

TEAM ANSHUK

SOLAR COOKER

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Abstract— the inception of this idea was the consequence of humongous usage of firewood as a source of fuel for cooking in villages. According to a survey, each family utilizes two full grown trees in a year. Our design of solar cooking is strictly based on robustness, cost efficiency, easy availability, workability and ergonomics. The geometry of the cooker includes simplest form of a cuboid surrounded by reflectors for enhanced efficiency. The ovens are placed symmetrically inside the cuboid and are surrounded by insulating and heat retaining materials & double layered glass pane with a thin air film in between, to make it work even after sundown. Moreover, we are putting in a provision of parabolic reflector attached to the cooker which fulfils the criterion of indoor cooking system by transmitting heat via steam. Thus, this design is simple enough to be replicated by the villagers.

Keywords— firewood, solar cooking, cost efficiency, reflectors and heat retaining materials.

I. INTRODUCTION

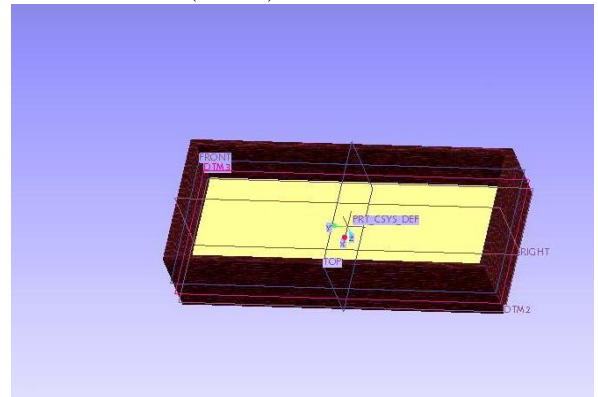
With the exponentially increasing demand of power, we have come to a stage where we need to put a thinking cap for the alternative sources. Till date, plenty of remote areas are using firewood as their basic source of fuel for cooking purpose. This has very low efficiency and adds up adversely to the environment. The sun is providing us with distinct answer for all above worries. We can harness sun's thermal energy by capturing it and utilising it for cooking purposes. In a day, sun radiates around 9 MJ of energy which is more than sufficient to run a thermal power plant. This explains the humongous potential of the sun.

II. ABOUT ANSHUK

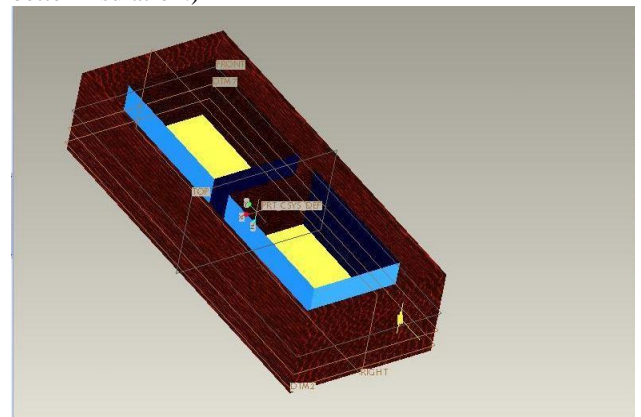
Our idea of solar cooking is based on the principle of concentrating the solar energy at the focus after reflection from a reflecting surface and entrapping it within the insulating boundaries. This will help us making the cooker functional even in the absence of sunlight.

- We launched off with a wooden casing which will act as the outermost constraint for the cooker. This will provide a specific geometry and wood being an insulating material provides insulation to the cooker.

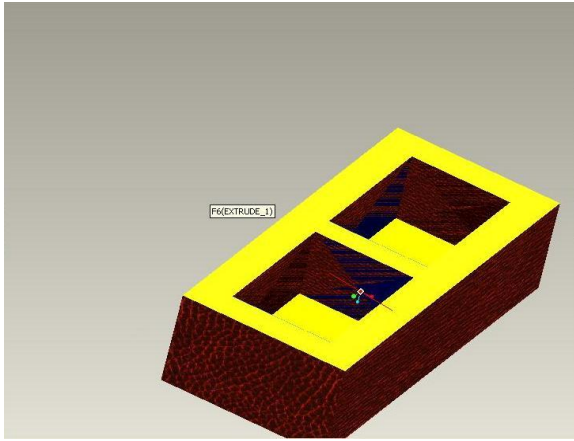
- The inside walls of the casing are layered by a layer of corrugated cardboard as it has high thermal insulation value (R3-R4).



