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Fabrication and Study of Light Weight Inexpensive Portable Solar cooker

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Abstract

Light weight inexpensive portable solar cooker (LIPS) is fabricated and its performance as solar cooker is studied. The size of the cooker is so small (0.3743 m^2) that, it can be easily transported from one place to other. Its performance is analysed with the help of an aluminium vessel which acts as an absorber. This vessel is painted with dull finished black board paint. Various food materials are cooked and the time consumed is noted. The time consumption by this type of cooker is acceptable for domestic cooking purpose. The fabrication cost of this cooker is also affordable for typical Indian lower middle class people. The objective of this study is to provide inexpensive cooking device for poor / lower middle class people and does not undertake comparative performance analysis with any type of commercial solar cooking devices available in the market.

Introduction

The abundance of solar energy is being used for various purposes. In India, domestic cooking is mainly done with the help of fossil fuels like kerosene, LPG etc. Many of the poor / lower middle class people of India are not in a position to offer the cost of the above said fuels. In many of the Indian villages, people use fire wood as the fuel for cooking which leads to environmental problem. The cost aspect of the fossil fuels and the current scenario force the mankind to look for alternate and renewable energy resources. Moreover, usage of fossil fuels like petroleum, coal and natural gas gives rise to pollutants such as soot, tar, particulate matter and ash. They further give rise to green house effect which leads to sea level rise and submersion of low lying areas, drought, wild fire, desertification of erratic rain, health problems, erratic seasonal conditions, acid rain and global warming. A sum of 32 x 10^9 tonnes of combustion products (gases) are thrown out into the atmosphere every year. It has been predicted that, if we continue the policy of using coal, oil and gas at the present rate, then by the year 2020 the global temperature will have increased by two degrees Celsius. Taking the above parameters into consideration, an attempt is being made to tap the solar thermal radiation for useful cooking and also to warm the already cooked materials [1 – 3]. A typical concentrating type cooker is deduced for the sake of cooking from unused commercial type bigger size dish antenna by the authors [4]. In the present work, light weight inexpensive portable solar cooker has been designed and fabricated which resembles that of a small sized elliptic paraboloid dish antenna and thermal studies have been carried out for the same.

Technical design specification

Efficiency of the concentrating type cooker mainly depends on the reflector and absorber assembly. The reflector and absorber assembly of this solar cooker are shown in Fig. (5). The aperture area of the reflector is refined in such a way that it can be easily transported [5, 6]. Similarly, the focal point is identified so as to enable the rays coming from the sun to fall on the absorber [7, 8]. The focal point lies at a distance of 32 cm from the reflecting surface as shown in Figure (6). Since the type of the cooker is elliptic paraboloid, an empirical formula is deduced for the calculation of surface area of the reflector.

Let ‘f’ be a positive function with continuous derivative on [c, d]. Then the surface area, “A” obtained by rotating the curve y=f(x) about the x axis is

$$A = \int_c^d 2\pi f(x)\sqrt{1 + f'(x)^2}\, dx$$

Let the function be

$$y^2 = 4ax, [a,b] = [c,d]$$

$$\therefore y = 2\sqrt{a}\sqrt{x} \Rightarrow \frac{dy}{dx} = 2\sqrt{a}\,\frac{1}{2\sqrt{x}} = \sqrt{\frac{a}{x}}$$

$$A = \int_c^d 2\pi 2\sqrt{a}\sqrt{x}\sqrt{1 + \frac{a}{x}}dx$$

$$A = 4\pi\sqrt{a}\int_c^d \sqrt{(x+a)}dx$$

$$A = 4\pi\sqrt{a}\left[\frac{(x+a)^{3/2}}{3/2}\right]_c^d$$

$$A = \frac{8\pi}{3}\sqrt{a}\left[(d+a)^{3/2} - (c+a)^{3/2}\right]$$

If c=0

Area of the Elliptic paraboloid = $\frac{8\pi}{3}\sqrt{a}\left[(a+d)^{3/2}-a^{3/2}\right]$

Where, **a** = Focal length of the paraboloid

d = Distance (height) from the origin.

