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Performance Analysis of a Box type Solar Cooker

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Abstract

The energy demand increases with the continuous development of technology. Therefore, the alternative devices are achieved which is based on renewable energy. For cooking total primary energy consumption is about 50%. Hence, replacing the traditional cooking methods by solar energy can be considered as an alternative for meeting the energy crisis. Box type solar cooker is the simplest device to collect the incoming solar radiation and convert it into heat energy. The aim of this research project is to increase the performance and efficiency of solar cooker without using any tracking system. The uniqueness of the device is that it uses reflectors at four sides and is allowed to tilt the device so that more radiation can be obtained even during winter season. This study has mentioned the thermal performance parameter such as efficiency, first figure of merit, power output etc. which are used to compare the cooker's performance. For better cooking maximum temperature was obtained 113°C in this project. The previous used solar cooker efficiency varies from 17% to 25%, which is increased to 30% in this project.

Keywords: Box type solar cooker, four sided reflector, efficiency.

1. Introduction

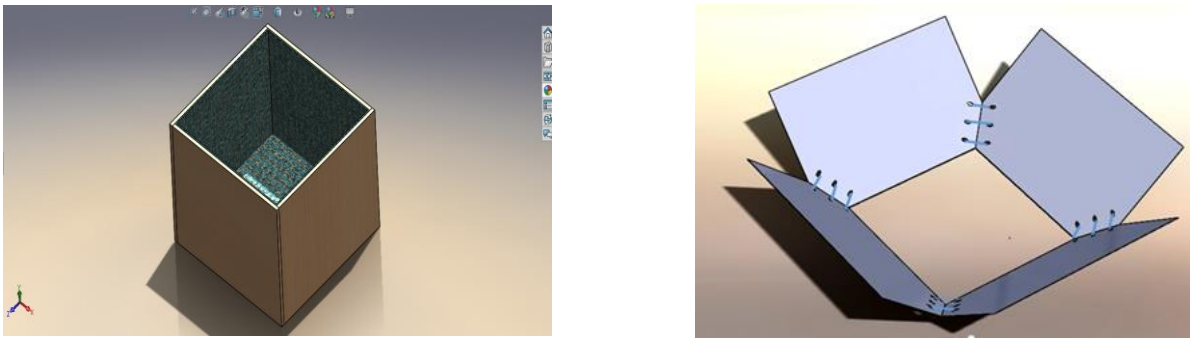
Total worldwide energy is limited and decreasing day by day due to high consumption rate. Moreover, fossil fuel is a big concern of environmental pollution. It is responsible for greenhouse effect, global warming, acid rain etc. It is also emphasized by the World Health Organization (WHO) that 1.6 million deaths per year are caused by indoor air pollution [1]. Major amount of energy consumption in the rural areas accounts for cooking purposes in developing countries. The demand for cooking in rural areas is met by fire wood (75%), cow dung cake and agricultural waste (25%) [2]. Therefore, there is a rising attention concerning the renewable energy options to meet the cooking requirements of people in developing countries like Bangladesh. Among the clean energy technologies, solar energy is recognized as one of the most promising choice since it is free and provides clean and environmentally friendly energy. The Earth receives 3.85 million EJ of solar energy each year [3]. Due geological location, Bangladesh has enormous solar energy possibility. Among the thermal applications of solar energy, solar cooking is considered as one of the simplest, the most viable and attractive options in terms of the utilization of solar energy. It has some advantages of simple construction and installation, almost no running cost and maintenance cost, environment friendly and no ash content etc. It is appropriate for hundreds of millions of people around the world with scarce fuel and financial resource to pay for cooking fuel [4]. Different types of solar cookers and ovens have been designed, developed and tested by many scientists [5]. Geddam et al. [6] analyzed thermal performance of a box type solar collector. Mahavar et al. [7] performed a study of box type solar cooker with electric powered heater. Solar cookers with booster mirrors which are relatively faster than the conventional box type solar cookers have also been developed Myrrha and Dhaliwal [3]. Different types of work on box type solar cooker was done with one side reflector. But there is not enough work by using four side reflector. The objective of this study to design and construct a box type flexible solar cooker that can be folded and unfolded and can be transferred easily.

