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Design, development and testing of a small scale hybrid solar cooker

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Abstract

A Small Scale Box type solar cooker (SSB) weighing 4.8 kg is modified into a novel photovoltaic and thermal hybrid solar cooker named as Small Scale Box type Hybrid solar cooker (SSBH) weighing 6.5 kg. Five solar panels each of 15 W are attached with this cooker. Cooking time is reduced due to the photovoltaic power generated by solar panels along with the solar thermal power. Any time cooking facility makes it a user friendly cooker. The design features of this hybrid solar cooker include proper sizing of solar photovoltaic panels, battery and dc heaters. The performance and costing of the cooker is compared with a baseline Solar Box type Cooker (SBC) weighing 12.3 kg. Efficiency of Improved Small Scale Box type Hybrid solar cooker (ISSBH) is 38%. Estimated cost ($120) of the developed solar cooker can be further reduced upon commercialization to make it more affordable and popular.

Keywords: Small Scale Box type Hybrid solar cooker; Solar thermal energy; Solar photovoltaic energy

1. Introduction

Major amount of energy consumption in the rural areas accounts for cooking in developing countries (Ramchandra and Shruthi, 2007). Solar cookers seem to be a good substitute for cooking with conventional natural sources like wood and animal dung. Most commonly used solar cookers are solar panel type, box type and parabolic type (Cuce and Cuce, 2013). Achievable temperature in box type solar cooker is lower than that of the parabolic reflector type solar cooker as it utilizes only thermal energy (Nahar et al., 1994). Reflector type cookers require the tracking of the sun after every 15 min which restricts its popularity. The cooker direction has to be changed for better efficiency according to movement of the sun. Use of this type of cooker becomes tedious job for a user to follow the track of the sun (Ahmad, 2000). As this cooker has open ends, blowing of winds reduces the efficiency of cooking drastically. User's eyes and skin can also be damaged due to direct reflection from the reflector of the cooker (Kimambo, 2007). The advantages and disadvantages of some popular solar cookers are summarized in Table 1.

Different types of solar cookers and ovens have been designed, developed and tested by many scientists (Suhail, 2013; Panwar et al., 2013). Solar cookers with booster mirrors which are relatively faster than the conventional box type solar cookers have also been developed (Mirdha and Dhariwal, 2008). Community type solar cookers for indoor cooking which are having very attractive features have also been developed (Kaushik and Gupta, 2008). Number of scientists have put in efforts in development and testing of solar cookers of box type (Kumar, 2005), concentrator type (Hermim et al., 2010; Purohit and Purohit, 2009) and oven type (Suharta et al., 1998). Solar ovens can achieve very high temperature range

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Nomenclature

F_1	first figure of merit	t_1	initial time
T_P	stagnation plate temperature	t_2	final time
T_a	ambient temperature	SBC	Solar Box type Cooker (BIS standard dimension)
I_s	solar insolation on horizontal surface at stagnation temperature	SSB	Small Scale Box type solar cooker
M	mass	SSBH	Small Scale Box type Hybrid solar cooker
C_p	specific heat of water	ISSBH	Improved Small Scale Box type Hybrid solar cooker
A	glazing area		

of 200–500 °C and are used for frying purpose but they are very bulky and costly which make them less convenient for use (Telkes, 1959).

In the earlier work of the authors, solar cooker was tested for certain analysis with dual axis solar tracker (Joshi and Jani, 2013a, 2013b, 2013c). A very small scale and light weight (1.6 kg) casserole type solar cooker was developed and tested for its maximum utilization. Different recipes were cooked in this casserole type cooker for its actual cooking performance (Joshi and Jani, 2013a, 2013b, 2013c). A photo voltaic and thermal hybrid solar cooker was tested using a fixed power supply of 30 W (Joshi and Jani, 2013a, 2013b, 2013c). Photovoltaic and thermal hybrid solar cooker makes it possibly a 24 h usable cooker as it is connected with the battery having capacity of 45 A h. This fully charged battery can be used for about 3 h without recharging. This duration can further be increased by employing other suitable batteries. The casserole type (1.6 kg) solar cooker with some modifications can also be utilized for drying applications. Bitter gourd chips and potato chips were dried in this solar dryer (Joshi et al., 2014). Conventional Solar Box type Cooker (SBC) meets with the figure of merit F_1 value as required by BIS (Bureau of Indian Standards) but still not popular as it can be used only during certain limited hours in day time. This fact has become the rationale of present work.

This paper reports the design, development and testing of a prototype Small Scale Box type Hybrid (SSBH) solar cooker with five foldable solar panels attached to it. The SSBH solar cooker incorporates photovoltaic and thermal effects simultaneously. It is connected with a 45 A h battery which is charged by the solar panels. This cooker can work with fully charged battery for about 3 h. During the idle conditions, the solar panels charge the battery which permits the cooking at night as well as for lighting purposes. The SSBH also facilitates the use of solar cooker by the people living in the high – rise buildings by placing it in side projection of the apartment with limited sunshine. A modification to SSBH into Improved Small Scale Box type (ISSBH) solar cooker is also reported in this paper. It offers following novel and user friendly features: (1) Cooking at any time convenient to the user (2) Fast cooking (3) Four to five meals preparation in a day (4) Affordable cost (5) Small size and light weight (6) Unattended cooking.

2. Design

Fig. 1(a) shows the photograph of Small Scale Box type (SSB) solar cooker (4.8 kg) with single pot. Fig. 1(b) shows the photograph of the SSBH solar cooker (6.5 kg) with folded solar panels and Fig. 1(c) shows the SSBH solar cooker with opened out solar panels. The Small Scale

Table 1
Advantages and disadvantages of some typical solar cookers.

Sr. no.	System	Advantages	Disadvantages
1	Solar Box type Cooker (SBC) (base line solar cooker)	Operates under direct as well as diffuse radiation	Slow cooking and limited cooking hours, bulky
2	Solar oven	Requires little intervention by users, easy to construct	Requires large concentration area, costly
3	Panel cooker	Low cost and small size	Very sensitive to wind
4	Collector cooker	Operates under direct as well as diffuse radiation	Bulky and costly
5	Concentrating (reflector) cooker (SK-14)	Quite efficient, cooker can achieve extremely high temperatures	Requires intervention by users, strong reliance on direct beam, more sensitive to wind, relatively high cost, burns or eye damage (Kimambo, 2007)
6	Parabolic dish type cooker	High energy efficiency	Very sensitive to wind (Panwar et al., 2013)
7	Modified solar cooker with booster mirrors	Higher temperature throughout the day	Large size (Mirdha and Dhariwal, 2008)
8	Community size solar cooker for indoor cooking (Scheffler cooker)	High energy efficiency	Large land area is required, very expensive (Kaushik and Gupta, 2008)