Design, construction and performance test of a portable solar cooker

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Abstract

This paper presents the thermal performance of a light weight portable solar cooker (PSC) based on a parabolic shaped umbrella with aluminum foil. An umbrella of 125 cm diameter was used as a frame of the portable cooker because it is more convenient to transport and its surface area is almost parabolic. The aluminum foil was attached to the inner side of the umbrella with white glue which acts as reflector plate. The focal length of the parabolic surface was 26.16 cm. The maximum temperature of the experimental water recorded was 97.8˚C at around 1:30PM. The experimental time period was from 10:00 to 14:00 solar time. The energy output of the PSC varied between 33.18 W and 182 W. The energy and exergy efficiencies were in the range 2.088% to 17.48% and 0.023% to 1.80%, respectively.

Keywords: Solar cooker, portable cooker, parachuina collector, aluminum foil

1. Introduction

The increasing population on the earth causes increasing demand of energy. To alleviate part of our energy crisis and environmental degradation, it has become imperative to make use of appropriate technologies for the possible recovery of resources from non-conventional sources, like solar energy technology. It is widely dispersed and could contribute zero net emission to the atmosphere. Cooking with solar energy has long been presented as an attractive solution to the world's problem of decreasing fuel wood sources and other environmental problems. The use of solar cookers results in appreciable fuel and time savings as well as increased energy security for rural households using commercial fuels [1].

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter [2]. Maximum amount of radiation is available on the month of March-April and minimum on December-January. So the climate conditions of Bangladesh are favorable for solar energy applications. Solar cooking is a good option for widespread use in Bangladesh.

Al-Soud et al. [3] designed, constructed and tested a portable solar cooker. The test performed for three days from 8:30 h to 16:30 h and showed that the water temperature inside the cooker's tube reached 90˚C in typical summer days, when the maximum registered ambient temperature was 36˚C. Badran et al. [4] designed, built and tested a parabolic portable solar water heater. The authors found that, the device was able to heat 30 kg of water from 20 °C to 50 °C in 2½ h in the collector mode. The highest efficiency obtained for this mode was 77% and the slope of the efficiency curve was 10.63 W/m^2 °C.

Ozturk [5] constructed and designed a low cost PSC and experimentally evaluated its energy and exergy efficiencies. The energy output of the PSC varied between 20.9 and 78.1 W, whereas its exergy output was in the range of 2.9–6.6 W. It was found that the energy and exergy efficiencies of the PSC were in the range of 2.8–15.7 and 0.4–1.25 respectively. Sonune and Philip [6] designed a Fresnel type domestic concentrating cooker, which has an aperture area of 1.5 m^2 and a focal length of 0.75 m and was found to provide an adequate temperature needed for cooking, frying and preparation of chapattis and capable of cooking food for a family of 4–5 persons. Concerning the application, designing, performance testing of PSC, studied has been carried out by many researchers [7-10].

Despite their ability to provide adequate temperatures needed for cooking, frying and preparation of chapattis, all the aforementioned types of concentrating solar cookers suffer due to some drawback. The main drawbacks of these previous works are heavy weight of the cooker, complexity in construction and comparatively high cost.

In this research a light weight umbrella have been used to construct the portable solar cooker. So, the presented work is able to resolve the above mentioned limitations.

2. Methodology

The experiments were carried out locally at Rajshahi, Bangladesh. The latitude and longitude of Rajshahi are 24˚ 22′ 0″ N and 88˚ 36′ 0″, respectively. The experiments were conducted on 2012.

Experimental Section

The photograph of the experimental set-up has been shown in Fig. 1. The main components of the developed PSC were (1) An Umbrella (2) Aluminum foil (reflection index: 85%) (3) Cooking pot and (4) Stand.

