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Efficiency Evaluation and Comparison of Solar Fresnel Lens Cooker and Box Type Cooker

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Abstract*—Solar energy has great potential in terms of supplying the world's energy needs. The project work aims at experimental work to find out methods to use the thermal part of sun light in effective way. The present status of application, the ongoing research and development works suggest that Fresnel lens solar concentrators bring a breakthrough of commercial solar energy concentration application. Solar concentrators are in use in the solar technology based equipments for past many decades. In this work performance in terms of heat absorption capability of flat bed mirror box type solar cooker has been compared with the Fresnel lens cooker. Efficiency evaluation for both type of cookers has been done and additional heat gain in case of Fresnel lens cooker compared to box type cooker has been worked. cost saving and incurrence of additional costs have been used to evaluate commercial feasibility and pay back period etc.. The solar cookers are very much popular in domestic and industrial applications such as water heating and food preparation etc. The project work opens up new avenues for improvements in efficiency of heat collection from sun i.e. effective utilization of solar radiations*

Keywords:— *Solar energy, Fresnel lens, wavelength, Solar Radiation, solar cookers, Thermal technology, Solar Power, Infrared*

1. INTRODUCTION

Fresnel lenses are used in solar concentration which take a large area of sunlight and direct it or concentrate the beam to a specific spot by focusing them. This is done both for heat and light applications. In other types some simple lenses are also used on the same principle. When they use a magnifying lens to focusing the sun rays on a stack of paper, the heat concentration goes so high that this triggers fires. Fresnel lenses have dart board shape, with concentric rings of prisms around a lens. All of these features allow them to focus scattered light from the Sun in a concentrated beam. Solar thermal technology is considered principally with the utilization of thermal part of solar energy. In the concentrating type of solar collector, solar energy is collected and concentrated so that high temperatures can be obtained the limit is the surface temperature of the sun.

Various designs of the solar concentrator have been studied in order to optimize their performance and the variation was depending on the geometrical form and the place of the pot. Initially, there have been a lot of developments involving the designs of solar concentrator.

A significant number of parabolic troughs have designed, built, and tested, primarily with private funds. Many types are

available in the market. Troughs differ in their reflective materials, structural materials, receiver concepts, etc. The attainable temperature reaches about 540 degree C (1000 [degrees] F). The designs vary with intended temperature application, since surface error, [2]

2. PRINCIPAL OF THE SYSTEM

To boil water using solar energy we need to rivet the solar radiation in order to increase the local temperature at the collector superficial to value higher than 100°C. There are many types of concentrators; most of them are of the reflecting type, which take placing the receiver at a level higher than the concentrator. This condition usually results in a very inconvenient condition for the household applications. The other option is to use a Fresnel lens focus which allows for the positioning of the cooking pot more conventional and easily accessible by the user during the cooking outgrowth. In this project there were design for the solar water boiler. The first was a single Fresnel lens of attribute 30.5*Andean a receiver located at the lower side of an insulated cooking pot. Heat is conducted through the bottom, side and the inner wall of the insulate pot to the water inside the pot. The pot capacity was about 2 liter. Figure shows the assemble of the first concept solar water boiler.

Figure 1 :Fresnel Lens

3. SOLAR RADIATION

The sun is sending us radiation over a wide range of wavelengths at varying intensities. The electromagnetic solar radiation striking on the upper edge of the atmosphere is called extra-terrestrial radiation. The mean integral for the complete spectrum is 1,367 W/ m² (Solar Constant).

The normal measurement of the wavelength of solar and atmospheric radiation is the nanometer (nm, 10-9 m) and for infrared irradiation is the micrometer (µm, 10-6 m). In astronomy and older books you may see wavelengths in Angstroms (Å, 10-10 m).

The methodologically significant spectral range extends from 300nm to 3000nm (short-wave radiation). Close to 96% of the complete extra-terrestrial radiation is situated within this spectral range. The maximum radiation intensity of the solar spectrum at 500 nm, towards the blue end of the visible range.

