DESIGN AND DEVELOPMENT OF DOUBLE EXPOSURE SOLAR COOKER WITH FINNED COOKING VESSEL

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Abstract

The main objective of this study is to design, construct and investigate the performance of a modified box type solar cooker supported by parabolic reflector disposed under the cooker. Energy cost for cooking purpose, indoor pollution and the time spent in gathering fuel woods are the main problems that led us to study and develop the cooker. Moreover, the very slow heat up time of box type cookers and their limitation for widespread deployment due to their low operating temperature are motivating factors to design this cooker. The developed cooker under field test gives stagnation plate temperature of 152°C. The "First figure of merit" of the cooker is 0.127 which represents the cooker marked as grade-A solar cooker. A comparative experimental study of double exposure solar cooker with two different cooking vessels (finned and un- finned) was also conducted and results show that under the same climatic conditions; temperature of finned cooking vessel and power are higher.

Keywords: Solar cooker, double exposure, parabolic reflector finned vessel

1. Introduction

Solar box cooker is the simplest type of solar cooker available because it is relatively cheap, low-tech device (Ramaswamy et.al, 1997). The cooking time depends primarily on the materials being used, the amount of sunlight at the time of cooking, and the quantity of food that needs to be cooked. However the low heat rate of most box type solar cookers and the lower working temperature limit are hindering its wide spread use for household cooking. This study is proposed as a remedial to avoid these two problems where both the highest temperature limit and heating rate are improved by a modified design. The double exposure solar cooker (DESC) proposed in this study is a box type solar cooker with support of parabolic reflector disposed under the cooker for additional heat input to the cooking vessel, in which the absorber is exposed to the solar radiation from both sides (at the top of the box from boosters and parabolic flat reflectors placed under the box). A box-part of DESC is single glazed at the top as usual to transmit sun radiation and a double-glass at the bottom allowing the absorber plate to receive maximum solar radiations reflected from parabolic flat reflector on its lower side.

2. Discription of the system

The double-exposure solar cooker used in this investigation consists of a box-part with a double-glass at the bottom allowing the absorber plate to receive solar radiations on its lower side as shown in Fig. 1. The box is equipped with three flat reflectors (one reflector is 50 cm x 60 cm placed at the front rear edge of the box frame) and the two side reflectors are 40cm x 50cm, which are installed upon a wood frame connected with hinges on the upper side of the solar cooker. The walls of solar box are made of a wooden layer (thickness: 2.5 cm), the inner sides of which are covered with an aluminum sheet (thickness: 0.1 - 0.2 cm).

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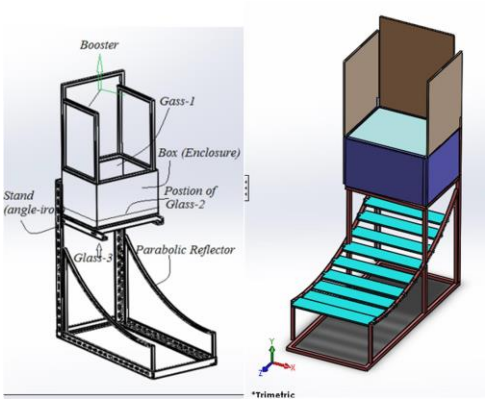


Fig. 1: Schematic diagram of the designed double exposure solar cooker.

The height of the back-side and front-side of the box are equal with 32 cm; the total volume of the box is (50 x 40 x 32 cm). Junction fragments were sealed properly to prevent escaping air from system. At the top of the box part, a glass plate of 4 mm thickness was fixed in position with wooden frame to avoid breakage due to expansion and also to make the cooking space airtight. The parabola is reflecting sun radiation from three different positions which should be adjusted properly to distribute the reflected sun radiation in different part of the absorber plate.

As presented in Fig. 2 below two commercial cooking vessels (finned and unfinned), of 20 cm in diameter and 10 cm in depth, were placed at the center of the box part.

