A Comprehensive Review on Solar Cookers

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Abstract- *In this paper, a thorough review of the available literature on solar cookers is presented. The review covers detailed description of various types of solar cookers, parameters which affects the performance of solar cookers such as mirrors, glazing, absorber plate, cooking pots, heat storage materials and insulation. It also covers the comparison, discussion and evaluation of the findings obtained by various researchers. Several attempts have been made to introduce effective solar cookers in different countries and have achieved great successes. There are still critical issues so far to be resolved in order to make the technology acceptable. Thermodynamic assessment of solar cooking systems and qualitative evaluation of thermal output offered by solar cookers are analyzed in detail. Objective of this review is to get the most appropriate types of solar cookers for specific locations, optimum size, capacity, types of materials to be used.*

Keywords- solar cookers, mirrors, glazing, absorber plate

I. INTRODUCTION

Cooking is an integral part of each and every human being as food is one of the basic necessities for living. Commonly used sources of energy for cooking are firewood, crop residue, cow dung, kerosene, electricity, liquefied petroleum gas (LPG), biogas etc. Half of the world's population is exposed to indoor air pollution, mainly the result of burning solid fuels for cooking and heating. Wood cut for cooking purpose contributes to the 16 million hectares (above 4% of total area of India) of forest destroyed annually. The World Health Organization (WHO) reports that in 23 countries 10% of deaths are due to just two environmental risk factors: unsafe water, including poor sanitation and hygiene; and indoor air pollution due to solid fuel usage for cooking. In under-developed countries, women have to walk 2kms on average and spend significant amount of time for collecting the firewood for cooking. The cooking energy demand in rural areas of de- veloping countries is largely met with bio-fuels such as fuel wood, charcoal, agricultural residues and dung cakes, whereas LPG or electricity is predominantly used in urban areas. India has abandon amount of solar energy in most of the regions making it most ideal place for harvesting solar energy. With almost 300 sunny days each year, one can confidently relay on this source of energy. India's geographical location is in such a way that theoretically it receives 5×1015 kWh/year of solar energy. Solar cooking is the simplest, safest, environmental friendly and most convenient way to cook. It is a blessing for those who cook using firewood or cow dung, who walk for miles to collect wood, who suffer from indoor air pollution. Hence solar cooking is going to play major role in solving future energy problem.

Solar based cooking has never been a strong contender in the commercial market or even close to being a preferred method of cooking. They have been relegated to demon- stration appliances to show case the solar based concepts. In this mode, cooking is no longer a time independent activity that can be performed at any time of day. One is forced to cook only at certain times when there is sufficient insolation. The geography of the cooking activity also shifts away from the kitchen. The kitchen is no longer the hearth of the home as the actual cooking activity shifts to the roof tops or high insolation platforms. This further adds to the inconvenience apart from being unable to cook at night or during cloudy conditions or during most of the winter days. Another issue of significant inconvenience is the general social structure in most families of the develop- ing countries wherein the cooking activity is carried out by the senior ladies of the home. In this paper, a thorough review of the available literature on solar cookers is presented. Many scientists of 17th century knew about the principle of greenhouse effect where glass is used to trap heat from the sun. But Horace de Saussure, a French-Swiss scientist extended this principle to heat up food materials. Group, et. al contributed to develop a advance type of solar cooker. The main differences between the box cooker are the pot is fixed in conductive contact to the absorber plate, allowing for better heat transfer the pot is set into the glazing, allowing access to the pot during cooking while protecting the interior of the cooker. Some qualitative results are glazing configuration (pot set into a circular hole in the glazing), un tempered single float glass resists thermal shock, insulated pot lids and pot lids made of single or double glass give roughly the same thermal results; therefore, single glazed pot lids were adopted. With these lids, the user can check the cooking results without opening the pot, thus limiting heat loss , single and double glazing of the cookers yield roughly the same results in the heat-up phase; therefore, single glazing was adopted. Thermal performance of solar thermal devices critically depend upon the testing and environmental conditions viz. available solar radiation intensity on the aperture of solar cooker, ambient air temperature, prevailing wind speed, diffused fraction in total solar irradiance, etc. Beam radiation from sun is partly absorbed and partly scattered by the atmospheric dust, gases , clouds, moistures etc. On clear day direct radiation beam radiation is reduced by 30% ,moderate clouds 10 to 50 % of values of extraterrestrial radiation, on very cloudy condition direct radiation may reduce even to 1%.[8] For flat plate collectors collect diffuse radiation with better efficiency .Effect on beam radiation due to atmospheric condition expressed by atmospheric clarity index

$$\text{Clarity index} = \frac{Solar\ Insolation}{Solar\ Constant}$$

Where Solar Insolation is Solar power on a flat horizontal surface of earth per unit area.(w/m^2), Solar Constant is Solar power per unit area outside earth's atmosphere on a surface normal to sun rays (w/m^2). Values of clarity index for cloud day=0.1, Clear day at noon =0.7[8]

II. LITERATURE REVIEW

Lots of modifications and exploration has been done on solar cooking in order to improve the efficiency and ease of cooking

Existing solar cooking methods:

Box type cooker is one of the basic solar cooking models. It is a simple rectangular box covered with either glass or. Sun beam entering the cooker through this cover turns to heat energy when it is absorbed by the black colored absorber plate and cooking vessel. This heat input raises the temperature inside the box cooker until the heat loss from the box equals to the solar heat input. The box is thermally insulated to reduce the heat loss to ambient, so as to attain higher temperature and better efficiency. Group**,** et. al. have investigated solar cookers box-type, their results have been useful as reference to other investigations. Among their investigations, they have showed a numerical simulation for a solar cooker box-type, their results were applied to determine the effects in the absorbent and the pot, as well as the thermal behaviour in the conductivity of the absorbent. In another work presented by Thulasi et al. they obtained a mathematical model for a solar cooker box-type and they exposed problems for a great quantity of parameters that participate in the thermal operation of solar cookers. A parametrical model for the operation in a solar cooker to predict their cooking power was presented by Funk and Larson. The model was based on three controlled parameters like area of solar collector, overall heat loss coefficient, and thermal conductivity of the plateful base's absorber and three not controlled variables (heatstroke, temperature difference, and load distribution). This model was validated using solar commercial cookers. Kumar**, S**., presented a simple test procedure to determine design parameters to predict the thermal performance in a solar cooker box-type. An out-door series experiments were performed on the double-glazed solar cooker with aperture area 0.24 m2 to obtain two figures of merit, F1 and F2. The proposed procedure is then applied to predict the heating characteristic curves in the solar cooker with different load of water.

