Thermodynamic study on Significance Utilization of Solar Energy for effective Cooking

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Abstract

The economic growth and demographic progression, environmental concerns and crisis for huge consumption of fossil fuels in different sector across the globe, awaits a sustainable option among different renewable sources of energy to mitigate such demands. In addition to this, massive use of fossil fuel creates the challenges for global warming and other environmental threats. As higher part of primary energy consumption in India is accounted in domestic usage, solar energy is encouraged as a promising resource to be utilized particularly in domestic cooking due to its abundant availability, cheaper production cost and zero emissions. Consequently, solar cookers are usually used in the domestic sector resulting lower release of CO2 in the environment. This paper provides the better understanding of solar energy and estimates the potential

Keywords- Renewable energy, Solar cooker,Solar energy

1. INTRODUCTION

On worldwide bases, wood is considered as the fourth most important source of energy after oil, coal and natural gas. For the world as a whole, 50% of the wood consumed as fuel is used for cooking. Many less developed countries depend upon wood as their major source of fuel. In rural areas of the third world where wood is readily available, nearly 95% of the households use it as primary source of energy and it has been referred to as the poor man's oil .One alternative to cover the energy demand for cooking purposes would be to harness solar energy in solar cooking. A solar cooker is a gadget that cooks food using sun energy. Pasteurization and sterilisation are two important processes that solar cookers enable. There are many different types of solar cookers in the world, and researchers and manufacturers are constantly improving them. As a result, classifying solar cookers is a difficult task. However, by utilising solar energy, most solar cookers today may be classified into three categories: solar panel cookers, solar box cookers, and solar parabolic cookers.

Figure 1. Box type solar cooker

HISTORY

The first academic description of the principles of a solar cooker is by the Swiss geologist, meteorologist, physicist, mountaineer and Alpine explorer Horace-Bénédict de Saussure, in 1767. The principle of cooking meals from the sun was largely developed in the French Foreign Legion, in the 1870s.

CLASSIFICATION

Basically, there are 3 types of solar cookers:

1. Box cookers.
2. Panel cookers.
3. 3.Parabolic cookers.

1. BOX COOKER

Solar box cookers (sometimes called solar ovens) are the most common and inexpensive type of solar cookers. These box cookers have a very simple construction and they are made of low cost materials. The outer box is often made of wood. The inner box is made of insulating material, which is covered with clear glass or with plastic, and often has a reflector of aluminum. According to Solar Cooker International, solar box cookers cook at moderate temperatures and often can accommodate multiple pots. It can reach a temperature of 140Ëš C. The solar box cooker, like other solar cookers, needs direct sunshine to operate and produces zero emission. However, the temperature is low and it cannot store and save solar heat for later use. Many nonprofit organizations promote these cookers worldwide in order to help reduce fuel costs and to slow down deforestation caused by firewood collection and charcoal production.

Review On Geometry And Thermal Performance

SBC is a system with transparent glass or plastic top, and it may have additional reflectors to concentrate sunlight into the box, the top can usually be removed to allow pots containing food to be placed inside. Geometry and thermal performance are two main aspects on which this review is drafted.

i. A Review on SBC Geometry :

Elements used in the solar cooker plays an important role in enhancing its performance. Booster mirrors, glazing, cooking pot and lid, insulation etc. proved effective in enhancing the performance of SBC.

