DEVELOPMENT OF SOLAR COOKER USING PARABOLIC REFLECTORS

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ABSTRACT: *For cooking we generally make use of gas which is a commercial source. Solar energy is a renewable and non-commercial source which is adequately available for usage. So, the idea of making use of solar energy to cook brought the existence of solar cookers. But the main problem with the model with it is, it is not effective during day start and end because rays cannot incident completely over it. So, it takes more time to cook. So, to overcome this issue, usage of a parabolic reflector is the solution where the incident rays meet at the focus which generate more heat and results in faster cooking that saves time.*

Keywords: *Solar energy, parabolic, cooker*

1.0 INTRODUCTION

1.1 Solar Energy

It has been calculable that the sun provides the maximum amount energy in quarter-hour as humans use in a very year. By taking advantage of that with heating and electrical generation, we will work to finish our dependence on fossil fuels. Solar power is that the energy obtained by capturing heat and lightweight from the Sun. Energy from the Sun is brought up as solar power. Technology has provided variety of how to utilize this thick resource. It's thought-about an inexperienced technology as a result of it doesn't emit greenhouse gases. Solar power is copiously accessible and has been used since long each as electricity and as a supply of warmth.

1.2 Solar cooker

A solar cooking utensil may be a device that utilizes solar power to cook food. Solar cookers additionally change some vital processes like pasteurization and sterilization. It’s a transparent proven fact that there are unit innumerable designs of solar cookers that area unit unendingly improved by researchers and makers. Therefore, classification of star cookers may be a labor. However, it should be declared that almost all of the solar cookers nowadays fall inside 3 main classes referred to as solar battery cookers, star box cookers and solar parabolic cookers.

1.3 Parabolic Reflectors

The reflector used are based on the geometry of a parabola. The light rays when fall on parabolic surface all the rays surface rays falling surface below focal point rays deflected/reflected upwards. In parabolic surface rays falling surface above focal point rays deflected/reflected downwards. Reflector design is based on the reflection pattern and temperature raise is based on reflections intensity and retention time of reflections in parabolic trough (Figure 1 & 2). The reflections vary w.r.t. to sun position. The reflector is placed on the box type cooker such that the focus of the reflector surface coincides with the cooker position. In this position in normal sky in 2 hours one kg of rice is boiled. This indicates if reflector is mounted on box there is increased boiling quantity and reflection losses reduction (falling out side box) reduced.

Figure 1: 9-segment reflector

Figure 2: The reflection pattern

1.4 Working

The solar cooker uses direct sunlight to produce heat for the cooking application. The setup is made with mirror reflectors which are joined as segments. All of them were combined together in the form of a parabola. A box is designed which has a black coating in it that is capable of absorbing heat energy where the utensils are placed for cooking. The reflectors arrangement is placed on the box and sun rays are made to focus on to the box (Figure 3). Concentrating all the sun-rays at a point produce too much heat energy at the focus point there by aiding cooking process (Figure 4).