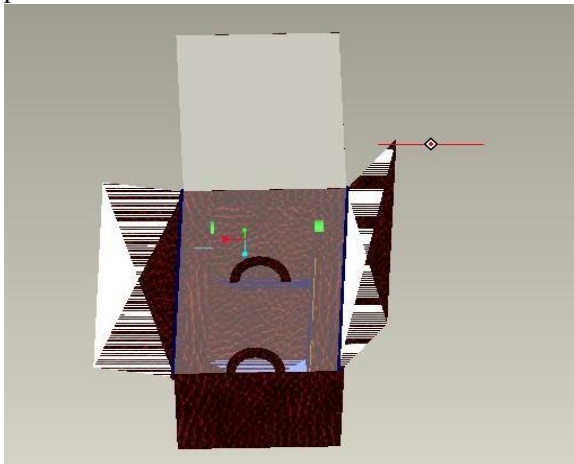
- The bottom of the casing is then surfaced with a layer of bricks as it has high thermal retention properties. Bricks have high specific heat capacity (0.840 kJ/kg-K) due to which it stores heat energy for a longer duration. Also, it is cheap and readily available.
- Further, two black painted aluminium boxes are placed symmetrically over the brick bed and these boxes are surrounded by bricks on all sides. (Note: the bricks shouldn't be joined together by cement or any other material. Rather, air should be allowed for better insulation.)



- The top surface of the bricked layer (leaving apart the metallic boxes) is covered with a black metal sheet in order to turn sunlight into heat.



- Then this setup is covered by a dual layered glass sheet with a thin air membrane in between. The glass has a property of allowing the sunlight through it and capturing the infrared rays (greenhouse effect) which heats up the box up to a longer duration. The air film in between helps in better insulation.
- The whole setup is aligned lengthwise such that longer sides are along east-west direction and the shorter sides are along north-south direction. Three reflectors are placed along the two longer sides and one shorter side. The reflector at the shorter end is detachable and can be placed on the opposite end as per the movement of sun.



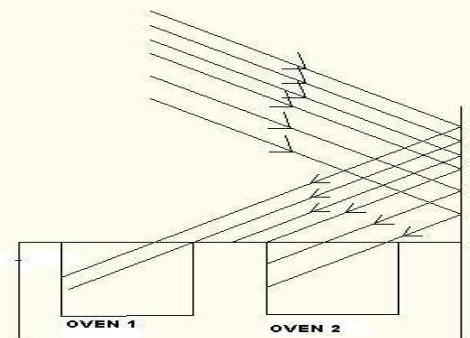
- An insulating material has to be spread over the cooker in the evening.
- In addition, we are assembling a parabolic reflector. When sunlight falls over them it gets reflected to a line passing through the focus of parabola. This leads intense heating of that surface. We are utilising this concentrated heat to generate steam and circulate it to provide indoor cooking provision.

III. THEORETICAL DESCRIPTION OF SOLAR COOKER.

- The thickness of the wood used for casing will be 20 mm, which suffices enough to provide perfect and robust geometry to the cooker. Two wooden planks of dimensions

1560mm*370mm*20mm, two of dimension 660mm*370mm*20mm and one of 1560mm*660mm*20mm (for the base) are nailed together in a cuboidal profile, keeping the top open. This box has to be enamelled properly by anti-termite coating and paint it thoroughly with black, both from inside and outside. The specific heat capacity of wood is 2 KJ/Kg-K which makes it a good insulating material.