2. Theoretical Design of the Setup

By following the theoretical efficiency, the area and dimensions of the reflectors and the cooker are determined. The result shows the important variables and indicate how they affect the performance of the cooker. The governing efficiency equation of a solar cooker is showed in Eq. 1.

$$\eta = \frac{mC_p(T_{w2}-T_{w1})}{\Delta t \times I \times A} \quad (1)$$

Where m is mass of water, Cp is specific heat of water, Δt is duration of water heating, I is solar radiation in terms of W/m^2, and A is inside surface area of the cooker.



(a) (b)

Fig. 1. (a) Prototype of box design (b) Prototype of reflector design

From the above equation for producing 100˚C temperature and taking the efficiency of the cooker as 33%, the inside surface area of the cooker is 1764 sq. inch. According to the calculations, the value of length and width of the box is 15 inch and 12.5 inch. Also the value of length and width of the reflector is 24 inch and 18 inch. According the dimensions, the final area of the reflector is 1600 sq. inch.

3. Fabrication of the Solar Cooker

At first, the wood was cut according to the specified design and then the cutting portions were finished by finisher. The upper portion has a three supporter to support the reflector sheets. Assembling the pieces of wood, the box was constructed. The plywood was cut according to the design, sand papers was used to clean the upper portion of the plywood, and then glue was used on the wood to trap the foil. Aluminum foil was wrapped on the plywood, which act as a reflector of the cooker. The inner portion of the box was filled with cotton about 1.5 inch with the help of glue showed in first figure and then covered with aluminum wrapped sponge wood (sola) which covered 0.5 inch as showed in fig. 2. The sponge wood was cut according to design and wrapped by aluminum foil with the help of glue.

(a)

(b) (c)

Fig. 2. (a) Box of solar cooker (b) Reflector of solar cooker (c) Box with insulator

4. Experimental Setup

According to the design, the black ceramic pot was placed into the box and a glass plate was placed on the pot. Another glass plate was placed on the top of the box. Then the reflector sheets were assembled according to the design and placed it on the box.

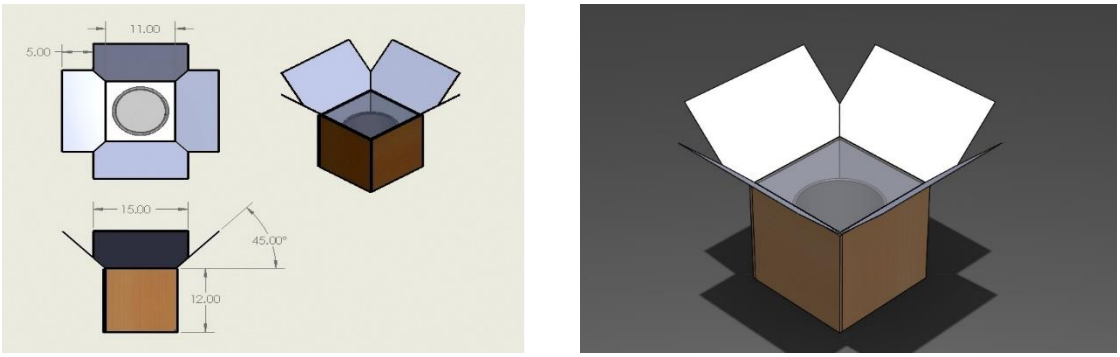


Fig. 3. Design setup

According to specified dimensions the prototype of our construction was designed with the help of solid works. The absorber pot, glass plate and the reflector sheets were placed at their correct position. According to the prototype, the final setup was done which is showed in fig. 4.