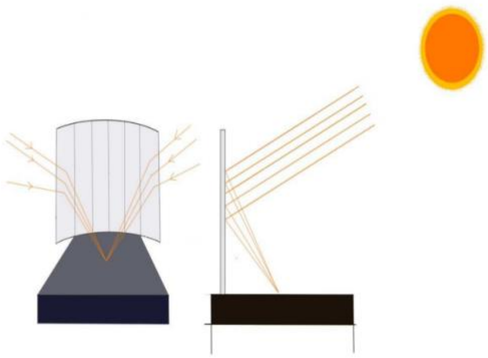

Figure 3: Illustration of sun rays falling on cooker

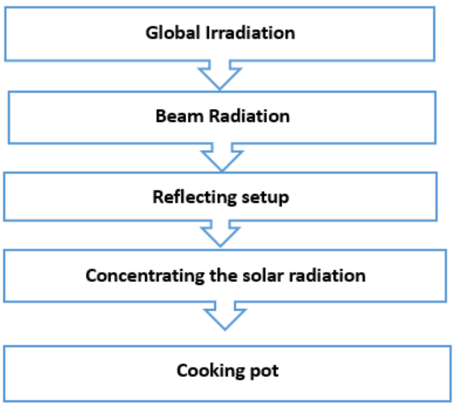

Figure 4: Block diagram of parabolic reflector

1.5 Sun Rays Analysis

As earth rotates, Sun rays travels East to West, East to noon the rising sun-shade length decreases- reduces the reflected light length the intensity of sun rays increases from morning to noon and reaches peak value at noon (Figure 5). Noon to west lowering sunshade length increases- increase the reflected light length. The intensity of sun rays reduces from peak value to minimum. In spite of this the shade rotates. The rotation of sun rays varies with respect to season wise.

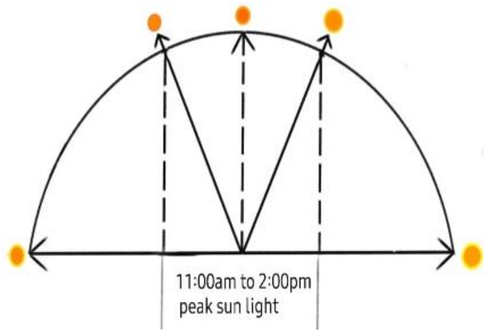

Figure 5 position of sunlight with time

In this way, from Figure 5 rays can be classified into inclined portion& vertical type. The sun ray's usage in inclined zone will increase the operating period of solar cooker. This is done with the help of tracking system using one direction& two direction using electrical/mechanical aids manually automatically

In the present design the tracking part is eliminated to maximum extent and incorporated in reflector design. In general the direction sun raising position varies season wise. The sun rises in east. Due to variation in east the directions west, north and south positions vary.

2.0 LITERATURE REVIEW

C Z M Kimambo [1] optimized various parameters and concluded that results obtained from this study show that under various conditions of insolation and wind, different types of solar cookers are superior to others. Viral K Pandya et al. [2] analyzed the performance of Box kind solar Cookers beneath Gujarat Climate Condition in Mid-Summer to boost the workability of cooking utensil a tiny low review on the box kind solar cooking utensil applications and its styles given here. Rahul Aadiwal et al. [3] discussed cookery energy dissemination within the country with associate objective of understanding the underlying socioeconomic factors governing the employment of assorted fuels/energy carries in cookery.

S. Mahaver et al. [4] performed thermal and preparation performance studies of a unique solar cooker; it's named as Single-Family solar cooking utensil (SFSC). Small size, convenient style, cheap light-weight hybrid insulation and specially designed light-weight compound glaze square measure the most options of this cooking utensil. Ouederni [5] developed parabolic star concentrator. Experimental measurements of solar flux and temperature distribution on the receiver are applied. The solar flux targeting receiver has been by experimentally determined. Lifang Li [6] developed a brand-new idea for coming up with and fabricating giant parabolic dish. The dish mirror was shaped from many optimal-shaped skinny flat metal petals with extremely reflective surfaces. hooked up to the rear surface of the mirror petals were many skinny layers whose shapes optimized to reflective petals type into a conic when their ends were force toward one another by cables or rods.

Ibrahim [7] developed parabolic dish solar storage tank for domestic hot water application. He found that the heater is providing 40 litres of hot water each day for a family of 4 members, presumptuous that every member of the family needs ten litres of hot water per day. At first, he expected the thermal efficiencies of fifty by the look however he obtained thermal efficiencies of 52 - 56 and this vary of efficiencies is above the expected designed worth. Fareed. M. Mohamed [8] studied transportable solar collector Concentrator and according style and fabrication of solar collector concentration with diameters 1.6 meters for water heating application and star steam was achieved. The dish was made-up using metal of galvanized steel, and its interior surface is roofed by a reflective layer with reflectivity up to (76 %), and equipped with a receiver (boiler) placed within the focal position. The dish equipped with pursuit system and mensuration of the temperature and solar energy. Water temperature enhanced up to 80ºC, and therefore the system potency enhanced by 30% at middle time of day time.