ii. Booster mirrors

A booster mirror reflects the extra solar radiation on the aperture area of the cooker and permit higher working temperature thus enhances

the output. Voluminous work of Narasimha Rao et al. are in a sequence including analysis due to effects of single adjustable booster mirror provision to find total energy falling on the aperture for various geographical factors, effects of mirror adjustment under different orientations to evaluate energy boost, investigations for effect of elongated design rectangular apertures with one single booster mirror, on energy collection pattern plus energy accretion pattern with a plane mirror along with the effect of latitude on the energy contribution by the mirror onto the cooker aperture, discussed an algorithm to assess the contribution of solar energy on a horizontal receiver by a plane booster mirrors, prepared a FORTRAN computer code to evaluate the contribution from the booster mirrors in different orientations or tracking modes . Ibrahim et al. designed and evaluated the performance of a box type solar cooker with a plane booster mirror reflector and adjusted the position for maximum solar radiation and the tilt angle of the booster reflector for maximum concentration manifested that using a transparent tight plastic cover for the cooking pot than an ordinary aluminium cover . Algifri et al. dafted a method for finding a reflector performance factor and an orientation factor which depend upon the elevation angle of the sun, the solar surface azimuth angle & the reflector tilt angle to find the relationship between the reflector tilt angle, elevation angle and SBC performance.

iii. Cooking vessels and lids

The major design factors of the cooking vessel are shape, size and the material it is made from. All these affects how quickly it heats up and how well it retains the heat along with the vessel lid. Khalifa et al. conducted experiments with insulated receivers containing transparent tempered glass Pyrex pots and provided with a single glazed insolation window at the bottom and a Teflon coated black aluminum plate placed inside, the pot was utilized for absorbing the incoming radiation, and then conveying the collected energy to the food . Gaur et al. developed a modified concave shaped lid instead of plain lid and reduced the cooking time by 10-13% with increase in temperature of SBC by 27% . A.V. Narasimha Rao et al. carried out a test by keeping a vessel on the mild steel lugs and improved the convective heat transfer in the vessel and found a rise in temperature by 3-5℃. Authors experimentally investigated regarding positioning of vessel, found their proposition reduced cooking time with hike in temperature of more than 20℃ . Geometrical shapes and corresponding arrangements were experimentally tested, proposed and reported by different researchers

iv. Insulation

Insulation is used to gain high temperatures for cooking, inside the SBC, for low conduction of heat from the inner box structure to outer box structural materials, establish on the walls and the bottom. Inference from the reporting of researchers indicate that locally available materials perform better Insulation, as they differently applied, tested, experimented to show enhancement in SBC‟s performance

v. Absorber tray

It is a black coated tray which absorbs sunlight and conduct heat into the pot. Many modifications proposed and reported by the authors on an absorber tray for performance enhancement of SBC‟s. Different publications establishes that performance enhancement of SBC‟s resulted through; tilt in absorbing surface, using colored trays, thickness of plate, exposure of bottom sides, shape of tray, exposing bottom, layering the casings, spacing between glass cover & absorber plate and use of other heat absorbing materials

vi. Geometrical shape of a cooking chamber

The work of several authors who have designed, modified and tested different shapes of the chamber to respective SBC‟s successfully improved the performance to attain reduced cooking time resulting enhance performance

Over all size	Width Length Height at front Height at back Aperture area	Dimension (in mm)
Outer box	Wood	610*469*289

Inner box	Aluminium sheet	450*550
glazing	Glass	550*405

(Table 1 dimension and material of cooker)

(Figure 2)

2. ENERGY AND ENERGY ANALYSIS

Energy analysis based on the first law of thermodynamics. This analysis determines the net heat supplied converted to work for cooking. Energy analysis ignores the reduction in potential of energy that limit its effectiveness. In SC case, the energy analysis can only be used for sizing and analyzing a system that is solely based on one type of energy. The Eo energy output by the fluid due to rise in temperature to the energy input due to solar radiation on the cooker. Energy input Ei from the sun in form of solar radiation to the solar cooker determined through Energy Efficiency ηENERGY which is ratio of energy output to energy input

The thermal energy storage (TES) can be defined as the temporary storage of thermal energy at high or low temperature. Solar energy or the product of solar process can be stored in different forms as electrical, chemical, mechanical and thermal energy [4]. Energy storage can minimize the rate of mismatch between energy supply and energy demand, and it plays an important role in energy conservation. Therefore, the need for the storage of solar energy can have a significant impact on energy sectors. Otherwise, solar energy has to be used as soon as it is received.