Top View Front View Right View

Fig. 4. Final setup of the cooker

The absorber pot, glass plate and the reflector sheets were placed at their correct position. The cooker was tilted towards the sun so that maximum amount of sunlight can get into the cooking chamber.

5. Working Procedure

A surface with high specular reflectivity is used to concentrate light from the sun onto a small cooking area. Depending on the geometry of the surface, sunlight can be concentrated by several orders of magnitude producing temperatures high enough to melt salt and smelt metal. Solar cookers concentrate sunlight onto a receiver such as a cooking pan. The interaction between the light energy and the receiver material converts light to heat. This conversion is maximized by using materials that conduct and retain heat. It is important to reduce convection by isolating the air inside the cooker from the air outside the cooker. Simply using a glass lid on pot enhances light absorption from the top of the pan and provides a greenhouse effect that improves heat retention and minimizes convection loss.

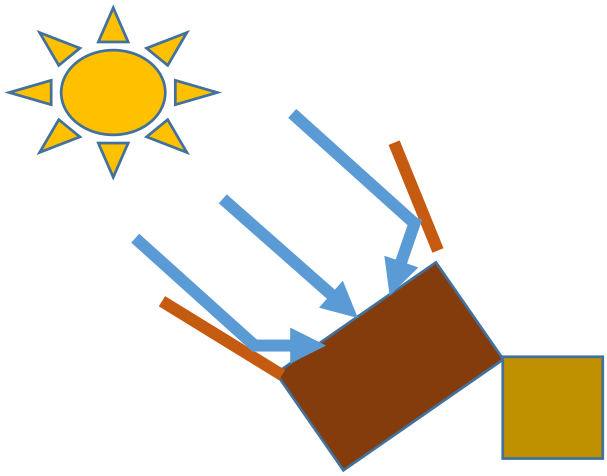


Fig. 5. Schematic diagram of principle of box type solar cooker

6. Result and Discussion

For the designed cooker, the highest temperature was 113 ºC and highest efficiency was observed 30.26%. For existing collector the temperature was 64 ºC with the help of tracking system and the efficiency was 23.43%. Fig. 6 shows increasing of temperature with respect to duration of time. The temperature of cooking chamber was increased to 109℃ within one hour 20th July. In 21th July the temperature of cooking chamber was increased to 97℃ within one hour. The average intensity was 720 W/m^2 within one hour. Again, fig. 6 shows that the temperature of cooking chamber was increased to 101℃ in an hour in 1st August. The intensity was 700 W/m^2 within one hour. At 2nd August the temperature of cooking chamber was increased to 97℃ within an hour. Similarly, at 3rd August and 4th August the temperature of cooking chamber was increased 99℃ and 103℃ within an hour. In these case, the average intensity was 720 W/m^2 and 730 W/m^2 within one hour.