3.0 DESIGN CALCULATION

3.1 Parts and materials used

The various materials used in fabrication of solar reflector is presented in Table 1.

Table 1: Material used

Sn.no	Parts in the final setup	Materials
1	Reflectors	Glass
2	Reflector template	Aluminum
3	Cover glass	Toughened glass
4	Insulation	Mineral wool
5	Parabolic trough	Aluminum (black-paint-coated)
6	Sealing material	rubber

The surface is of the solar reflector is calculated using Eq. 1. The paraboloid surface area is:

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

Focal distance - f
Depth of the parabola - h
Radius of the parabola - R
The concentrator diameter - d
The equation giving the focal distance (f) is given by: $f = h^2/4R$

3.2 Effective heat utilized

Total area of light: Area of reflector (RA) + Direct incident rays received by black trough area (Tr A). Due to variation in Sun, hourly angle the reflector reflections will be varying and varying heat inputs will be given to boil the food.
Effective heat generated (ideal situation where total light falls in to box) = incident light of the total area. The maximum heat = (RA +Tr A)
Quantity of food boiled = Q (heat used for boiling water& food material-for boiling. For frying quantity kept in the utensil for frying).
Considering solar constant 1000W/Square meter/Hour or 860Kcals/hour/Square meter.
Effective heat input = 860(RA+ TrA) Kilo calories

3.3 Finding the Critical Angle

Because the position of sun in sky perpetually ever-changing, we tend to have an interest in determinant the focal height and radius that may collect the foremost mirrored rays with the foremost angle to a solar cooker incorporates a large angle tolerance, it implies that it's ready to replicate light onto the absorbing surface at extreme or smaller incoming angles. For a generic model the aperture length of the star cookware is control constant at one whereas the radius (r) and focal height (f) square measure taken as ratios of the diameter.

All reflected light is incident on the cooker however at what angle will the sunshine begin missing the cooker, it's given by the Eq. 2.

$$critical\ angle = \arctan\left(\frac{1}{16} \frac{\sqrt{1 + 32f^2 + 256f^4 - 256r^2f^2}}{rf} \right) \qquad \text{Eq. 2}$$

This critical is that the widest incoming angle for a given r and f and an aperture length of one that concentrates all the mirrored rays to the pot with radius r. In solar cooker cooking starts from top to bottom on portion. Within the present model reflector space (mirror area) = 0.585 square meter. Trough incident space = 0.1764 square meter.

4.0 EXPERIMENTATION

4.1 Reflector design

The reflector used are based on the geometry of a parabola. The light rays when fall on parabolic surface all the rays surface rays falling surface below focal point rays deflected/reflected upwards. In parabolic surface rays falling surface above focal point rays deflected/reflected downwards. Reflector design is based on the reflection pattern and temperature raise is based on reflections intensity and retention time of reflections in parabolic trough (Figure.6). The reflection varies w.r.t. to sun position. The reflector is placed on the box type cooker such that the focus of the reflector surface coincides with the cooker position.

Figure 6: Reflector design

4.2 Parabolic trough design

Since parabolic profile will deflect/reflect the incident rays to focal point. The parabolic surface (parabola: Square Y=4aX-where a is focal point) incident light rays falling on parabolic surface (Figure 7) below focal point rays will be deflected/reflected to upwards& incident rays above focal point rays will be reflected/deflected to downwards. Paraboloid cross section is circle in shape. If the circles are replaced with squares then compound paraboloid forms & the shape formed is two parabolas focal axes of which perpendicular to each other. In this way the compound 34 parabolic surface type absorber is designed to take care of vertical rays. At noon the reflector reflections are nil and only. Compound parabolic surface take care of the heating of the food and utensils.