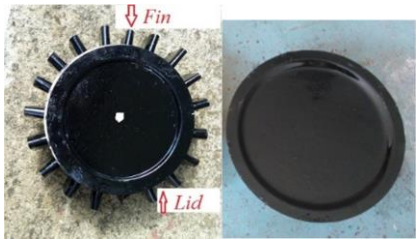


Fig. 2: Finned and un-finned cooking vessel.

The cooking vessels are made of an aluminum sheet of 0.2 cm thickness and the outer surfaces of the cooking vessel are painted black.

3. Methodology

The family size double exposure solar cooker is designed based on the cooking energy requirement for average households for selected food item and or specific site.

3.1 Cooking power.

The power required to cook the food can be obtained as presented in (eq.1) which is then divided by $\Delta t = 600s$ to account for the number of seconds in each 10-minute interval. P is normalized to compare the various cookers in various countries and under various climates. (Funk, 2000) has shown that the power of radiation is standardize to 700 W/m^2.

$$P = \frac{M_w C_{pw} (T_f - T_i)}{\Delta t} \qquad \text{(eq. 1)}$$

3.2 Size of the cooker

Sizing of the cooker can be determined based on the power obtained for cooking using (eq. 2)

$$MC_p \frac{dT}{dt} = (\eta_0 I - U\theta)A_C \quad \text{(eq. 2)}$$

Where θ is the temperature difference between the pot content and the initial temperature in K, η_0 is the optical efficiency, I is the global solar radiation in W/m2, U is the thermal loss coefficient in W/(m2K), A_C and is the collector aperture surface in m2.

The parabolic part of system is composed of 9 flat reflectors, 10cm x 46 cm, each parabolic flat reflector is mounted on a parabolic curve placed 2cm apart in order to rotate freely and to set the reflection of sun radiation towards to different part of the absorber plate.

Fig. 3: photographic view of double exposure solar cooker

4. Result and Discussion

Based on the existing international testing standards (Funk, 1998; ASAE, 2003) tests were performed on the solar cooker to obtain stagnation temperature, cooking power, instantaneous and cumulative efficiency (Ibrahim, 2005), and the effect on finned and un-finned cooking vessel.

4.1 Stagnation Test

The result of stagnation temperature under no load condition is shown in fig. 4 and the maximum absorber plate temperature of 152°C was recorded at 12:30pm and at an insolation value of 950 W/m^2 and the ambient temperature 31.9°C. The stagnation temperature without the parabolic temperature has reached 120 °C.

