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Modification in the Design of Pot Lid and Its Arrangement in Solar Cooker to Enhance Its Performance

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ABSTRACT: Energy is the life line of civilization. In the course of development of civilization the rate of energy consumption in all forms has been rising all over the world. This may be due to increase in population as well as change of lifestyle which attract people towards mechanization. So dependence on fossil fuel energy resources like oil, coal and gas as is increasing day by day. Increased use of fossil fuel not only reduces the earth's limited fossil fuel reserves, but also causes environmental problems both locally and globally. Developing countries depend mostly on natural fuel sources such as wood fuel, fossil fuel (kerosene and liquid petroleum gas) etc. for cooking purpose. However, these are expensive and also lead to the threads like deforestation as well as environmental degradation. An alternative renewable energy source like solar energy can contribute a solution towards the adverse crisis of fuel consumption along with environmental pollution of developing countries. In different studies related to solar cooker it is obtained that conduction is the strongest mode of heat transfer when placed on the tray bottom in compare to convection and radiation. In this study work it has been carried out to enhance convection and radiation and to remove the radiation and convection losses from metallic lid of the pot by replacing it by transparent glass lid and increasing convection effect under pot bottom by placing it over black painted meshwire stand and black painted mildsteel stand one by one. This work study results that when a metallic lid of stainless steel solar cooker pot is replaced by transparent glass lid and pot is placed over meshwire stand having 25mm height, its temperature get enhanced by 4.99% but when the above arrangement is replaced by vessel attached with mild steel four lugs 90° w.r.t. each other having 18mm height and 13mm thickness, also pot metallic lid is replaced by transparent glass lid, its performance get enhance by 7.67%. By performing the experiment, it is found that the vessel with glass lid and attached mildsteel four lugs is the best combination for thermo-economic advantage. The objective of the present paper study is to make the solar cooker popular and friendly in Indian houses. In present work the experiments are performed on solar cooker (ISI 13429:2000 Part 1, 2000).

KEYWORDS: Box Type Solar Cooker, Double Reflector, Tilt Angle, Latitude Angle, Tracking of Reflector

I. INTRODUCTION

Solar energy is a very large, inexhaustible source of energy. The power of the sun intercepted by the earth is approximately 1.8×10^{11} MW, which are many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy need of the world on a continuing basis. This makes it one of the most promising of the unconventional energy source. Solar cookers are not a new idea. Designers as far back as the 19th century recognized the potential of the sun's energy to provide heat for cooking and other purposes and designed appropriate tools to harness it. It is indeed likely that solar energy was used for cooking long before then. Solar cookers have many potential benefits, both to their user and to the environment. A frequently cited advantage of solar cookers is that they reduce users' dependence on fuel sources for cooking. This reduction has economic benefit to the user by reducing their expenditure on fuel and also environmental

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benefit by reducing deforestation (in regions where wood is used as a cooking fuel) and release of combustion products into the atmosphere. Because a good deal of wood-based cooking is performed indoors with poor ventilation, solar cooking also has the potential to reduce smoke inhalation and related health difficulties.

II. DESIGN OF BOX TYPE SOLAR COOKER

It consists of an insulated outer and inner box, metallic cooking tray sat inside the box, double glass lid on the cooking tray, and two reflecting mirrors fitted to the two sides of the lid of the box and an adjustable stand. The cooking tray is insulated on the sides and bottom. The cooker box consists of a top open black painted inner box kept inside of the box and the space between the two boxes is filled with glass wool insulation. The two reflecting mirrors are placed on the upper side of the box with a gap between them and are in hold by a hinge joint with the cooker box. This is a conventional type of cooker and its length is three times its width and depth is same as that of width. The cooker is to be placed facing sun, keeping longer side vertically inclined position and the inclination of the cooker box can easily be changed from 15 degree to 45 degrees with respect to the ground by the adjustable stand, attached at the back side of the box. The reflectors are set along the length of the cooker box cover, one in each side, by hinge and holding strip. So length of reflectors is equal to the length of the glass cover. The widths are equal to the width of the glass cover. The reflectors are inclined at an angle of 115 deg with the face of the box cover. The face of the cooker is to be placed perpendicular to beam radiation to collect the maximum energy. This perpendicular position can be easily achieved simply by the rotation of the cooker towards the sun with the help of caster wheels, suitably attached at the bottom side of the cooker and by changing the inclination of the cooker by adjustable stand of the back side. But the position of the reflectors remain unchanged throughout the working period. Black painted stainless steel cooking pots are used and are placed side by side at the longer side of the cooker on cooking trays.