By measuring the values of ***a*** and ***d***, the surface area is calculated as 4.02 Sq. ft.

At the focal point, a black painted aluminium vessel is kept as the absorber for heating and cooking purposes. A holder is designed to hold the vessel for easier cooking conditions. The entire surface is pasted with locally available aluminium reflector sheet for good reflection purpose. As seen from the Figure (6), the reflected rays of the sun fall on the bottom of the absorber thereby producing intense heat.

Experiment

Heating Tests on Solar Cooker

The performance of the solar cooker is generally assessed by water heating tests [9]. The following observations have been made with the assumption that the vessel and water are heated to the same temperature and the shadowing effect of the absorber is neglected. We have carried out the water heating and saturation tests in light weight inexpensive portable solar cooker on a bright sky day (Average solar direct radiation is around 910 W / m^2 – the maximum radiation is 940 W / m^2 and the minimum radiation is 880 W / m^2) and the effect due to wind velocity is also noted. Water heating test and saturation test for castor oil are taken by insulating and not-insulating the absorber to analyse the maximum temperature attained in each case and also to estimate the dissipation due to radiation to the surroundings. Tracking is done for every 15 minutes towards the zenith and azimuth direction of the movement of sun for higher heat efficiency.

(i) Total quantity of water in the aluminium vessel is 500 cc. Water boiled in 16 min.
(ii) Total quantity of castor oil in the aluminium vessel is 500 cc. Maximum temperature attained is 208^{o}C.
(iii) The average solar intensity (direct radiation) is estimated to be around 910 W/ m^2.
(iv) Aperture area of the concentrator is 0.3743 m^2.

Cooking Tests

Cooking tests have been performed to determine the time of cooking for Raw Rice, Dhal, carrot, egg and Corn. Materials have been put into the container at room temperature and kept at the focal point of the cooker. The values are presented in the Table I.

Table I: Cooking tests for various food items.

Cooking Material *	Quantity Material + Water	Time taken for cooking (Minutes)	Already reported time From literature (Minutes) (V. Ponnusamy, 1999) [10]
Raw Rice [a]	0.250 Kg + 800 ml (1 : 3 volume)	20	22
Dhal [a]	0.250 Kg + 750 ml	22	24
Carrot	0.250 Kg + 500 ml	16	----
Egg	2 Pieces + 500 ml	18	28
Corn (Boiled up to eatable condition)	3 pieces + water 600 ml (1 : 3 volume)	20	---

a. Soaked in water for 30 minutes before cooking.

Results and discussion

A Light weight Inexpensive Portable Solar Cooker (LIPS) has been designed and fabricated. Its performance as cooker has been analysed. It can be seen from the table II that 500 ml of water is brought to boil in 16 minutes. The saturation test for castor oil indicates that temperature above 200^o C can be achieved with this type of cooker in duration of 2 hours. Further, it is found that for an ideal Indian family of 3 members, entire cooking (typical South Indian food) can be done within 2 hours on a clear sky day (Minimum solar direct radiation of 800 W / m^2). The saturation test for castor oil shows that the cooker takes more time for attaining saturation temperature when the wind velocity is high. Further, this type of cookers can be used for baking items. The time required for various food items are shown in table I. The time consumption is appreciably less for domestic cooking. This is mainly due to the high optical performance of the concentrator. The weight of the cooker is nearly 6.5 Kg. Care is taken for the selection of reflector assembly for easier transportation. In addition to that, light weight inexpensive portable solar cooker can be fabricated at a cost of about Rupees 550/- (INR) (approximately US $ 10), which we strongly feel that it is affordable for lower middle class / poor Indian public.

Table II: Water Heating Test.