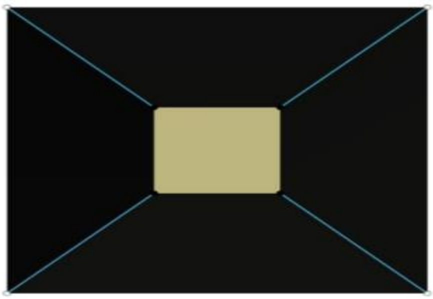

Figure 7: Parabolic Trough

The Sun rays falling on parabolic trough as mentioned above from reflector through double cover glasses it is seen clearly with necked eye. This shape will take care of inclined sun rays which are reflected by mirror. As the experiment is carried out at residence due to lack of sophisticated cameras the photos could not be taken. Though shade is formed in the trough due to rays of different directions the effect of shade in reduced to large extent and improved performance observed in the form of sustenance of higher temperature for higher periods. Due to sustenance of higher temperatures increasing the number of times boiling increases.

More over the depth/thickness of food layer will affect the cooking period. By selecting parabolic surface suitably with respect to utensils used the height of utensil can be reduced in turn lessen the food layer thickness.

4.3 Box type cooker design

Below Figure 8 indicates the cross-sectional view of insulated box fixed with rubber sealing and cover glasses. In the insulated box food containers black coated outside and lids coated with black outside with food material are placed in black coated compound parabolic trough as mentioned above. The insulation mineral wool to withstand more than 200°C. Sealing rubber is fixed on the insulated box. The sealing should be of rubber material to withstand more than 200ºC. Cover glasses are of toughened glasses. One toughened glass is directly placed on rubber packing. The toughened glasses are placed at 10 mm apart. The total load on the ceiling is weight of toughened glass and reflector material weight plus reflector template weight and in turn transferred on to insulated box (Figure.8).

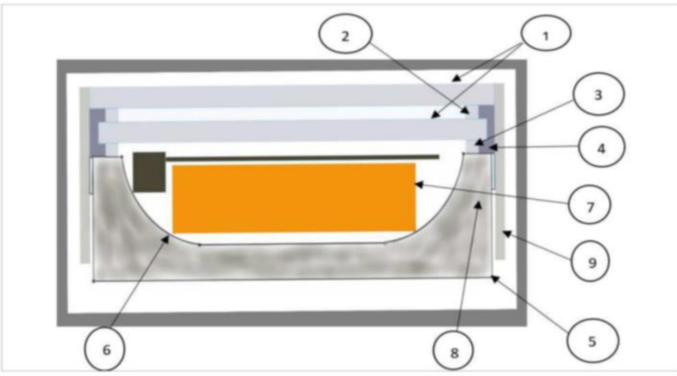

Figure 8: Sectional view of the box

1-Cover glass (toughened)
2-Packing (for maintaining gap)
3-Sealing packing
4-Box lid
5-Box
6-Compound parabolic trough (Aluminium made)
7-Utensil (S.S made and brass coated with black non-selective coating)
8-Thermal insulation (Hot)
9-Aluminium angles

4.4 Experimental Setup

In pilot model Rice 370 grams & leafy vegetable with dal 75 grams boiled. The reflector is taken out and cover glasses are taken out in the Figure 9 thermometers 3 nos are placed to monitor the temperature. They are used to measure temperature at different time periods.19 months temperatures were monitored continuously to rectify the problems arise during this experimentation This has led to ensuring guaranteed performance in normal sky conditions at different seasons.

If we closely observe Figure 10 we can find moisture accumulation. Due to moisture accumulation in winter slight cloudy sky there is increase in cooking period. In pilot model sealing material used is papers.

Figure 9: Utensils in the trough

Figure 10: Accumulation of moisture

The black trough in which leafy vegetable boiled in brass utensil& rice boiled in stainless steel utensil of standard pressure cooker 12 litres (smaller one). The lids are in open condition. Utensils outside black coated and lids outside black coated. In Figure.10 slight increased load with 2nd cup. Moisture accumulation is observed.