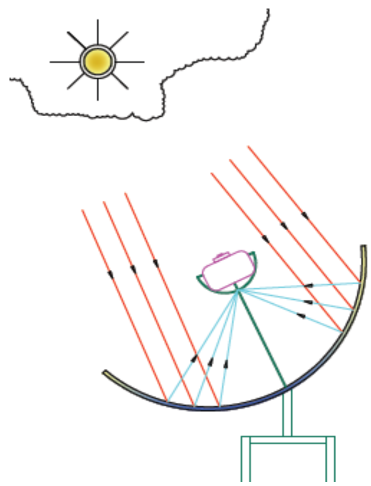

Fig. 1. Schematic of portable solar cooker

The portable solar cooker was designed to be both adjustable and dismountable, with a screen and heat concentrator made from reflective aluminum foil. The solar cooker is divided into two units- the supports and reflector. The support is a stand made of iron (angle bar) and G.I. pipe in which the whole arrangements are mounted by screw mechanism. An umbrella of 125 cm diameter was used as a frame of the presented portable solar cooker because it was more convenient to transport and its surface area is almost parabolic.

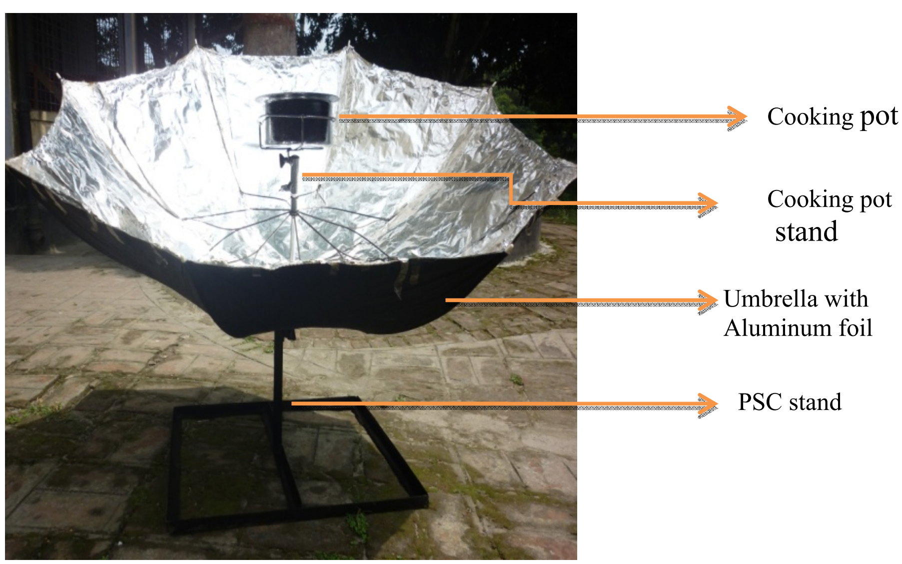

Fig. 2. Photograph of the portable solar cooker.

The aluminum foil was attached to the inner side of the umbrella with white glue which acts as reflector plate.

The reflector surface was faced towards the sun, such that the most shining zone was located on the handle with permanent leveler that was obviously on the focal point of the reflection surface. The focal length of the parabolic surface was 26.16 cm. The umbrella can be tightly attached by the screw to give a stable footing on uneven ground and allowing any necessary inclination for the reflector. The pressure cooker stand can also be inclined to any direction by screw mechanism for keeping it in most shining zone. The sunlight was reflected off of the inner surface of the umbrella and onto the underside of the kettle.

3. Result and discussion

A large of experiments has been carried out on a parabolic concentrator type solar cooker under various operating and climatic conditions. The experimental set up has been established at Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh (latitude=24°24′ N, longitude=88°30′ E). Experiments on the proposed PSC were carried out on May 15, 2012; May 15, 2012; June 12, 2012. The experimental works was fully carried out in the heat engine laboratory at Rajshahi University of Engineering & Technology located in Rajshahi, Bangladesh. Each experiment started from 11.15 h to 13.15h.