The complete spectrum comprise the ultraviolet (UV), seeable (Vis) and infra-red (IR) wavelengths. However, these wavelength ranges need to be sub-divided depend on the individual application field. Best known are the prismatic colors of visible light, the colors of the rainbow. IR Split into near infra-red (NIR) and far infrared (FIR).

6++UV is normally sub-divided into UV -A, UV-B and UV-C radiation. Just about 6% of the total solar radiation falling on the earth is ultraviolet. Shorter wavelength (higher frequency) has higher energy, thus increasing the effect on biological and chemical systems.

4. BOX-TYPE SOLAR COOKERS

Box-Type Solar Cookers - or more precisely solar cooker-cum-ovens (or solar ranges) - consist of a well-insulated box with a black interior, into which black pots containing food are placed. The cover of the box usually comprises a two-pane “window” that lets solar radiation enter the box but holds the heat from escaping. This in addition to a lid with a mirror on the inside that can be adjusted to intensify

the incident radiation when it is open and improve the box's insulation when it is closed.

Figure 2. Solar Box Type Cooker

5. RESULT AND DISCUSSION

The stagnation test was conducted at Two absorption of solar heat radiation in the solar cooker (Box type solar cooker & Fresnel lens cooker). The test started 21-05-2014 at 9:30 Am till the maximum absorber temperature was reached after 1 hour. Details or measurement results of the test Discussed. The table indicates the value of temperature measured both in the Fresnel lens and Box cooker and in the ordinary flat bed flat mirror box type cooker. Both cookers are identical devices in term of solar radiation reflection area and also in terms of capacity of water hot pot in the cooker for measurement of heat absorption water. Both box cookers have sun radiation absorption area of (869.25 cm^2).

The cooker capacity of hotpot in both type of cooker is (2 liter) as such for identical energy of sun radiation absorption. The rise in temperature in both type of cooker is expected to be identical. However the result obtained are as tabulated below with same time/temperature hot pot of Fresnel lens solar cooker has been recorded to be temperature of 37.3 ^{o}c & Box type solar cooker temperature 34.2 ^{o}c. has been recorded to be through digital based thermometer of high recoding accuracy.

Table 1: Solar Radiation of Fresnel Lens Type Cooker and Box Type cooker Temperature Experiment Conducted on 21-05-2014

S.N	Time	Fresnel Lens Type Cooker Tempera-ture ^{o}c	Box Type cooker Tempera-ture ^{o}c	Solar Radia-tion w/ m^2
1	09:30 am	30.00	30.0	553
2	09:35 am	30.7	30.4	586
3	09:40 am	31.3	31.7	629
4	09:45 am	32.0	31.1	640
5	09:50 am	32.6	31.5	650
6	09:55 am	33.3	31.8	660
7	10:00 am	33.9	32.2	680
8	10:05 am	34.6	32.5	685
9	10:10 am	35.0	32.8	710
10	10:15 am	35.5	33.1	715
11	10:20 am	36.0	33.5	720
12	10:25 am	36.6	33.8	730
13	10:30 am	37.3	34.2	870
Total				8828
Average of solar radiation =8828/13				679.07

The Fresnel lens temperature attained was 37.3^{o}c the corresponding solar box cooker temperature and average solar radiation were 34.2^{0}c and 679.07 w/m^2 respectively.

Although one set of experiment was done on 21-05-2014 in order to avoid inaccuracy one is sudden change weather condition and to have better averaging for another experiment has also been performed on 23-05-2014. First experiment was done during morning time & the second experiment has been planed in midday time (12 pm.)

Table – 2: Solar Radiation Graph Technical Data

Concentrator	Area	Lens/ glass thick-ness	Water level of pot	Temp. in ^oC 21-05-2014 23-05-2014	Cost lens/ Mir-ror
Box Type	869.25 cm2	4 mm	2 Liter	4.2 4.6	50/-
Fresnel Lens	869.25 cm2	4 mm	2 Liter	7.3 9.6	450/-
Average solar radiation W/ m2	-	-	-	79.07 999.2	-

Solar Radiation Graph based on the solar radiation reading recorded by the weather monitoring system installed in the Gyan Ganga Institute of Technology & Science Jabalpur.

