

Simulation Studies on Concentrating Type Solar Cookers

V. K. Krishnan, T. Balusamy

Abstract—A solar dish collector has been designed, fabricated and tested for its performance on 10-03-2015 in Salem, Tamilnadu, India. The experiments on cooking vessels of coated and un-coated with 5 Liters capacity have been used for cooking Rice. The results are shown in graphs. The solar cooker is always capable of cooking food within the expected length of time and based on the solar radiation levels. With minimum cooking power, the coated pressure cooker of 5 Liters capacity cooks the food at faster manner. This is due to the conductivity of the coating material provided in the cooker.

Keywords—Solar cooker, solar concentrator type, thermal performance, simulation.

I. INTRODUCTION

THE use of renewable energy is receiving growing interest worldwide. Many scientists have pointed out the relevance of alternate renewable sources of energy to overcome 'Energy Crisis'. Among the renewable sources of energy, solar energy offers a practical solution for the energy problem which is clouding the prospects of mankind. Solar energy, which is an abundant, clean and safe source of energy, is an attractive to substitute for the conventional fuels for cooking [1]. Developing solar energy is an appropriate policy for reducing the dependence on imported energy and promoting environmental protection. To promote renewable energy technologies, many governments throughout the world, are adopting environment-friendly policies. In many parts of the world, direct solar radiation is considered to be one of the most prospective sources of energy. A simple and efficient approach to utilize solar energy is the direct conversion to thermal energy for various applications such as water heating, cooking, drying, etc.

Cooking is the major necessity for people all over the world. Solar cooker is an environmentally-friendly and cost effective device for harnessing solar energy. Solar cookers have long been presented as an interesting solution to the world's problems associated with fuel demand for cooking. Much of solar energy research in India is concentrated towards developing solar cookers for domestic use. Solar cooker is an environmental friendly and cost effective device for harnessing solar energy. The available solar cookers are broadly categorized under two groups: (1) Solar cookers without storage and (2) Solar cookers with storage. The classification of cookers under each group is shown in Fig. 1.

In that type of cookers commercially successful types are box type and concentrating type cookers [2].

A. Box Type Solar Cookers

Box type solar cooker is an insulated container with a multiple or single glass cover. This kind of cooker depends on the green-house effect in which the transparent glazing permits the passage of shorter wavelength solar radiation, but is opaque to most of the longer wavelength solar radiation coming from relatively low temperature heated objects. A double-walled insulated box can also serve to hold the heat inside the cooker. Mirrors may be used to reflect additional solar radiation into the cooking chamber. The speed of the cooking depends on the cooker design and thermal efficiency [3], [4].

B. Concentrating Type Solar Cookers

In the concentrating solar cookers, the cooking pot is placed at the focus of a concentrating mirror. Concentrating type solar cooker is working on one or two axis tracking with a concentration ratio up to 50 and temperature up to 300°C, which is suitable for cooking. Concentrating cookers utilize multifaceted mirrors, Fresnel lenses or parabolic concentrators to attain higher temperatures [5].

The concentrating type of solar cookers is further subdivided into parabolic dish/trough, cylindrical, spherical, and Fresnel. This type of cookers usually employs mirrors/reflectors to concentrate the total solar energy incident on the collector surface, so the collector surface is usually very wide and the temperature achieved is very high. Parabolic dish cooker has the highest efficiency in terms of the utilization of the reflector area because in fully steerable dish system there are no losses due to aperture projection effects. Also radiation losses are small because of the small area of the absorber at the focus [6]. Additional advantages include higher cooking temperatures, as virtually any type of food can be cooked and short heat-up times.

Schwarzer and Silva (2008) presented the general types of solar cookers, their basic characteristics, and experimental procedures to test the different types of solar cookers like flat plate collector with direct and indirect use and parabolic reflector with direct and indirect use [7]. The measured variables by adopting the experimental procedures were necessary to calculate parameters such as solar cooker tracking period, unattended cooking period, heat losses without solar radiation and continuous cooking. The calculated values were compared with the thermal performance of the solar cookers. Further, they designed simple cooking systems using a simplified analytical model.