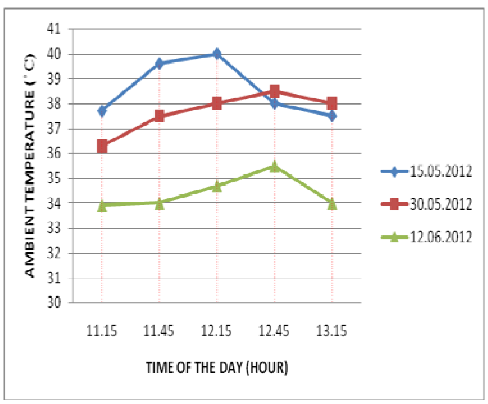

Fig. 3. Hourly variation of the ambient temperature

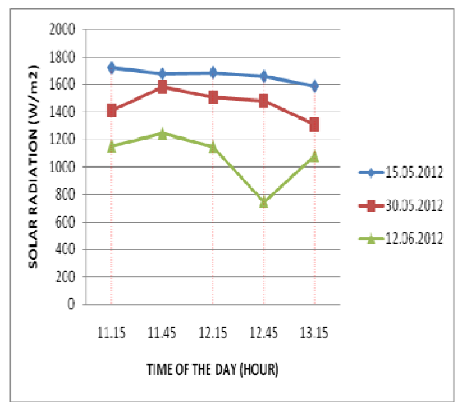

Fig 4. Hourly variation of the solar radiation

The electronic measurement instruments and devices were tested and calibrated before being used. Fig 2. exhibits the proposed parabolic solar cooker. Fig. 3 shows the ambient temperature measured at the site during the test hours for the three days in which the experimental part was conducted. Higher temperatures were observed during daytime with peaks occurring between 12.15 h and 12.45 h. Hourly variation of the solar radiation, during the test period is exhibited in Fig. 4. Higher values of solar radiation were noticed between between 11.15 h and 12.45 with a peak occurring at about 11.15 h. Fig. 5. show the measured values of hourly variation of water temperature inside the pressure cooker. An increase in water's temperature was noticed during early hours of the day until it reaches its maximum values around noon hours when solar radiation values are the highest.

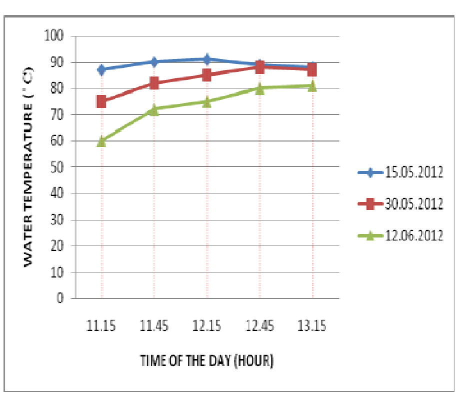

Fig 5. Hourly variation of water temperature

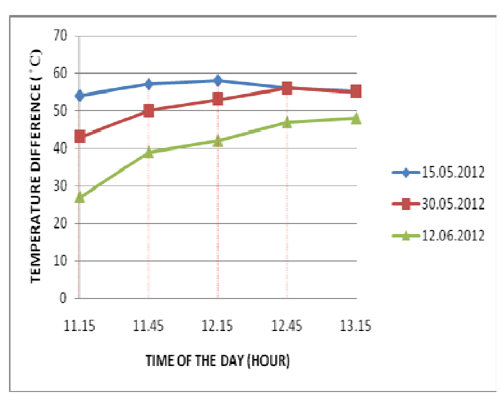

Fig 6. Hourly variation of the temperature difference

The water temperature inside the pressure cooker reached 90 □ C in typical summer days, where the maximum registered ambient temperature was 38 □ C. It was noticed that the water temperature inside the pressure cooker increases when the ambient temperature is higher or when the solar intensity is abundant. Fig. 6 Shows the change of the temperature difference between the water in the pressure cooker and the ambient air over time. The temperature difference was only 42 □ C at 11.15 in the morning and it reached 57 □ C at 12.45 in the noon for a specific day.