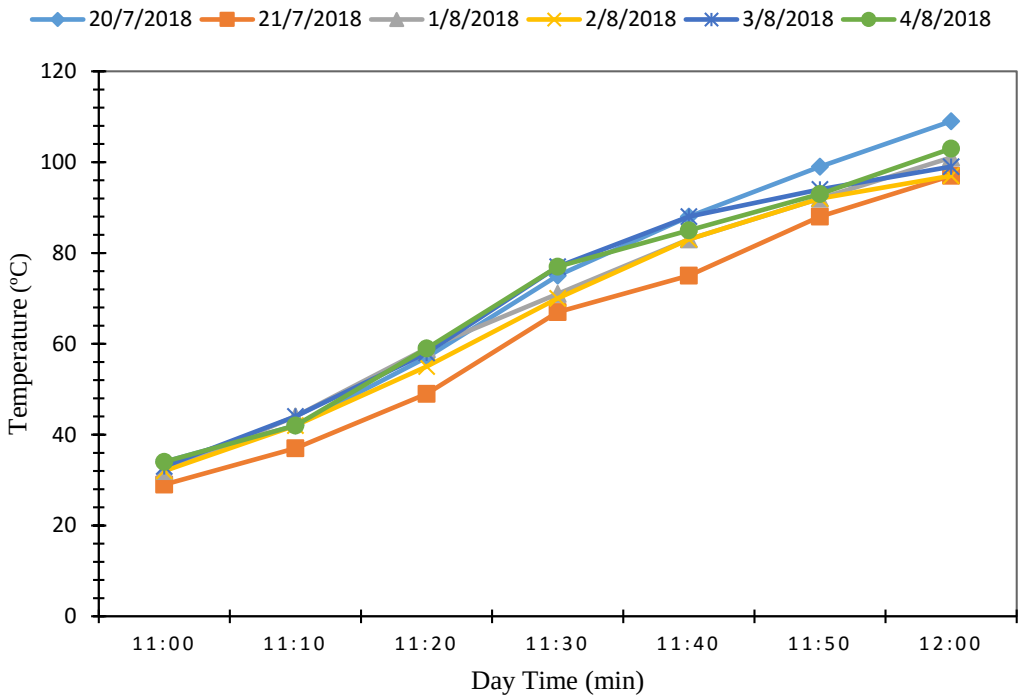


Fig.6. Temperature vs. day time curve at different dates

Fig. 7 shows thermal efficiency of the designed solar collector at different day. Maximum temperature was obtained at 21st August among six different observations with solar intensity 700 W/m^2.

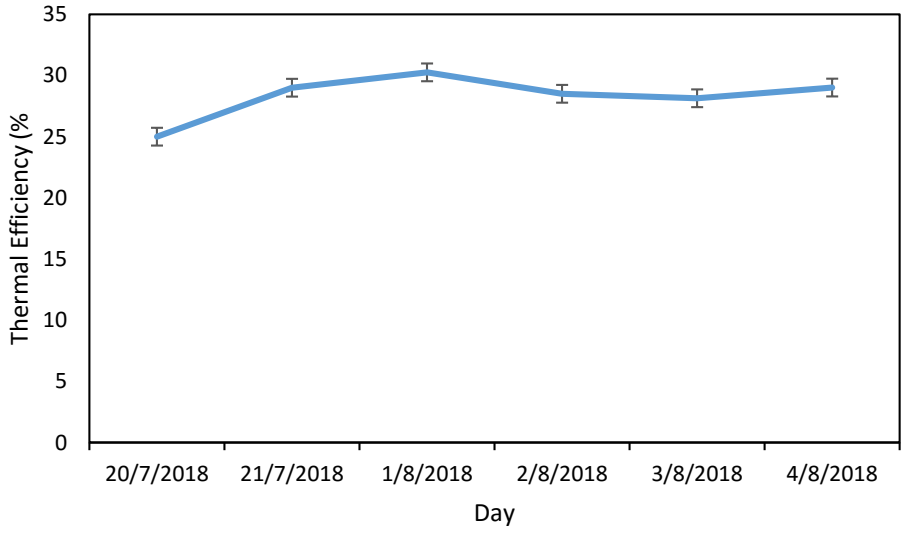


Fig. 7. Thermal efficiency curve at different day of the year.

7. Conclusion

A wooden box type solar cooker was successfully constructed without tracking system. The cooker is flexible and it can be folded and unfolded which also can be transferred easily. Four-sided reflector was used instead of tracking

system and they were placed at correct angle. In this project, maximum efficiency was 30.26%, which was about 7% higher than the existing cooker, maximum temperature was obtained 113°C, which was about 50°C higher than the existing one, and the figure of merit was 0.102.

8. Recommendations

Much better result can be obtained if the aluminum reflector sheet is used instead of aluminum foil as reflector. The performance of the solar cooker will be increased by sealing the cooking chamber by high insulating material. Maximum amount of heat can be transmitted and trapped by using low tempered iron glass instead of normal glass.

9. References

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