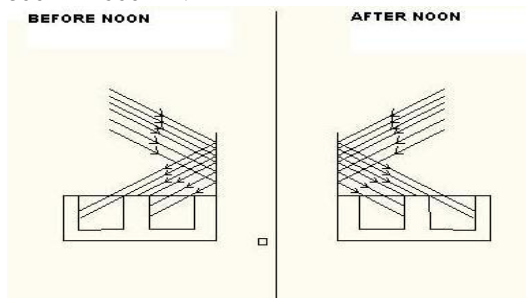
- After the casing is done, the inside walls of box are lined with corrugated cardboards using some adhesive agents. Corrugated cardboard has insulating properties due to the fluting design of its interior. The flutes trap air between the two layers of cardboard, extending the amount of time needed to transfer heat energy from the interior of the box to the exterior. The thermal insulation value of cardboard is R3-R4.
- Bricks have got a unique property of storing heat. Its purpose is to store heat energy from the hottest part of one day, for the cooler portion of the rest of the day and night. The bricks are aligned along the inside walls of the casing (touching cardboards). These bricks are not joined together by cement such that a film of air is trapped between each of them which add up to its heat storage property.
- Two metal containers made of metal sheets (pref. Aluminium), of same dimensions are painted black (to absorb heat & prevent corrosion) and are placed inside the casing symmetrically over the brick bed. The leftover area in the casing is packed with brick lining (without any binding agent). Aluminium has got high strength to weight ratio and a better thermal conductivity in comparison to other metals. Thermal conductivity of aluminium is $237 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$. The dimensions of the container are 600mm*400mm*250mm.
- The exposed layer of brick at the top is covered by thin black painted metallic sheet. This converts the sunlight falling on it into heat.



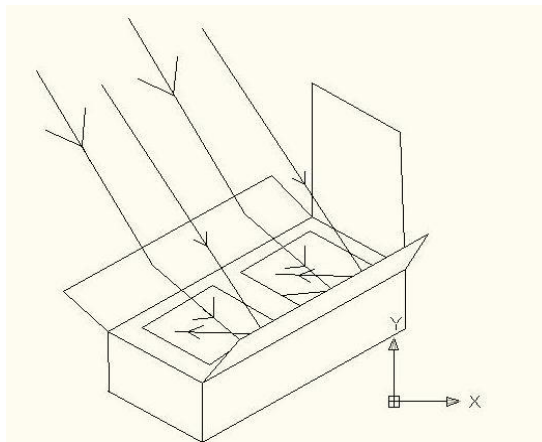
- Once all this is done, each half of the setup is covered with double layer of glass pane with air film in between. This is done as glass holds a

property of allowing sunlight to pass through it and it traps infrared radiations which heats up the oven (greenhouse effect). The dimensions of each section of the glass pane is 780mm*660mm*5mm (thus, total thickness becomes 5+5+2=12mm). The arrangement of glass panes is done so to make it user friendly. The ergonomics of the cooker is maintained by providing accessories to the assembly (handles for the glass pane).

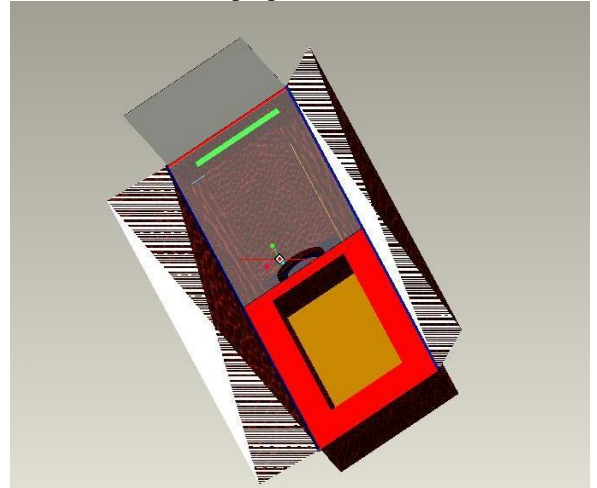
- To increase the intensity of the sunlight falling over the oven, we have installed three reflecting surfaces (made of aluminium sheets) along the three consecutive edges of the cuboidal profile.
- The reflector on the shorter edge is placed perpendicular to the top of the oven. This reflector is placed in such a way that it always faces the sun i.e. in the first half of daytime (6 am to 12 noon), it is placed at the west side of the cooker and vice-versa for another half. Hence, this reflector has a detachable mechanism such that the sides can be altered manually and very easily. The dimension of this reflector is 800mm*660mm.



