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A WATER WHITE GLAZED BOX TYPE SOLAR COOKER: PERFOMANCE TESTING AND ANALYSIS

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ABSTRACT

In this paper present a water white box type solar cooker has been designed, fabricated, tested and compared the performance with the conventional box type solar cooker. A 5mm thick water white glass is used in the double glazing cover of the new box type solar cooker. And the single reflector consists of a wooden framed commercially available plane mirror which is sized to form a cover for box when not in use. And other the conventional box type solar cooker having same shape and material but the glazing glass is of 4mm thick simple glass. The performance testing and comparison were done experimentally. Both the cookers are tested simultaneously during summer season in the month of April at Jabalpur. A series of outdoor experiments were performed to obtain first and second figure of merits F1 and F2. The first figure of merit is obtain under no load condition resulted as F1 is 0.144 and 0.11 for new and conventional solar cooker respectively. Under the full load condition the second figure of merit is calculated as F2 = 0.34 & 0.26 for new and conventional cooker respectively. By these results we can analyze by comparing the values of F1 and F2 that the improvement in every part of cooker will give us better results so further improvement will be helpful for better performance of the box type solar cooker.

Keywords— *New and conventional box type solar cooker, first and second figure of merit, water white glass.*

I. INTRODUCTION

Cooking is the primary need of human life for their survival. Cooking has major share of energy consumption in developing countries. Fifty percent of the total energy consumed in India is for cooking. India is the fourth largest energy consumer in the world. Most of the cooking energy requirement is met by non-commercial fuels such as fire wood, agricultural waste, cow dung cake, kerosene in rural areas [12]. Fertilizer consumption can be reduced if cow dung is not burnt for cooking. And the deforestation will reduce by avoiding the use of firewood. Therefore there is a need of renewable source of source of energy for cooking. Solar cooker seems to be a good substitute for cooking. Horace-de –Saussure (1740 - 1799) was the first in the world to use the sun for cooking. Adams, an army officer, made India's first solar cooker in 1878 and he cooked food in it at Bombay, India [5]. Since then different types of solar cookers have been developed all over the world. Solar cooker is an environmental friendly and cost effective device. There are various types of solar cooker like box type, concentrator type, oven type and heat transfer type. Out of these types of solar cookers, only the box type solar cookers have so far been disseminated at the mass level in India. In the box type solar cooker, which is the simplest in terms of operation and fabrication, the temperature of around 100^0C is achieved. This range of temperature is suitable for cooking by boiling, which is prevalent in the most parts of India. There are several deigns parameters which have their influence on thermal performance of box type solar cooker. The optical efficiency of any solar cooker depends on several factors that include angle of incidence of solar radiation, the number of covers (glazing), material for covers etc. [9]. Therefore the material of glazing is replace by water white glass in new box type solar cooker which will improved the transitivity and maximum solar radiation are entering into the cooker. In this paper present a new and conventional box type solar cooker are compared by performance parameter like first and second figure of merit. Mullick et al. proposed a standard test procedure for box-type solar cookers. In this procedure, two figures of merit F_1 and F_2 have to be determined by conducting the stagnation temperature test (without load) and by heating a known mass of water, respectively. F_1 ($^oCm^2/W$) is defined as

Where T_{ps}, T_{as} and H_s are, respectively, the absorber plate temperature, the ambient temperature and the solar radiation on a horizontal surface at the time stagnation temperature is reached. The second figure of merit F_2 involves the measurement of increase in temperature with time of a known amount of water placed in the cooker as given by the relationship.

Where, τ is the time interval in second during which water temperature raises from T_{w1} to $T_{w2.}$ H and T_a are the average horizontal solar radiation (W/m^2) and the average ambient temperature (^0C) over the time interval τ. A, M and C are the aperture area of cover, mass of water taken and specific heat of water.

