of the pot is provided shallow and wide design to minimize cooking time. Outer surface of both the container and lid are painted flat back for heat absorption as shown in Fig 16. Suitable cooking pots are important prerequisites for successful solar cooking. [5]

Fig. 16. Cooking Pot

V. SOLAR BOX COOKER OPERATION

One of the beauties of solar box cookers is their ease of operation. For mid-day cooking at 20° N - 20° S latitude, solar box cookers with no reflector need little repositioning to face the sun as it moves across the mid-day sky. The box faces up and the sun is high in the sky for a good part of the day as shown in Fig 17. Boxes with reflectors can be positioned toward the morning or afternoon sun to do the cooking at those times of day. Solar box cookers used with reflectors in the temperate zones do operate at higher temperatures if the box is repositioned to face the sun every hour or two. This adjustment of position becomes less necessary as the east/west dimension of the box increases relative to the north/south dimension. [5]

Fig. 17. Test of Solar Box

Box type solar cooker make use of both direct and diffuse radiation with part of it being reflected off of the mirror lid and remainder entering the cooking space directly through the transparent cover. Since practically everything in the box is black and most of incoming radiation is absorbed. The black surfaces heat up and begin emitting long wave thermal radiation that is unable to escapes through the glass cover. Additionally, steady circulation of the air in the box supplies more heat to the pot by convection. The pot also heat up and cook the food by thermal conduction with the aid of radiant heat from the lid. [5]

VI. TEMPERATURE TESTING

The inside of a solar cooking box can reach a peak temperature of over 150℃ on a sunny day in the tropics; that amounts to a thermal head of 120 K, referred to the ambient temperature . Since the water content of food does not heat up beyond 100˚C, a loaded solar cooker will always show an accordingly lower inside temperature. The following Fig 18 shows time and temperature testing for box type solar cooker.

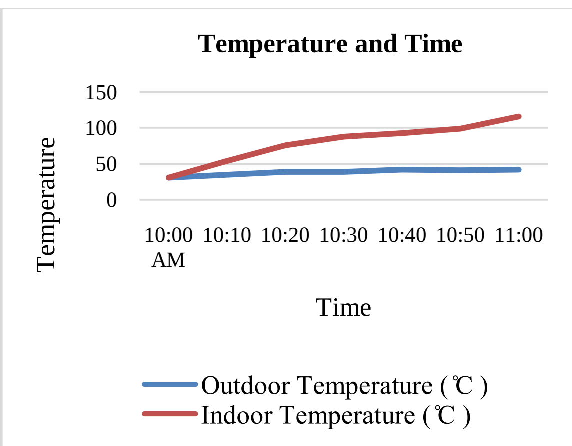


Fig. 18. Temperature and Time Graph

VII. COOKING TIME

Cooking food using solar energy will take on average two hours longer than in a normal oven so they need to be used in an area with a near constant supply of sunshine. After the design and construction, testing is the vital step in the process. The foods of egg, rice and prawn were cooked by box type's solar cooker as shown in the following Fig 19.

(a)

(b)

(c)

Fig. 19. Testing of (a) Eggs (b) Rice (c) Prawns

From the result of the test as shown in Fig 20, the cooking time was found to be 1.5hr, 2.25hr and 4hr for egg, rice and prawn respectively.

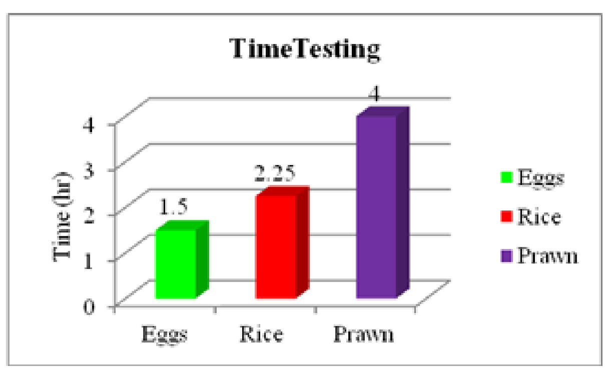


Fig. 20. Time Testing of Different Food

VIII. CONCLUSION

Generally, the solar cooker is simple design of the storage box and safety in operation. Solar cooking does not require any electricity but uses solar thermal energy to cook foods. This means that can use a solar oven anywhere that has loss of sun. Design is simple and it can easily be constructed and operated with local materials. So, the operator doesn't need strict operating procedures. The box type solar cooker is low cost compared with other types of solar cookers. Depending on the weather, it cannot always be used.This system is used in a lot of heat gain region. It is particularly useful when other sources of fuel are unavailable. This paper gives some facts and knowledge of solar cooker to fabricate the economical solar cooker and also describes the temperature testing and cooking time calculation of box type solar cooker. The average cooking time for eggs is about 1.5 hr, for rice about 2.25 hr and 4 hr for prawn. In that case, the cooking time for prawns is a slightly long because of opening the box and turning them side by side. So, heat losses occur and need more cooking time. It is clear that, solar box is one the choice for rural areas because it has unlimited supply of sunlight. It does not require the electricity, no electric cost and it is simple to use, clean, save energy, no noise and reliable.

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