III. EXPERIMENTAL SET UP

3.1 Solar Cooker Specification and Design

The cooker consists of 0.5mX0.5mX0.15m steel sheet box with 25 SWG thick black painted aluminium sheet trapezoidal tray. It is supplied with blackened cylindrical stainless steel cooking utensil with flat base (180mm in diameter and about 60mm in height with tight fitting flat lid in position) as shown in Figure 3.1 and Figure 3.2. The blackened aluminium tray surface area is 0.425m^2 and it acts as an absorber of solar radiation. The bottom surface of the tray is 0.130m^2 in area. Four cooking utensils can be kept inside it. The cover plate is double glazed with glass ($L \times W = 420 \times 420\text{mm}^2$). Gap between 4mm thick glass plates is about 20mm. The cover plate can be kept at any inclined position for loading and unloading of the cooking pots in the cooker. Plane mirror free of any defects, is hinged at the side of the box to increase solar radiation flux on solar cooker glass cover. The mirror can be adjusted in any inclined position. The mirrors have reflectance of 0.85 and transmittance of 0.66 which is greater than the 0.65 as per IS 13429(Part2). The reflecting area of mirror is $450 \times 450\text{mm}^2$ which is greater than the glass area. The un-concentrated solar radiation is admitted through the opening or intercepts area $L \times W$. Thus, the radiation falls upon the glass cover both directly and indirectly i.e after reflection from mirror. Polyurethane foam seals joint between the cover plate and tray the pressure due to the weight of the cover glass assembly. The space between the aluminium tray and outer metal body of the cooker is filled with glasswool insulation. Thermal resistance R of about 40mm thick glasswool insulation having conductivity of 0.06 W/m/k at 380k, in the present cooker works out to be $0.66\text{ m}^2\text{k/w}$ at 380k.

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Figure 3.1: Two identical solar cooker use for experiment



Figure 3.2: Box type solar cooker with top cover and thermocouple arrangement

3.2 Temperature Measurement

Temperature probe of the calibrated copper-constantan thermocouple has been placed in the cooking pots. The thermocouple wire hole in cover has been sealed using M-seal as shown in Figure 3.3. Four thermocouple have been fixed at the middle of the tapered sides of the tray. The ambient temperature has been measured by digital temperature sensing device as shown in Figure 3.4.

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Figure 3.3: Cooking pots with thermocouples



Figure 3.4: Digital temperature sensing device and millimetre

3.3 Experimental procedure and conditions

The test was conducted in the morning between 09:00am IST from 26/05/2014 to 06/06/2014. Readings of water temperature were recorded after half hour intervals. The interval was reduced to 15-20 min after the water temperature reached about 75°-80°C. The upper limit of water has not been taken as 100°C (boiling temperature at the atmospheric pressure) because the rate of variation of water temperature approaches zero as the water temperature approaches 100°C and hence there is a great uncertainty in deciding the termination point of time interval. Therefore the upper limit of sensible heating has been fixed in the temperature range of 90°C to 95°C and the data recorded was continue till water temperature reached about 90°C to 95°C. The tilt of the reflector was adjusted after every observation so that the reflected radiation does not fall outside the glazing and covers the glazing completely. The similarity test of solar cooker-1 and solar cooker-2 was carried out to check the unbiasedness of both the cookers by interchanging the pots in the cookers.

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IV. EXPERIMENTAL RESULTS

The temperature readings obtained in mv units get converted into °c and following observations were obtained.

Table:4.1 Blackened stainless steel pot-1 in solar cooker-1(pot over mesh wire stand and transparent glass lid) and Blackened stainless steel pot-2 in solar cooker-2

S.NO	TIME(Hrs)	COOKER-1(°C)	COOKER-2(°C)
1	9:00 am	30.3	30.3
2	9:30 am	37.6	40.0
3	10:00 am	51.9	49.5
4	10:30 am	68.1	65.8
5	11:00 am	81.6	79.3
6	11:30 am	88.2	83.8
7	11:45 am	92.6	88.2