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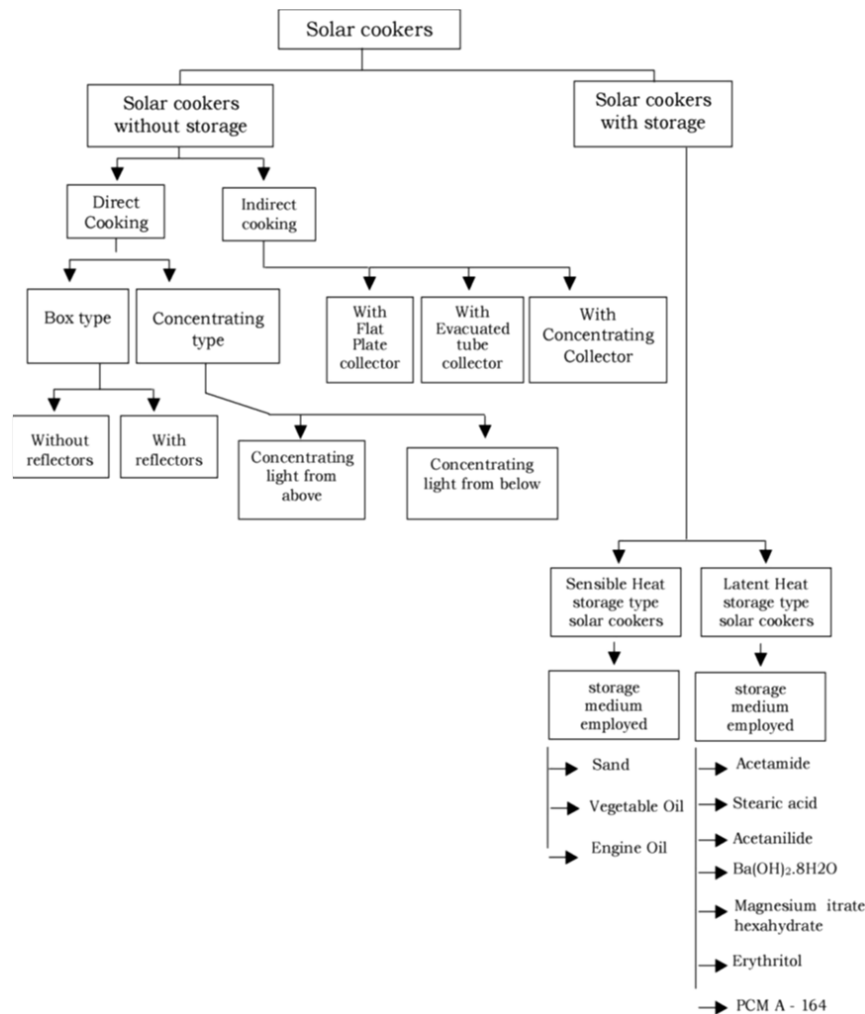


Fig. 1 Classification of solar cookers



Fig. 2 Box type solar cooker

Habeebulla et al. (1995) developed the transient heat balance equations for predicting the thermal behavior of an oven type concentrating solar cooker [8]. They performed the simulation to prove theoretically the great advantage of using a glass-sided oven over the conventional bare receiver pot. The developed mathematical equations were solved using Numerical Integration techniques. The effect of wind speed variation and the transient nature of solar radiation were

considered for performing the mathematical analysis. The analysis showed that the oven type receiving pot has both a higher fluid temperature and overall receiver efficiency compared to the bare receiver type, working under similar conditions.



Fig. 3 Concentrating type solar cooker

Al-Soud et al. (2010) developed a parabolic solar cooker with automatic two axes sun tracking and tested to overcome

the need for frequent tracking and standing in the sun, facing all concentrating solar cookers with manual tracking [9]. A programmable logic controller was used to control the motion of the solar cooker. They inferred 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.

In this research work, solar heating system has been designed and fabricated to study the behaviour of cooking vessels under solar radiation. The time required by the cooking vessels to cook one kg of rice is estimated. Two different cookers of same make and same capacity of 5 litres such as coated and un-coated aluminium cookers have been selected for the investigations. Experiments were conducted using a solar dish designed in such a way that the focal points are falling at the bottom surface of the cooking vessel. A manual sun tracking system has been used to follow the position of sun throughout the experiment.