Time	Temperature (Without Insulation) ^{o} C	Wind Velocity (Knots)	Temperature (With Insulation) ^{o} C	Wind Velocity (Knots)
0	30	5	32	2
5	50	14	53	8
10	68	6	75	0
15	85	8	95	13
20	98	12	110	10
25	118	2	132	3

Table III: Saturation Test for Castor Oil.

Time	Temperature (Without Insulation) ^{o} C	Wind Velocity (knots)	Temperature (With Insulation) ^{o} C	Wind Velocity (knots)
11.00	33	0	34	2
11.15	78	5	86	4
11.30	114	3	125	4
11.45	126	2	142	3
12.00	140	10	160	1
12.15	155	11	165	0
12.30	170	7	185	0
12.45	180	2	201	0
13.00	180	2	208	0
13.15	180	0	208	6
13.30	180	0	208	2
13.45	180	0	208	1
14.00	173	4	204	0
14.15	161	11	190	0
14.30	153	2	182	0
14.45	150	1	170	10
15.00	145	2	165	2

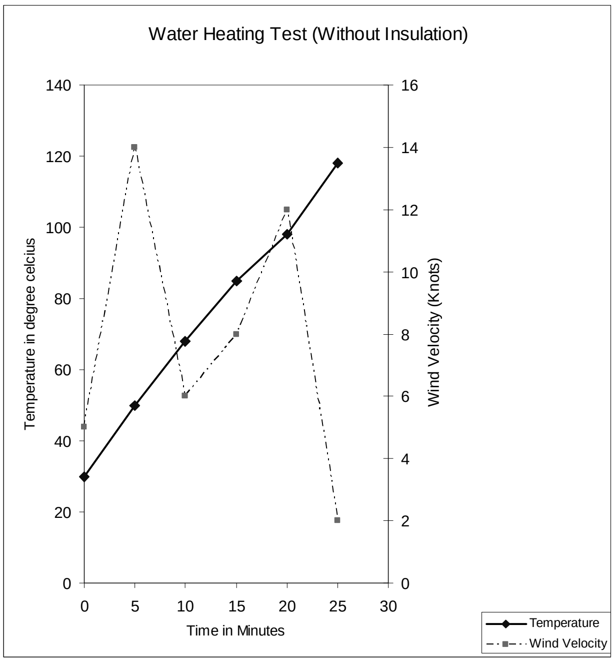

Figure 1: Water Heating Test (without insulation).

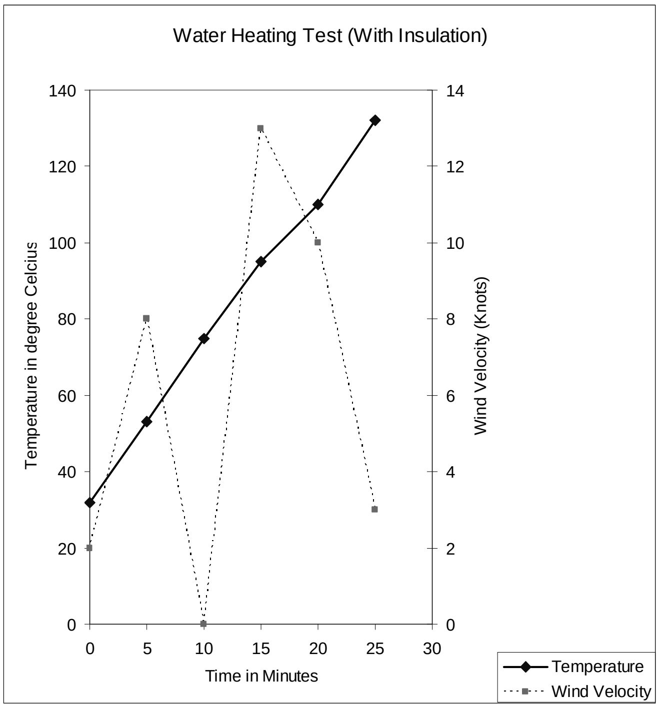

Figure 2: Water Heating Test (with insulation).