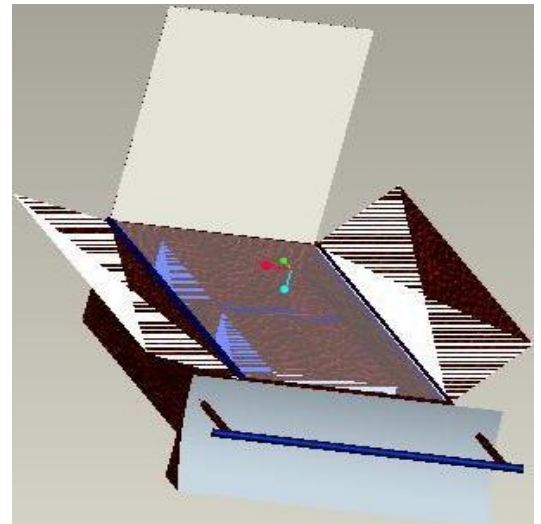
- The reflectors along the longer edges are placed through hinged support such that these can be adjusted to the desired angle based on the solar declination. The reflectors are angled towards the angle of declination of the sun. In this way, the largest area of the reflectors will not need to be re-adjusted during the course of the day. The dimension of these reflectors is 1560mm*660mm.



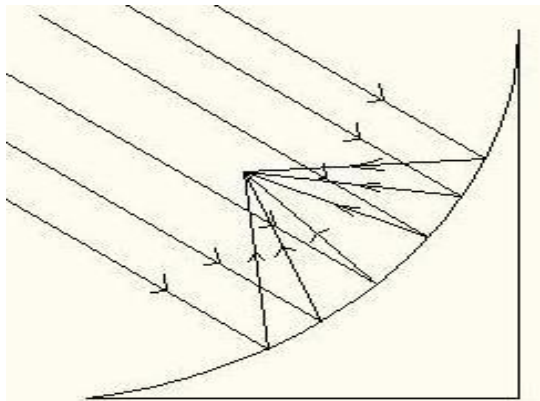
- The utensils to be used in the oven should be painted black from all sides and it should be covered with a lid for rapid cooking (circular base vessels are preferred).
- At the sundown, the whole setup is covered uniformly with a large insulating material. Jute bags can be preferred as it is light in weight, readily available and economically efficient. Apart from that, corrugated cardboards may also be used to serve this purpose.



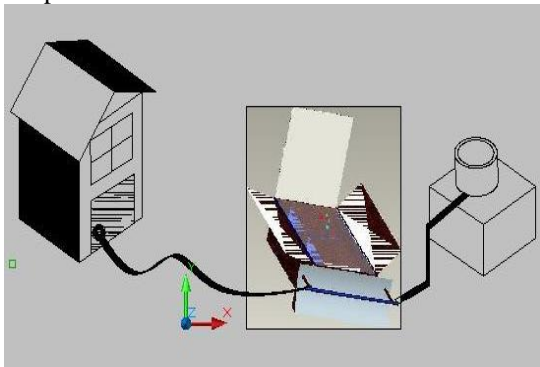
- In addition, the parabolic reflector attached reflects back the sunlight falling on it over a straight line passing through its focus. Thus, the heat gets concentrated and when a vessel is placed in those constraints, it gets maximum heat.



- A cylindrical vessel will be passing through the line of focus. Water will be stored in this vessel which will be transformed into steam due to enormous concentration of heat at this point.



The circulation of water is done by varying pressure between the source and the sink. This is done by difference in datum levels and not by using electrical pumps. Nearby, an indoor cooking provision will be installed where an oven will be placed. High temperature steam, generated in the vessel is transmitted to this oven through PVC pipes (cheap, light weight and easily available). The diameter of this pipe should be lesser than the diameter of the vessel which helps in maintaining the temperature of the steam throughout the process by increasing the pressure.