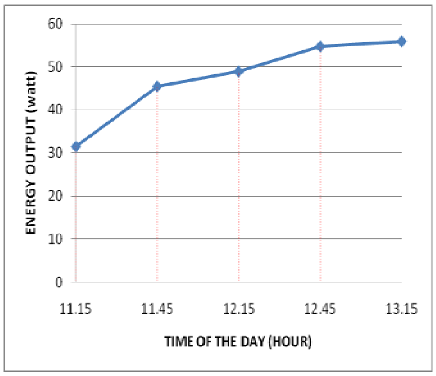

Fig.7. Hourly variation of energy output

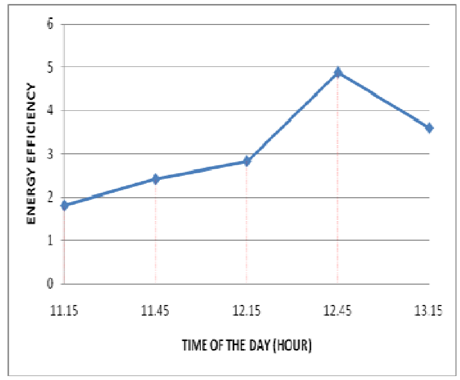

Fig. 8. Hourly variation of energy efficiency

Fig. 7 shows the variation of the energy output as a function of time. The energy outputs were calculated according to the respective numerators of the efficiencies expressions. The energy output varied from 31.5 to 56 W. As indicated in Fig. 7, the energy output increased at a fast rate in the first 1 h, and then at slow rate during 12:15–13:15. During the experimental period the average daily energy output of the SPC was around 47 W. The exergy output was significantly different from its energy output.

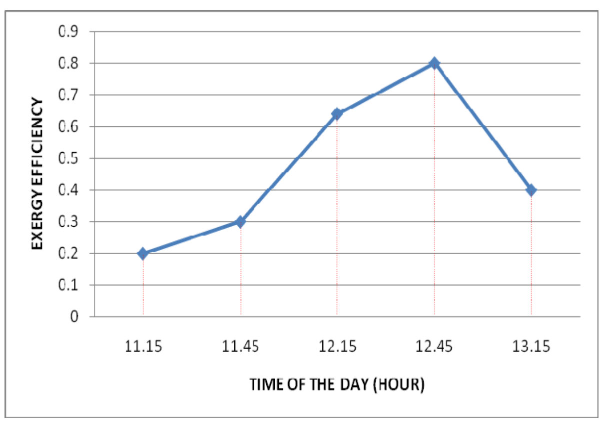

Fig. 9. Hourly variation of exergy output

The exergy output ranged from 2.9 to 4.8 W at the daily average of 3.50 W. The maximum energy output (56W) occurred at 13:15, while the maximum exergy output (4.8 W) occurred at 12:45.The variation of the instantaneous energy and exergy efficiencies as a function of time for the SPC is presented in Fig. 8 and 9 respectively. The energy efficiency of the SPC varied from 1.81% to 4.88%. The daily average energy efficiency of the SPC was 3.10%. The exergy efficiency of the SPC varied from 0.20% to 0.80% and the average daily exergy efficiency was found to be 0.50%. Energy and exergy efficiencies are affected mainly by three factors; the level of water temperature Tw, solar radiation energy I and ambient temperature Ta. The combination of these three factors generates a characteristic maximum of exergy efficiency, whereas the energy efficiency monotonously diminishes during the measurement time period.

4. Conclusion

The use of readymade umbrella frame have simplified the design of the solar cooker for the user, reducing the assembly (2 min) and disassembly (1 min) times to a minimum. Even with all these improvements, the cooker can be sold at a reasonable price. The low weight (5 kg) and volume (approximately the same as a conventional umbrella when folded) of this solar cooker make it easy to take anywhere using conventional means of transport. Trials carried out with the prototype have determined that the solar cooker reaches an average power of 50 W on a sunny day, assuming that adjustment toward the sun occurs every 20 or 30 min. This supplies sufficient energy to cook a simple meal for two in an average time of 2 h. This parabolic solar cooker therefore provides a portable, inexpensive, and environmentally friendly food heating system, which will contribute to improving the quality of life of needy people in the third world and reduce consumption of conventional energy.

Acknowledgements

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