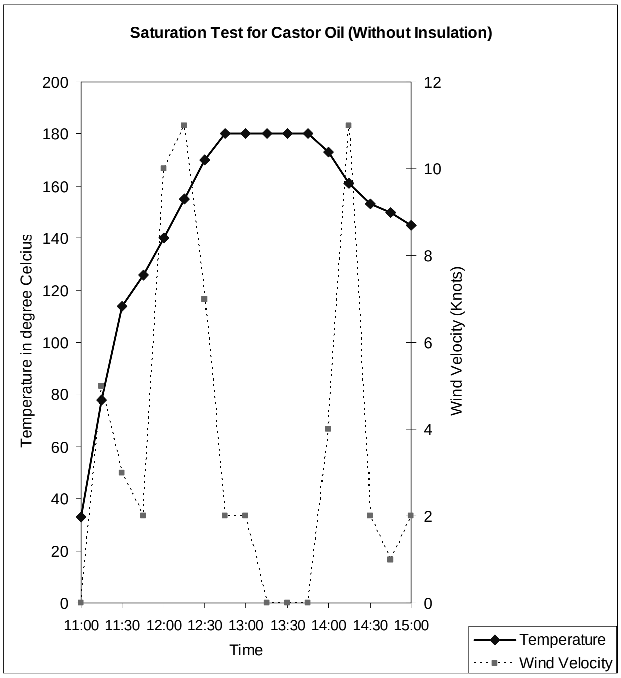

Figure 3: Saturation Test for castor oil (without insulation).

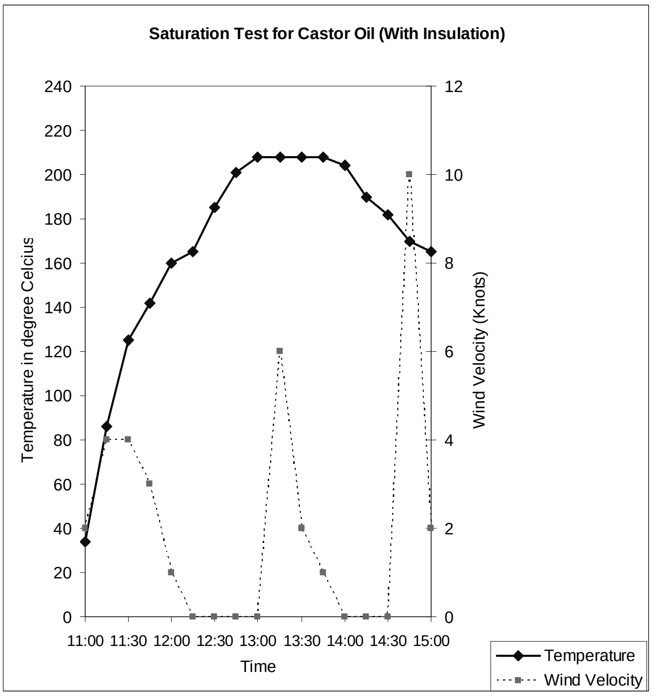

Figure 4: Saturation Test for castor oil (with insulation).

Figure 5: Light weight Inexpensive Portable Solar cooker (LIPS).

Figure 6: Absorber assembly.

Conclusion

The primary objective of this work is to provide light weight inexpensive cooking device for lower middle class / poor people. The cost and the weight of the cooker fulfil our purpose (affordable and transportable). Further, we wish to state that, this type of cooker resembles a small sized dish antenna; it is possible that any unused, small sized dish antenna can be readily modified into a light weight inexpensive portable solar cooker (By removing the LNB and providing required provision for absorber assembly). Water heating and saturation tests have been carried out and that data will be compared with commercial type solar cookers in future. Compared with the commercial solar cookers available in the market, the cost is lower by 3 – 4 times. Hence, it is concluded, that this type of cookers can be employed for water heating and cooking purposes and also to heat the already cooked food stuff during tours and picnics.

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