II. DESIGN DESCRIPTION OF SOLAR COOKER

The new box type solar cooker is fabricated by the wooden ply of 18mm and 12mm thick for side and lower walls respectively. The overall dimension of box type solar cooker is 615mm X 615mm X 220mm with one opening. The absorber plate is made up of aluminum sheet (24 gauges) of trapezoidal shaped having dimension 365mm X 375mm from bottom and 525mm X 520mm from top and 70mm depth. The thermal conductivity of plate is 204 W/m^0C and specific heat is 0.996 KJ/Kg^0C. The glass wool having the thermal conductivity of 0.04 W/m K is used as an insulation in the gap between wooden plywood and absorber plate. The absorber plate is painted with blackboard paint therefore it is capable of absorbing most of the incident solar radiation. The top aperture of solar cooker is covered with double glass cover. This glass cover is made up of double glazing glass of 5mm thickness with the gap 10mm is maintain between the glasses and this glass cover make an aperture area of 510mm X 525mm or $A=0.267m^2$. The water white glass of Saint Gobin (SGG Diamant) is used in the cover of box type solar cooker which having their light transmission is 91%, weight is 12.5 kg/ m^3, and solar factor is 0.9, have been fixed in wooden frame which can be opened and tightly closed the cooking zone. The single reflector of dimension 535mm X 535mm X 4mm is also used for reflection of solar radiation to the aperture area of cover and also acts as lid of cook.

A) Significance of water white glass

The water white glass is such type of glass which is highly transmissible and clear. Therefore as maximum as possible solar beam radiation will enter into the box type solar cooker and reduction in reflection and absorption of solar beam radiation through the glazing glass which is required to decrease the losses of solar radiation through the aperture area of the cover of box type solar cooker. 5mm water white glass of Saint Gobin (SGG Diamant) is used in the new box type solar cooker which has their light transmission is 91%, weight is 12.5 kg/ m^2, and solar factor is 0.9.

B) Instrumentation

During the experimentation solar radiation intensity on a horizontal surface was measured by Eppley precision pyranometer. The temperature of every parts of new and conventional solar cooker was measured by K-type thermocouple with sensitivity (0.5^{o}C) and each thermocouple was calibrated with the help of hypsometer and DPM. And a digital processing meter was used to show the output of temperature in mV and these output values was converted from mV to degree centigrade.

Fig.1 Photograph of New box type solar cooker

Fig.2 Photograph of Experimental setup in left side new solar cooker and in right side conventional cooker.

III. EXPERIMENTAL PROCEDURE

The outdoor experiments were performed for the determination of two figure of merit F_1 and F_2 during the month of April at the geogr aphical location of Jabalpur (latitude L= 23° North and longitude Φ = 80° East). The experiment was performed two hours before and after the solar noon. The first experiment was done for first figure of merit under the no load condition. In this experiment both the ne w and conventional box type solar cookers was simultaneous testing in sunshine. The absorber plate stagnation temperature T_{ps} (maxi mum temperature attained by absorber plate according to its heat capacity) was measured and at the same time ambient temperature w as measured by the calibrated K type thermocouple with sensitivity (0.5°C) connected to the digital panel meter (DPM) which gives u s output by digital display in mV. During the experiment solar radiation intensity on a horizontal surface was measured by Eppley pre cision pyranometer connected to DPM which display the reading in mV at the same time of stagnation and these values are used to cal culate value of F_1 and the same procedure applied for conventional solar cooker, values of T_{ps}, T_{as} and H_s are recorded and use these v alues for calculation of F_1.

The second outdoor experiments were conducted to calculate second figure of merit. This test is also called as water sensible heating test were performed under the full load condition here 1kg of water is taken as load for cooker and this 1kg of water was taken in one container which is also made up of aluminum and black painted this experiments was also performed at the noon. And simulta neously same type of container with 1 kg of water was used for conventional box type solar cooker. These water containers were put i n the cookers and tightly close the cover to avoid the losses. The water is allowed to increase temperature up to the boiling point of wa ter and T_{w1} =63.5°C and T_{w2} =96.5° C were taken under the temperature range mentioned by Mullick et al. for the calculation of F_2. An d similarly T_{w1} =63.7°C and T_{w2} =97.8° C are taken for conventional solar cooker. The average ambient temperature and average solar insolation were also taken during the water sensible test under the temperature range for the calculation of F_2. The time was also recor ded for the water to reach from T_{w1} to T_{w2}. The same procedure was followed for the conventional cooker simultaneously and finally F_2 will be calculated by these values.