II. EXPERIMENTAL STUDIES

The concentrating type solar cooker is a preliminary construction for experimental purposes (Fig. 3). The system is installed at Government College of Engineering, Salem, Tamilnadu, India (23.7° N) where the average solar radiation is in the range of 5-5.5 kWh/m²/day. The focal point of the collector is concentrated at the bottom surface of the cooking vessel. The technical details of the fabricated parabolic solar collector are given in Table I. The cooking vessels were directly placed on the focus of the concentrator. A manual sun tracking system has been used to ensure the focus of the solar radiation always falls on the bottom surface of the cooker [10], [11]. The radiation of the solar power is measured for every 30 minutes. An average heat flux of 837.45 W/m² is determined from the experimental results.

TABLE I
TECHNICAL SPECIFICATIONS OF THE FABRICATED PARABOLIC SOLAR COLLECTOR

Sl. No.	Parameter	Technical Detail
1	Materials of Reflectors	Bright Anodizing Aluminium Sheet
2	Reflectivity	Above 80%
3	Size of Focal Point	100 mm approximate
4	Focal Length	280 mm
5	Dimension and Shape	1.4 m diameter, Paraboloid
6	Surface Area of Reflector	2.2 m ²
7	Aperture Area of Reflector	1.5 m ²
8	Tracking system	Manual



Fig. 4 Coated and Un-coated 5 Litres pressure cookers

The cooking vessel used in this research work has a capacity of 5 liter with and without coating materials (Fig. 4).

The cooker is made from aluminum and also comes with induction base [12]. The minimum amount of temperature required for safe cooking is given in Table II [13]. Solar reflector dish along with cooking vessel is shown in Fig. 5.

TABLE II
TECHNICAL SAFE MINIMUM COOKING TEMPERATURES

Category	Food	Temperature (°C)
Ground Meat & Meat Mixtures	Beef, Pork, Veal, Lamb	71
	Turkey, Chicken	74
Fresh Beef, Veal, Lamb	Steaks, roasts, chops	63
	Chicken & Turkey, whole	74
	Poultry breasts, roasts	74
Poultry	Poultry thighs, legs, wings	74
	Duck & Goose	74
	Stuffing (cooked alone or in bird)	74
Pork and Ham	Fresh pork	63
	Fresh ham (raw)	63
	Precooked ham (to reheat)	60
Eggs & Egg Dishes	Eggs	Cook until yolk and white are firm
	Egg dishes	71
Leftovers & Casseroles	Leftovers	74
	Casseroles	74
Seafood	Fin Fish	63 or cook until flesh is opaque and separates easily with a fork.
Grains	Dried rice	100 – 110

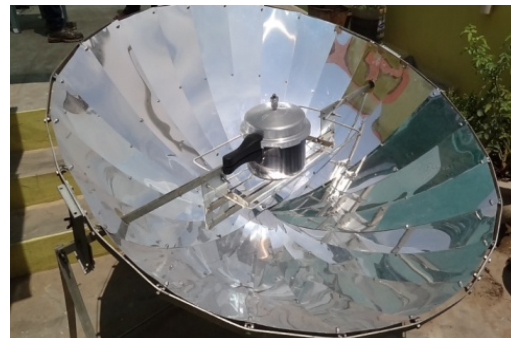


Fig. 5 Solar reflector dish along with cooking vessel

III. PROBLEM IDENTIFICATION

This research work improve the utilization of the renewable energy like solar to cook food instead of using conventional fuel for cooking. An attempt is made to investigate experimentally the heat transfer effects of solar cooking vessels of same capacity of 5 liters with and without cooking medium. Finding the time required for achieving the desired temperature for cooking is an importance issue in tropical country like India where there is sunshine for nearly 9 months in a year. Solar cooker of 5 liter capacity is used with and without coating material for this purpose.

IV. RESULTS AND DISCUSSIONS

Experiments were conducted during sunny days in Salem, Tamilnadu, India. Two different cooking vessels (Fig. 4) with

and without coating materials were used for cooking. Cooking was done on the vessel with and without cooking medium to understand the temperature distribution in the cooking vessel and to measure the cooking wall temperatures in the solar cooking system.

Fig. 6 shows the solar insolation on the solar dish collector. Fig. 7 shows the temperature distribution in the empty vessel of 5 liters capacity during heating by means of solar radiation. It is understood that the temperature of the bottom portion of the vessel heated to maximum temperature with very short time duration as compared to the other portions of the vessel. This further concludes that the bottom portion of the vessel has directly exposed to the solar radiation and the remaining parts of the cooking vessel are having contact with the atmosphere. Hence, the convection effect of the air absorbs some amount of heat from the vessel and also the conductivity of the material plays a significant role in reduction in temperature.