In bigger size model Figure 11 boils 1 kg rice. (The reflector used is 5 segments model used for ½ kg boiling). Reflector is mounted on box.

In this position in normal sky in 3 hours one kg of rice boiled. This indicates if reflector is mounted on box there is increased boiling quantity and reflection losses reduction (falling out side box) reduced.

Figure 11: Cooking rice using solar energy

5.0 ANALYSIS OF EXPERIMENTAL DATA

After the experimental setup is done, the parabolic solar cooker is subjected to different weather conditions that impact the cooking time. Temperatures at different locations are measured using pyrometer at different time intervals in different climatic conditions in Visakhapatnam. By performing the entire experiment throughout the day, the required data will be tabulated in the following way.

With respect to Visakhapatnam geographical location the following is the sun rays' position tentatively. To track the sun the reflector is to be rotated once in a day at noon when Sun moves towards west at noon, the amount of rotation 90 degrees w.r.t. vertical circle from early September to Middle April. In this period sun rays falls on East & rotates to south of box up to noon. After noon sun rays falls on south& west sides of box. In the remaining period mid-April to early September early hours to noon rays fall East& North and after noon South & West. In this period sun rays falls east& North during morning to noon11:30 hrs& at noon sun rays are vertical. After noon beyond 12:30 hrs the rays fall on South & West faces of box. The reflector is to be rotated 180 degrees at noon with respect vertical circle.

CASE:1

Analysis in working condition (no load) at Wind speed = 2 m/s were presented in Table.2 and the variation of temperature with time in no load condition is presented in Figure 12.

Table 2: No load readings

S.No	Time (hrs)	Air temperature (°C)	Average Global Solar Radiation(W/m^2)	Tray temperature(°C)
1	10:30	22.3	721.9	34
2	10:35	22.1	750.2	52

3	10:40	22.1	759.7	62
4	10:45	22.0	770.4	71
5	10:50	22.3	773.4	75
6	10:55	22.8	783.8	79
7	11:00	22.6	782.9	83
8	11:05	22.7	784.8	86
9	11:10	23.3	785.2	88
10	11:15	23.1	783.2	91
11	11:20	23.4	788.8	93
12	11:25	23.2	760.2	95
13	11:30	23.1	798.6	97
14	11:35	23.1	789.6	97
15	11:40	23.3	695.5	98
16	11:45	23.5	777.6	98
17	11:50	23.6	778	99
18	11:55	23.7	787.0	101
19	12:00	23.6	770.8	101
20	12:05	23.6	772.5	101
21	12:10	23.8	708.9	102
22	12:15	24.3	766.7	102
23	12:20	24.0	765.7	103
24	12:25	24.8	764.9	103
25	12:30	24.4	750.7	103

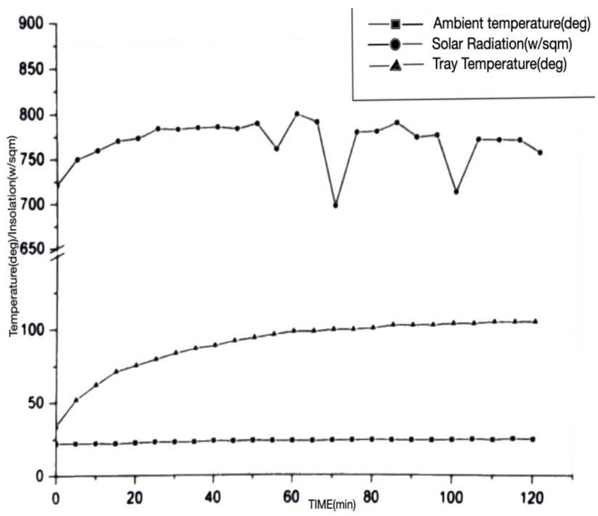

Figure 12: Variation of temperature with time in no load condition

CASE: 2

Sensible heating of water at average wind speed=2.2 m/s was presented in Table.3and the variation of temperature with time in sensible heating is presented in Figure 13.