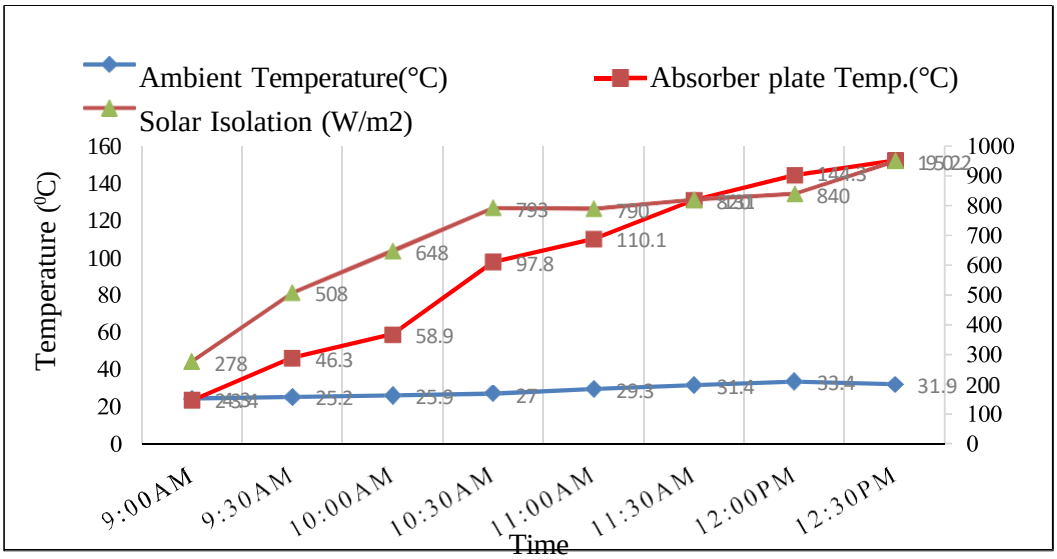
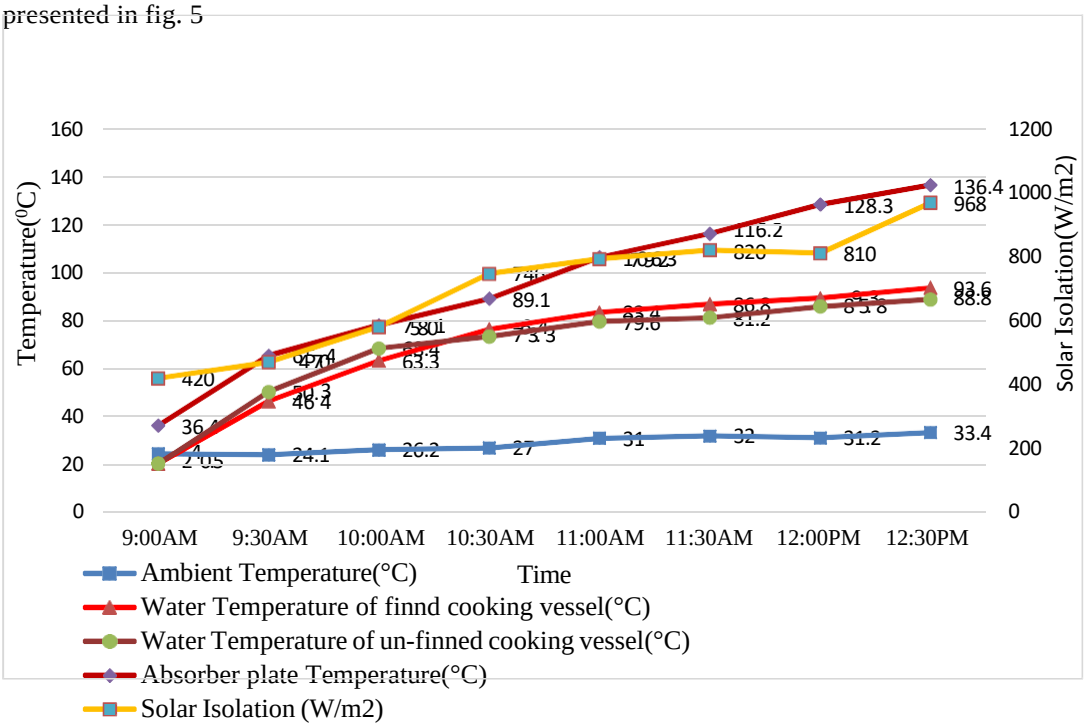


Fig. 4: Thermal performance curve of the double exposure solar cooker under stagnation test condition.

4.2 Loaded Test (Water Heating Test)

Test was conducted by placing a 2kg of water-filled cylindrical pot covered by a lid, for both finned and un- finned cooking vessel. The finned cooking vessel give reached maximum temperature as presented in fig. 5



5. Conclusion

The double exposure solar cooker is the best alternative way to improve the performance of the box solar cooker by adding parabolic flat reflector with minimum production cost with better additional heat input to the absorber plate. The presence of parabolic reflector results absorber plate temperature of 152°C, which is additional temperature of 31.9°C compare to the cooker without parabolic reflector. Cooking power and efficiency of the cooker are also improved with an increased thermal efficiency and a cost benefit ration of greater than one.

6. References

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