IV. RESULTS AND DISCUSSION

The cooker was kept under the sun until the temperatures of the cooker elements achieved their maximum values or stagnation temper ature with reflector. The maximum or stagnation temperatures of the absorber plate T_{ps}, ambient temperature T_a, lower T_{gl} and upper T_{gu} glass covers temperatures were 191, 46, 151.5, and 95.7 ⁰C respectively. And solar insolation was also recorded at same time as H_s =1006 W/m^2

Using the above results, the first figure of merit F_1 for new cooker was calculated to be 0.144 (m^2 ⁰C /W) by using equation (1) given as

By same procedure the values of old cooker are also obtained as absorber plate stagnation temperature T_{ps}, ambient temperature T_a, lo wer T_{gl} and upper T_{gu} glass covers temperatures were 144, 44, 109.5 and 47 ⁰C respectively. And solar insolation was also recorded at same time as H_s = 946W/m^2 and we get F_1=0.11 m^2 ⁰C /W approximate.

Table.1. Comparative Observation for the Values of F_1 for New and Conventional Solar Cooker:

Box Type Solar Cook er	Stagnation Temperatur e (⁰C)	Ambient Temperature (⁰C)	Solar Insolation (W/ m^2)	First figure of merit (m^2 ⁰C/W)
New Box Type Solar Cooker	191	46	1006	0.144
Old Box Type Solar C ooker	144	44	946	0.11

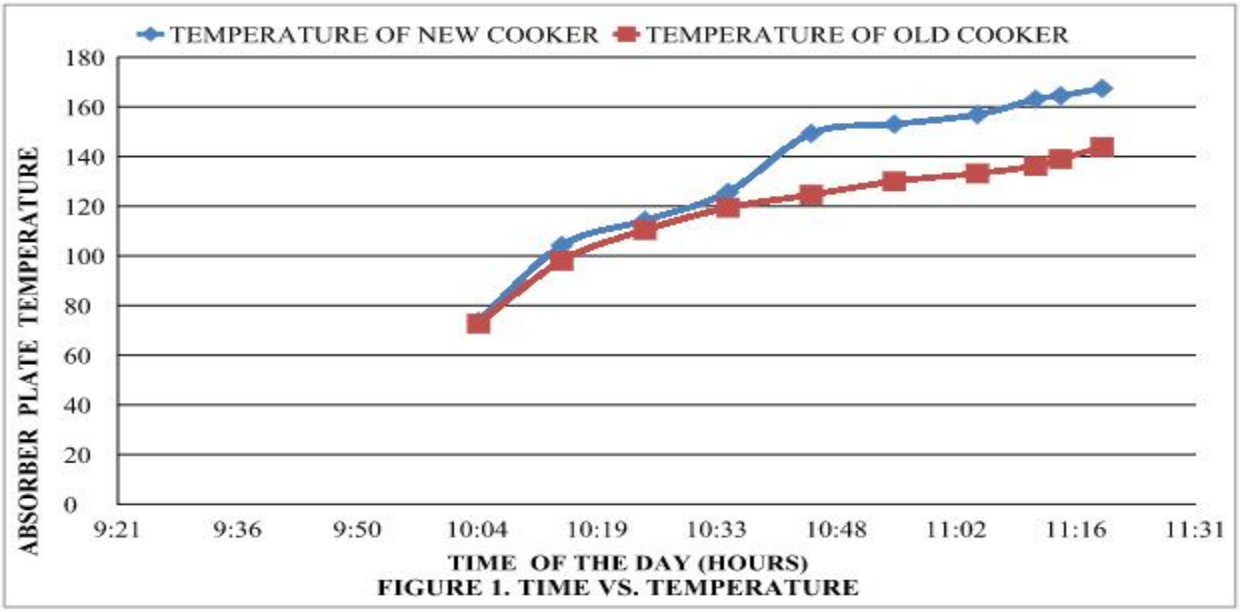

Figure 3: A comparative graph between the time and absorber plate temperature of both solar cooker dated on 24/042014