Table 3: Sensible heating of water

S.No	Time (hrs)	Air Temperature (°C)	Average Global Solar Radiation (W/m²)	Water Temperature (°C)
1	10:00	22	218.7	20
2	10:05	22.3	506.9	24
3	10:10	22.5	527.1	24
4	10:15	22.7	545.7	25
5	10:20	22.6	584.3	27
6	10:25	22.8	553.3	28
7	10:30	23.4	584.0	30
8	10:35	23.3	600.4	31
9	10:40	23.2	609.6	33
10	10:45	23.7	627.5	35
11	10:50	23.7	641.9	37
12	10:55	24.7	645.7	39
13	11:00	24.4	662.7	42
14	11:05	24.2	657.7	44
15	11:10	24.6	679.7	46
16	11:15	24.5	659.8	48
17	11:20	24.4	664.3	51
18	11:25	25.3	698.7	53
19	11:30	24.9	717.5	56
20	11:35	25	729.0	58
21	11:40	25.3	734.3	60
22	11:45	26.1	741.3	63
23	11:50	26.1	751.7	66
24	11:55	25.9	759.1	69
25	12:00	26.4	763.4	72
26	12:05	25.9	769.5	75
27	12:10	26.9	769.6	77
28	12:15	26.5	784.2	80
29	12:20	26.3	768.9	82
30	12:25	26.8	790.0	84
31	12:30	26.8	799.1	87
32	12:35	26.6	805.6	89
33	12:40	26.8	808.3	91
34	12:45	26.8	813.7	93
35	12:50	26.6	798.4	95
36	12:55	26.7	789.2	96
37	13:00	27.1	810.7	97

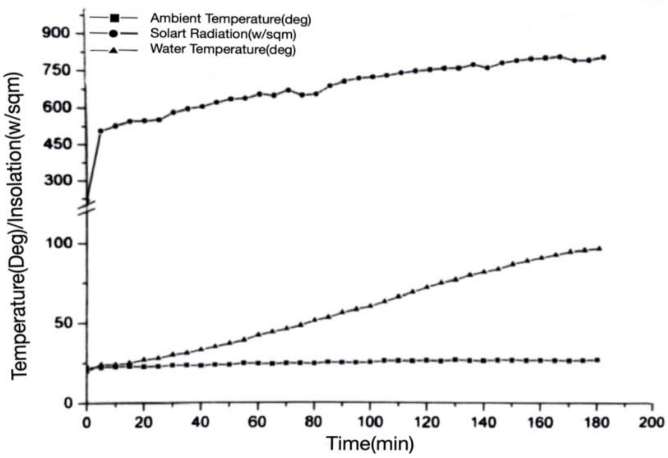

Figure 13: Variation of temperature with time in sensible heating condition

6.0 CONCLUSIONS

Cooking with solar energy remains a fuel-saving technique, which can provide definite help in situations of fuel scarcity. Solar cookers and especially cooking boxes can be successfully locally made. By performing the experiment, we can come to an assumption that the parabolic reflector solar cooker performs far better than a box type solar cooker when it involves subjecting additional heat into the box. As the number of segments increases the effectiveness also increases. Continuously tracking of sun automatically increases the manufacturing cost as it involves sensors and moving objects. Parabolic Solar Cooker helps in avoiding crores of tons of biomass and wood fuel can be saved.

7.0 FUTURE SCOPE

There is a great deal of work that can still be done in this area. Several advanced models can be designed and fabricated in such a way that most of the solar energy can be made use of by concentrating the accumulated sun rays on to the working zone. Usage of different materials as collectors can help in improvement of the model. By making use of solar cookers depletion of non-renewable energy sources can be controlled.

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