After performing the test with the empty vessel, cooking was done with the same vessel filled with water and rice items. The temperatures of cooker walls are captured through a thermography device (Fluke make) and are given in Figs. 7 and 8.

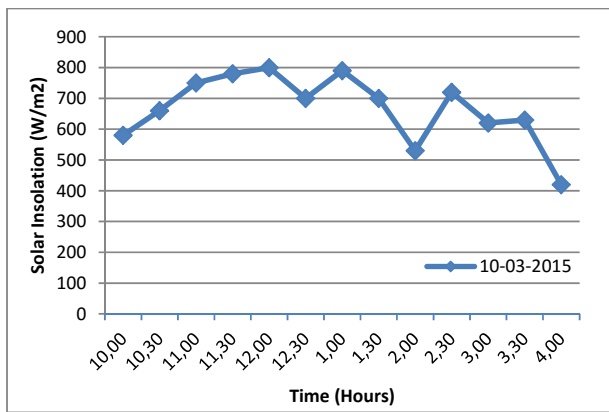


Fig. 6 Hourly variation of solar insolation on the solar dish collector

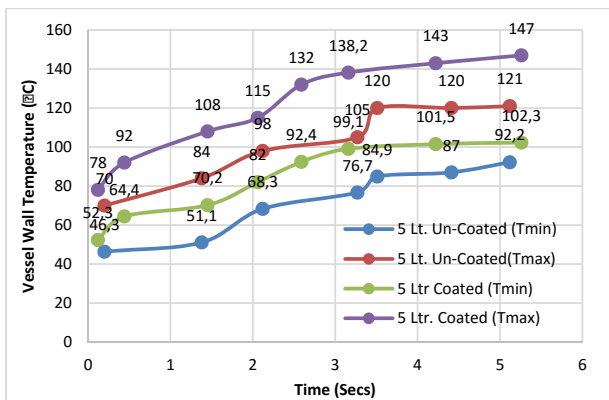


Fig. 7 Temperature variations of 5 Liter Empty vessel

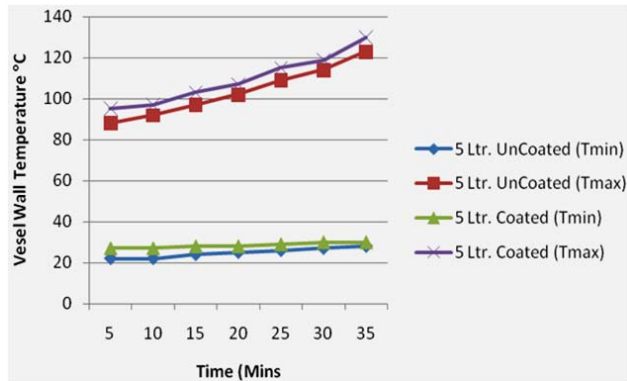


Fig. 8 Temperature variations of 5 Liter cooker vessel during cooking

From the experimental results the average cooking time for rice in 5 liters pressure cooker with and without coating material was found out and it is presented in Table III. From the results, 5 liters pressure cooker with coating medium takes less time for cooking than 5 liters pressure cooker without coating material.

TABLE III
AVERAGE COOKING TIME OF PRESSURE COOKERS

Date of Experiment	Time of Experiment	Type of Cooking Vessel	Cooking Period (Minutes)
10.03.2015	10:40 to 11:20 AM	5Ltr Coated	20 - 25 Minutes
	11:26 to 11:52 AM	5LtrUn-Coated	25 - 31 Minutes

V.CONCLUSIONS

A solar dish collector has been designed, fabricated and tested for its performance during summer in Salem, Tamilnadu, India. The experiments on cooking vessels of coated and un-coated with 5 Liters capacity have been used for cooking Rice. The temperature of the cooking vessel walls along with the food items were recorded and based on the experimental outcomes, the following conclusion have been drawn:

- The solar cooker is always capable of cooking food within the expected length of time and based on the solar radiation levels.
- The bottom portion of the cooking vessel is directly exposed to the solar radiation and the remaining parts of the cooking vessel are having contact with the atmosphere.
- The convection effect of the air absorbs some amount of heat from the vessel.
- The conductivity of the material plays a significant role in reduction of temperature.
- With minimum cooking power, the coated pressure cooker of 5 Liters capacity cooks the food at faster manner. This is due to the conductivity of the coating material provided in the cooker.

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