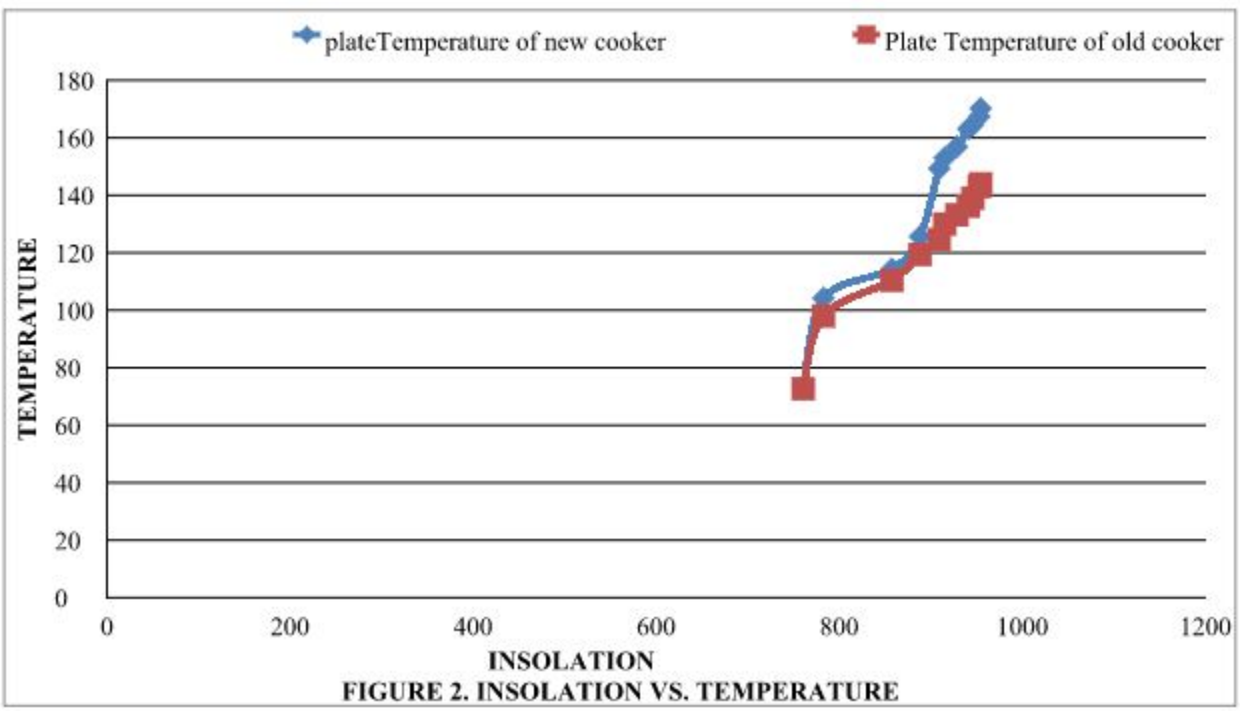

Figure 4: A comparative graph for both solar cooker between solar insolation and plate temperature dated on 24/04/2014

The second outdoor test was established in noon in same month of April for the calculation of F_2. This test for second figure of merit was performed under the full load condition means one pot is used and fill it with 1kg of pure water and put it in the new cooker and t hen this whole setup was kept under the sunshine until the temperatures of the water is reached to boiling temperature.