Energy storage materials are mainly of two types depending on the way it stores energy. These are: (a) Sensible/Specific heat storage materials, (b) Latent heat storage materials/phase change materials (PCMs). Specific heat storage materials are those which stores energy in the form of specific heat are called specific heat storage materials. The most probable specific heat storage materials used are sand, used engine oil, mineral oil, water, pebbles etc. The amount of energy stored by these materials is dependent on specific heat, temperature change and mass of the storage material. Large mass of material is required for storing solar energy if material has low specific heat; which makes the system bulkier and requires large time for cooking. Latent heat storage materials/phase change materials (PCMs) have advantage over the specific heat storage materials because they require small mass for storing large amount of energy. So these materials are helpful in making energy storage system compact.

Table 1. Properties of sand and water

Properties	Sand	Water
Density (kg/m^3)	1450	1
Thermal conductivity (W/m K)	0.23	0.6
Specific heat (kJ/kg K)	0.87	4.187
Thermal diffusivity (m^2/s)	0.37×10^{-6}	0.143×10^{-6}

(Table 2)

The main properties considered for using as TES are its density, thermal conductivity, specific heat, thermal diffusivity, heat capacity, etc. [5]. The storage materials used and their properties are shown in Table 1. Due to the ease of availability, sand and water are used as thermal energy storage in this

experiment. The experimental analyses done and their results obtained will be discussed in the further sections.

3. COMPONENTS OF BOX TYPE SOLAR COOKER

1. OUTER BOX (PLYWOOD)
2. ALUMINIUM REFLECTOR
3. GLASS PLATE
4. ALUMINIUM SHEET
5. INSULATING MATERIAL
6. DIGITAL THERMOMETER
7. ALUMINIUM UTENSILS

As per specification, the performance analysis of box type solar cooker, the temperature of the absorber plate, the temperature of water in cooking vessel, and the upper and lower glazing temperatures need to be measured. For measuring temperature at these points, insulating material of suitable range can be incorporated. Here the used is J type, which has a temperature range of -40 to 800 °C.

Five pieces of ceramic fiber blanket (insulation) are necessary for experiment.

We are covering 4cm of insulation all the sides of sola cooker (except upper side)

glazing and outer glazing of cooker in order to measure the inner glazing temperature and outer glazing temperature of solar cooker respectively. The remaining one thermocouple can be placed as per the experiment. Thermocouples are connected to digital displays, which show the temperature reading directly. Solar radiation was measured using the solarimeter.

4. OPERATION

Different solar cooker has different working principle but
most of them have same basic principle.Food cooks faster when it is in smaller pieces. Usualy ,small pieaces of food placed in solar cooker. potatoes are normally cut into in small peice and cook. They should not whole.For simple cooking like melting butter it is not neccessary. If we have to cook different foods ,then put them in different containers . After that container is placed inside the solar cooker. Food that cook quickly that should placed latter. Rice for lunch might be started early in the morning.Depending on size and capacity of solar cooker ,quantity of cooked food, family can use one or more cooker. Solar cooker turned towards the sun and left until and unless food is cooked. Food in a solar oven is generally not stirred. Solar oven may be checked every one
and two hrs , to turn the oven towards the sun . Make ensure about shadow of nearly building or tree. Cooking being used, quantity of food, air temperature, wind and latitude also affect on performance. By using small solar panel cooker it might be possible to cook rice for four people in four hrs , melting butter in 15 minutes.

(Figure 3)

5. PRINCPLE

A mirrored surface having high reflectivity is used to concentrate light coming from sun on a small cooking area, but it is depend on geometry of cooking surface. Solar cookers are typically designed to achieve temperature 650 to 4000 on a sunny day. Solar cookers concentrate sunlight on cooking pan. Interaction between receiver material and sunlight converts sunlight

into heat energy. Pots and pan used for cooking must be in black color only. It is most important to insulate the cooker simply by using glass lid on pot .It minimize convection loss of heat energy in the solar cooker.