- These reflectors are detachable such that, with the change in position of the sun, this can be placed at the opposite end the cooker similar to the reflector at the shorter side.

IV. CALCULATIONS

- i. Wooden box:

$$\begin{aligned} \text{Total surface area of wooden box} &= 2672400 \text{ mm}^2 \\ &= 26.613 \text{ ft}^2 \end{aligned}$$

- ii. Aluminium sheet:

- a. For each oven:

$$\begin{aligned} \text{Total surface area} &= 800000 \text{ mm}^2 \\ &= 8.611 \text{ ft}^2 \end{aligned}$$

- b. Over top layer of the bricks = 462400 mm^2
= 4.977 ft^2

- c. For reflectors:
Total area covered by reflectors = 2412800 mm^2
= 25.971 ft^2

- d. For parabolic reflectors :
Total area of reflector = 806225 mm^2
= 8.67 ft^2

Thus, total area of aluminium sheets required = 56.84 ft^2

- iii. Bricks:

$$\begin{aligned} \text{Total volume covered by brick} &= 195440000 \text{ mm}^3 \\ \text{Volume of one brick} &= 1707720 \text{ mm}^3 \\ \text{Total no of bricks required} &= 115 \end{aligned}$$

- iv. Glass:

$$\text{Surface area of each layer of glass pane} = 942400 \text{ mm}^2$$

$$= 10.144 \text{ ft}^2$$

- v. For parabolic reflector:

$$\begin{aligned} \text{Length of reflector} &= 1000 \text{ mm} \\ \text{Breadth of the reflector (D)} &= 700 \text{ mm} \\ \text{Depth of reflector (d)} &= 200 \text{ mm} \\ \text{Focus} &= D^2/16d \\ &= 150 \text{ mm} \end{aligned}$$

- vi. Solar declination:

$$\delta = 23.45 \sin[360^\circ/365 \cdot (N+284)]$$

Here, N= day number of the year

$$\sin \theta_s = \cos h \cos \delta \cos \Phi + \sin \delta \sin \Phi$$

Power incident on window:

$$P_{\text{inc}} = I_o A_w (\sin \theta_s + r(M/L) \sin \alpha)$$

Here,

M/L=1(ratio of width of reflector to that of window)

I_o = incident solar power density (1.38 kW/m^2)

A_w = area of top of each oven.

α = angle of reflector with vertical

r=reflectivity of aluminium sheet (0.88)

θ_s = the solar elevation angle
h = the hour angle, in the local solar time
 δ = the current Sun declination
 Φ = the local latitude

Therefore, the overall cost of solar cooker is Rs 2333/- ,this will serve one for lifetime, only the reflectors are needed to be changed once in five years.

Max. P_{inc} (for each oven by all 3 reflectors)
= $0.5495+0.5495+0.3243$
= 1.4233 kW/m^2

Power absorbed by each oven:

$$P_{abs} = I_o A_w a \tau (\sin \theta_s + r(M/L)\sin\alpha)$$

a = the absorption coefficient of the cavity walls
 τ = the optical transmission coefficient of the window material

A typical value τ for is ≈ 0.92 .

A typical value for a is $\approx 0.9-0.96$.

Max. $P_{abs} = 1.178 \text{ kW/m}^2$

(Note: All these above calculation were done for max power which was obtained at noon. The latitude of Chennai region is taken in consideration.)

V. COST ANALYSIS

Disclaimer: these prices are liable to be changed from place to place.

a. Wood:

For 18mm thickness

Rate (per ft^2): Rs. 30/-

Cost of wood: Rs. 800/- approx.

b. Glass:

For two sheets of 10.144 ft^2 each

Rate (per ft^2): Rs. 20/-

Cost of glass: Rs. 400/- approx.

c. Aluminium sheet:

For interior of oven & reflectors and parabolic reflector

Rate (per ft^2): Rs. 15/-

Cost of aluminium: Rs. 850/- approx.

d. Bricks:

Cost of one brick: Rs. 2/-

Total cost of bricks: Rs. 230/- approx.

e. PVC Pipes:

Cost per 10m: Rs 35

Total Cost of 15m : Rs 52.5

THANK YOU