In this test we take the initial and final temperature of water under the range as mentioned by Mullick et al. from T_{w1}= 63.5 ^{0}C to T_{w2} = 96.5 ^{0}C and the time taken to reach water temperature from T_{w1} to T_{w2} is 2700 second, average insolation, average ambient temperat ure during the test is taken as 867.5 W/m^2, 38.5 ^{0}C respectively. The aperture area of cover is 0.267 m^2.

Using the above results, the second figure of merit F_2 for new cooker was calculated to be F_2 = 0.34 by using equation (2) is given as

By same procedure the values of old cooker are also obtained as T_{w1} =63.7 ^{0}C, T_{w2} = 97.8 ^{0}C and the time taken by water to at tain temperature from T_{w1} to T_{w2} is 3600 second. The average insolation, average ambient temperature and aperture area of the conven tional solar cooker are recorded as 914 W/m^2, 41.2 ^{0}C respectively. The aperture area of cover of conventional solar cooker is 0.28 m^2. Using these values the second figure of merit F_2 for conventional cooker was calculated to be F_2 = 0.26

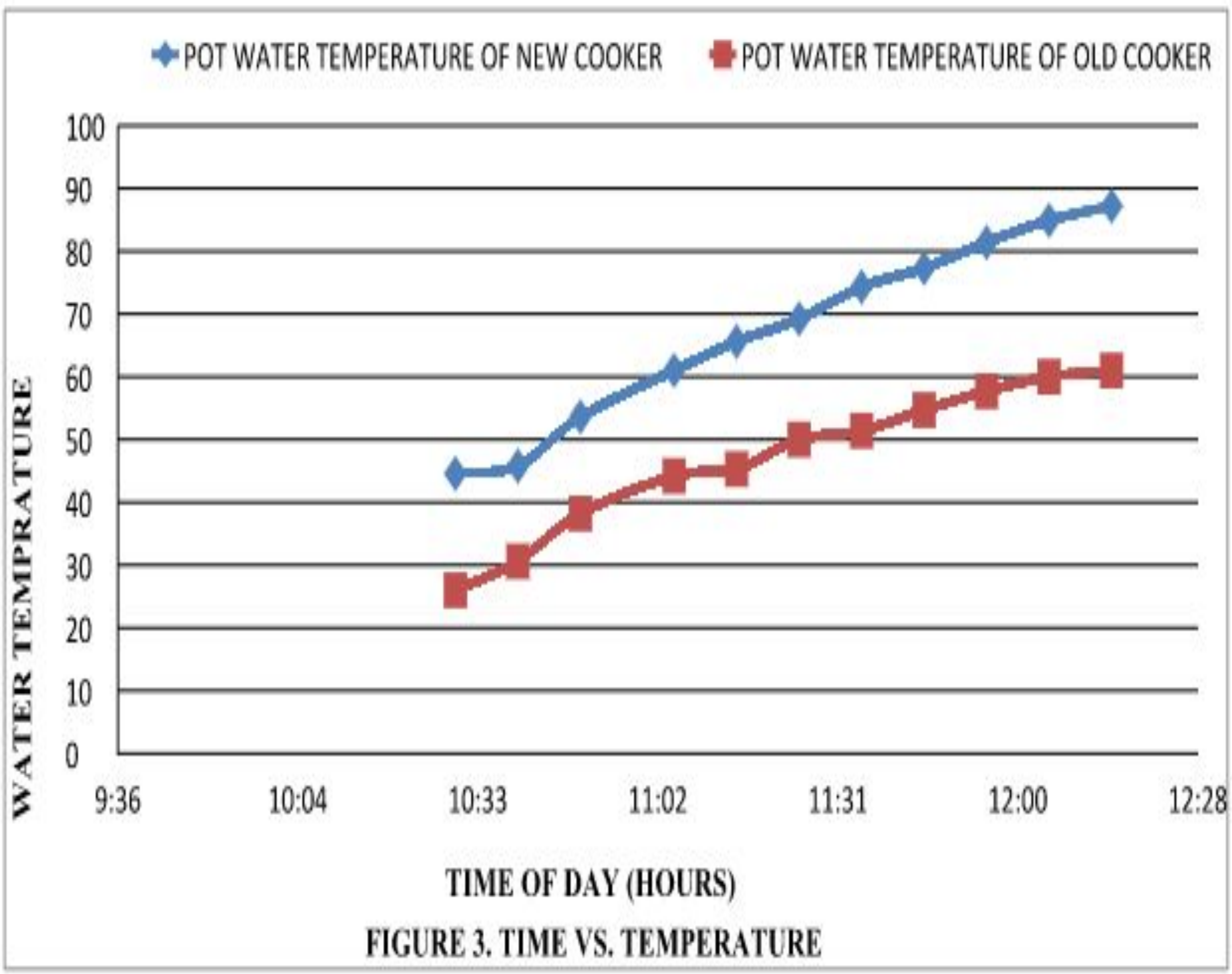

Figure 5: A comparative graph between time and water temperature of both solar cookers dated on 22/04/2014

Table2. Comparative Observation between New and Conventional Solar Cooker by the Values of F_2

Box Type Solar Cooker	Initial Water Temperature T_{w1} (^0C)	Final Water Temperature T_{w2} (^0C)	Average Solar Insolation H_s (w/m^2)	Average Ambient Temperature T_a (^0C)	Time Taken T (sec.)	Aperture Area (A) (m^2)	Second Figure Of Merit (F_2)
Old Cooker	63.7	97.8	914	41.2	3600	0.28	0.26
New Cooker	63.5	96.5	867.5	38.5	2700	0.267	0.34

V. Conclusion and Future scope of work:

A) Conclusion

It is concluded from the experiments that every element of a solar cooker has great importance and has directly depend on the performance of cooker in any climatic conditions. For quality cooking no one parameter has been eliminated among these. Therefore the modification in the cover of solar cooker give the better results as F_1 = 0.144 for new cooker and F_1 = 0.11 for old cooker. These values of F1 for conventional and new cooker ensure that the glass cover of new cooker has better optical transmission than conventional cooker and the new cooker has low overall heat loss factor.