6. DESIGN

Box-type solar cooker consists of an insulated outer and inner box,metallic cooking tray sat inside the box, double glass lid on the cooking tray, and two reflecting mirrors fitted to the two sides of the lid of the box and an adjustable stand. The cooking tray is insulated on the sides and bottom.The cooker box consists of a top open black painted inner box kept inside of the another box and the space between the two boxes is filled with glass wool insulation.The two reflecting mirrors are placed on the upper side of the box with a gap between them and are in hold by a hinge joint with the cooker box.This is a conventional type of cooker and its length is three times its width and depth is same as that of width.

(figure 4)

The cooker is to be placed facing sun, keeping longer side vertically inclined position and the inclination of the cooker box can easily be changed from 15 degree to 45 degrees with respect to the ground by the adjustable stand, attached at the back side of the box. The reflectors are set along the length of the cooker box cover, one in each side, by hinge and holding strip. So length of reflectors are equal to the length of the glass cover .The widths are equal to the width of the glass cover .The reflectors are inclined at an angle of 115 deg with the face of the box cover. The face of the cooker is to be placed perpendicular to beam radiation to collect the maximum energy. This perpendicular position can be easily achieved simply by the rotation of the cooker towards the sun with the help of caster wheels ,suitably attached at the bottom side of the cooker and by changing the inclination of the cooker by adjustable stand of the back side .But the position of the reflectors remain unchanged throughout the working period. Black painted aluminium cooking pots are used and are placed side by side at the longer side of the cooker on cooking trays. For each cooking tray two bolts acted as hinge are fixed at both longer sides of the cooker inner box. The cooking tray is suspended from the end of the bolts through M.S strips. Length of these strips is equal to the cooking pot radius and these strips are fixed with the ends of tray aligned with the exact middle position . When the cooker box inclination is changed the cooking tray along with cooking pot, for its own weight, rotated around the bolts and always remained in horizontal position. To avoid the chance of tilting of pots, square shaped trays, length of which are kept equal to the diameter of pots are used and ends of the trays are folded upward.

(figure 5)

EXPERIMENTAL READING

SI NO	DATE	TIME	TEMP. (IN DEGREE CELSIUS)
1	19.1.22	12:50PM	30
		1:12PM	40
		1:27PM	42

2	**20.1.22**	**11.00AM**	**32**
		12:15PM	**49**
		1:30PM	**56**
3	**21.1.22**	**12:20PM**	**45**
		1:30PM	**53**
		3:05PM	**62**
4	**22.1.22**	**10:30AM**	**30**
		1:00PM	**82**
		2:00PM	**92**
5	**10.2.22**	**10:10AM**	**29**
		11:55AM	**55**
		2:20PM	**69**
6	**11.2.22**	**9:40AM**	**28**
		10:20AM	**47**
		1.00PM	**77**
7	**14.2.22**	**9:50AM**	**27**
		11:00AM	**53**
		1.:00PM	**80**
		2:00PM	**78**
8	**15.2.22**	**9:40AM**	**28**
		11:00AM	**72**
		1:50PM	**78**

(Table 3)

7. CONCLUSION

In this paper, study of different solar cooker for domestic use has been done. Also, explanation has given about working and construction of different type of solar cooker and their advantages and disadvantages. There are many aspect about solar cooker require development and that should be subject for working in future. Cookers are not working at night but by using thermal storage will be possible in future.

8. FUTURE SCOPE

1. It will help to reduce use of firewood as a fuel.
2. This will help to reduce percentages of pollutant, which will be liberating during cooking. After studying different type of solar cooker we can say that parabolic type solar cooker has better performance than that of box and panel type solar cooker. Because of it reaches extremely high temperature (300-350 Degree Celsius) than that of other type.

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