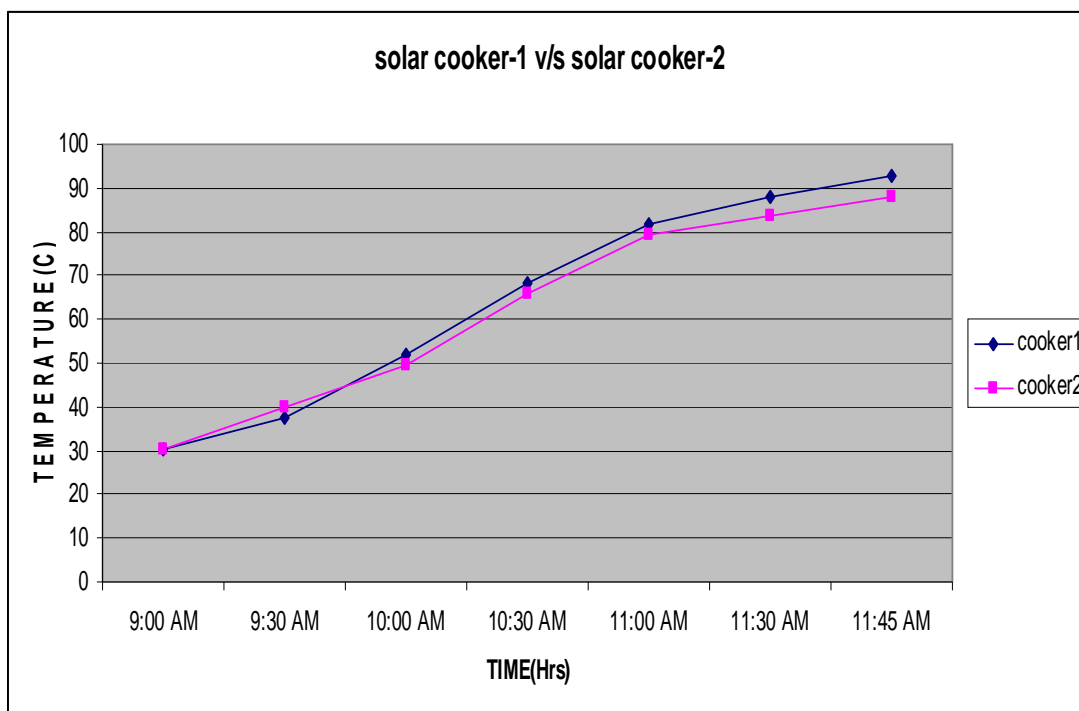


Figure 4.1: Blackened stainless steel pot-1 in solar cooker-1(pot over mesh wire stand and transparent glass lid) and Blackened stainless steel pot-2 in solar cooker-2

Enhancement: 4.99%

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Table 4.2: Blackened stainless steel pot-1 in solar cooker- 1(pot attached with mild steel lugs and transparent glass lid) and Blackened stainless steel pot-2 in solar cooker-2.

S.NO	TIME(Hrs)	COOKER-1(°C)	COOKER-2(°C)
1	9:00 am	22.9	22.9
2	9:30 am	32.7	30.3
3	10:00 am	47.1	42.4
4	10:30 am	65.8	61.2
5	11:00 am	77.1	72.6
6	11:30 am	86.0	79.3
7	11:45 am	92.6	86.0

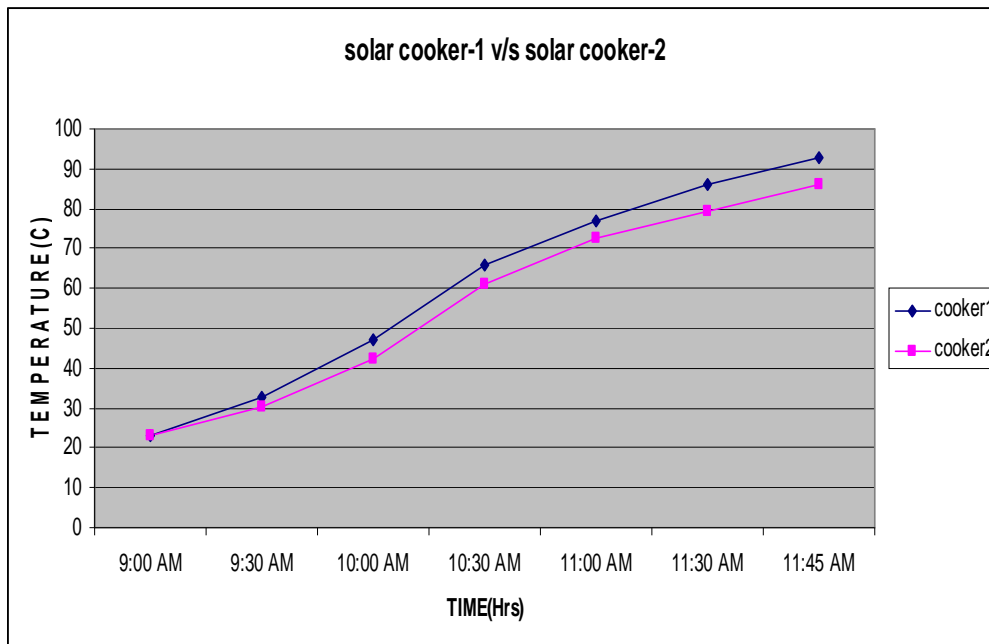


Figure 4.2: Blackened stainless steel pot-1 in solar cooker- 1(pot attached with mild steel lugs and transparent glass lid) and Blackened stainless steel pot-2 in solar cooker-2.

Enhancement: 7.67%

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V. CONCLUSION

In the present research work, performance of modified solar cooker pot and its arrangement is compared with another identical solar cooker. The experimental study verifies the fact that by replacing cooking pot metallic lid by transparent glass lid and placing it over meshwire stand its temperature gets enhanced by 4.99% but if it is replaced by pot attached with mildsteel lugs and transparent glass lid its temperature get enhanced by 7.67% and also the transparent lid reduces the metallic lid heat losses. The principal goal of this experimental study is to reduce the metallic heat loss and improve conduction, convection and radiation effects of solar cooker

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