The second figure of merit is also increased for new solar cooker as F_2=0.34 as compare to old solar cooker as F_2 = 0.26. These values tells us that there is good heat transfer to the contents in the container means that the value of F' is high.

It is concluded that objective parameters are those parameters which can provide all the necessary information of the cooker related to cooking, on the basis of which the best cooker suitable for a particular climate and geographic location may be selected. Box type solar cooker is simple cheaper and also easy to handle so the development in the design of this cooker will solve the problem of energy for cooking.

B) Future scope of work

According to the future aspect the demand of box type solar cooker will increase drastically because of their simplicity in handling and better performance than other type of solar cooker. Due to continuously consumption of conventional fuel and urban people mostly use LPG, Natural Gas and electrical energy for cooking purposes. Solar cooker will fulfill the need in future. By the further researches the scarcity of cooker will be removed. The performance of box type solar cooker can also increased by further improvement in glazing by reducing the losses offered by cover. And by improvement in every element of solar cooker will give us better results.

VI. NOMENCLATURE

SYMBOLS	DESCRIPTION
F_1	First figure of merit
F_2	Second figure of merit
U_L	Overall lose factor in watt/m^2/ ^0C
η^0	Optical efficiency
T_{ps}	Plate stagnation temperature in ^0C
T_{as}	Ambient temperature at time of stagnation in ^0C

H_s	Insolation on a horizontal surface in watt/m^2
$(MC)_w$	Product of mass and heat capacity of water in KJ/ ^{0}C
C_R	Heat capacity ratio
T_{w1} & T_{w2}	Initial and final temperature of water in ^{0}C
T_a	Average ambient temperature for second figure of merit in ^{0}C
τ	Measured time for sensible heating of water in sec.
A	Aperture area of box type solar cooker in m^2
F'	Heat exchange efficiency factor

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