During the summer peak period of may has been plotted and result are as under.

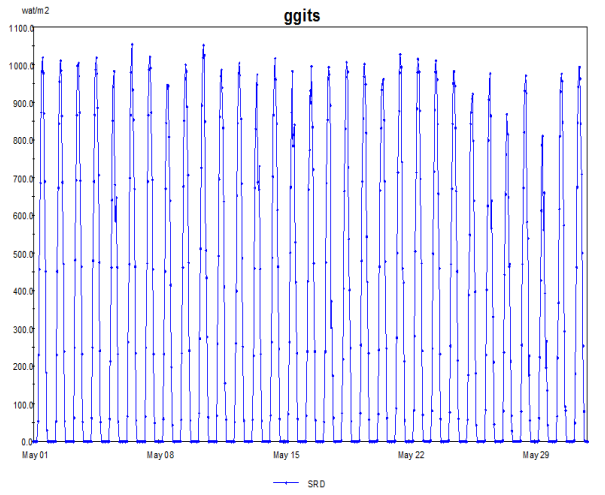

Figure 3:- Solar radiation graph

6. CALCULATION

Experiment Conducted on 21-05-2014

i) Fresnel lens solar cooker –

Initial Temperature of Water = 30^oc

Final Temperature of Water = 37.3^oc

Temperature Rise = 7.3^oc

Water Level of Pot = 2 liter

Size of lens = 30.5×28.5 cm^2

= 869.25 cm^2

= 0.0869 m^2

Solar radiation = 679.07 w/m^2

Solar power = Area of lens × Solar radiation

= 0.0869 $m^2 \times$ 679.07 w/m^2

Power = 59.011183 watts.

1 watts = 859.85 cal/hr.

So for 59.011183 watts. = 859.85× 59.011183

= 50740.765703 Cal/hr.

We known -: 1 calorie = 1 gm by 1^0c

And

1 k cal = 1 liter by 1^0c

So

2 k cal= 2 liter by 1^0c

So for

2 k cal = 2 liter by 7.3^0c

= 14.6 k cal

Water absorb Kcal = 14.6 Kcal/hr

Total sun radiation = 50.74076 Kcal/hr

Therefore of Fresnel lens

Solar cooker efficiency

$$= \frac{14.6}{50.74076} = 0.2877\%$$

= 28.77%

ii) Flat box solar cooker:-

Initial temperature of water = 30 °C

Final temperature of water = 34.2 °C

So temperature difference = [34.2–30]°C

= 4.2 °C

Water level of pot = 2 liter

Temperature rise = 4.2 °C

So 2 Kcal = 2 liter × 1 °C

So 2 Kcal = 2 liter × 4.2 °C=8.4 Kcal/hr

Sun radiation = 50.74076 Kcal/hr

Therefore

$$\text{efficiency} = \frac{8.4}{50.740763} \times 100\ \%$$

= 0.16554 × 100 %

= 16.554 %

Gain in efficiency = 28.77 – 160554

= 12.3152 %

7. DISCUSSION

The principal objective of this work is a preliminary testing of a two solar Cooker first Box type and second Fresnel lens solar cooker. A box-type solar cookers have been simple designed use a mirror reflector and glass and second solar cooker used Fresnel lens and both are same size A comparative experimental test of heating power of the solar cookers was carried out during the successive days from the 21st and 23rd may 2014. Each experiment starts from 9:30 am in the 12:00pm. The electrical and electronic parts were tested. The experimental work was fully carried out at Electrical engineering Department, Gyan Ganga Engineering College Jabalpur (M.P.) India. First one, we have performed experimental test on both solar cooker is same time and same water level takes in pots then takes the reading the starting temperature was same in both cookers and after some time lead the Fresnel lens solar cooker temperature. Than entire solar cooker was placed in sun and orientated to receive maximum solar radiation to heat water contents of the pots.

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