More people can be attracted towards thes olar cooking by improving the performance of solar cookers . These performances can be determined by an elaborate analysis of the optical and thermal characteristics of the cooker materials and the cooker design or by experimental performance testing under different operating conditions. There are some perfor- mance parameters that have been adopted all over the world such as standard cooking power(Ps), first figure of merit(F1), second figure of merit(F2), energy(η) and exergyefficiency (ψ) etc.These parameters have been widely analyzed by many researchers and are used for evaluating the performance of solar cooking devices. Mullick et al. presented a method to analyze the thermal performance of solar cookers. According to this method, two figures of merit can be calculated. The first figure of merit F1 is determined by stagnation test at no-load conditions using follow- ing expression

$$F_1 = \frac{T_{ps} - T_{as}}{IG}$$

where Tps is maximum absorber plate temperature, Tas is ambient air temperature (atstagnation) and IG isinsulation on a horizontal surface at the stagnation time (inW/m^2). The second figure of merit F2, is obtained from the full load water heating test as follows

Table 1: dimensions and material used for different types of solar cooker

Reference	**Outer dimension (sq.cm)**	**Casting material**	**Aperture area (sq.cm)**	**Absorber tray material**	**Shape of material tray**	**Insulation material**	**Glaze material**
Vishaya et al.	-	GI sheet	50*50	GI sheet	Square (erect)	Glass wool	Double glass
Pande and thanvi	92*40*20	aluminum	90*36	Aluminum	rectangular	fiber glass bonded	Double glass
Nahar et.al	57*57*20	steel	47*47	Aluminum	Square(trapazoidal)	fiber glass wool	Double glass
Nahar et.al	207*57*23	steel	-	Aluminum	Rectangular	fiber glass wool	Double glass
Nahar et.al	56*56*23	aluminum	46*46	Aluminum	Square(trapazoidal)	Glass wool	Double glass with(TIM)
Negi and purohit	-	aluminum	43.33*43.33	Aluminum	Square (erect)	fiber glass wool	Double glass
Nandwani	54*35*25(back side) and 54*35*20(front side)	steel	-	-	Rectangular	glass wool	Double glass
Kumar et al.	60*60*16.5	fiber body	24*50	Aluminum	Square(trapazoidal)	glass wool	Double glass
Harmani et al.	-	wooden	60*50	Aluminum	-	date palm bark	Double glass
Sengar et al.	54.6*52*24	cardboard	40*40	used oican tin	Square (erect)	thermocole	Double polymeric sheet
Sengar et al.	л *(45*45) * 24	bricks and cement plaster	л *(31.5*31.5)	Aluminum	Cylindrical	thermocole	Double polymeric sheet
S.B.joshi and A.R.JANI	30*30*0.15	aluminium	40*40	-	Square	Glass wool	Double glass
Naveen kumar	-	-	32.6*32.6	Aluminum	-	-	Glass
H.M.Naher	0.560*560*180	aluminium	40*40	-	Square	Glass wool	Double glass

$$F_2 = F'\eta_O C_R = \frac{F_1(MC)_W}{A_c \Delta t} \ln\left[\frac{1-(1/F_1)(T_{wi}-\overline{T}_a)/\overline{IG}}{1-(1/F_1)(T_{wf}-\overline{T}_a)/\overline{IG}}\right]$$

where F0 is heat exchange efficiency factor, ηO is optical efficiency, CR is heat capacity ratio, M is the mass of water, C is the heat capacity of water, Ac is absorber plat area, Δt is time interval, Twi is initial temperature of water, Twf is final temperature of water, T a is average ambient air temperature and IG is the average solar radiation on horizontal surfaces.

A high value of F1 indicates good optical efficiency and low heat loss factor. A high value of F2 indicates good heat exchange efficiency factor F0 , good optical efficiency ηo, and low heat capacity of the cooker interiors and vessels compared to a full load of water. Their study reveals that F1 to be in the range 0.12– 0.16 whereas F2 should be in the range of 0.254–0.490.

In 2000s ,researchers demonstrated interest in developing new designs of solar box cookers in order to optimize their thermal performance and efficiency.In,theearly 2012,Mahavar et al. presented the design development and thermal and cooking performance studies of the novel Single Family Solar Cooker (SFSC). Complete theoretical consideration for the fabrication of the SFSC was also presented. During testing ,the high es tplate stagnation temperature under no-load condition was approxi- mately144 1C. The value so ft wo calculated figures of merits F1 (0.116 1C m²/W) and F2 (0.466)indicate that he cooker can be used for consecutive cooking on a sunny day.

During the same year ,Joshi et al. described a methodology of optimization of cooking systems to enhance the effi-ciency from the conventional level of 15–20% to 65–75%. For this purpose, they developed an efficient novel design of cooking systems with cooking equipment, which gain energy from condensing steam on the outside surface ,and the cooking load received heat by the mode of natural convection. The CFD results indicated that the optimum heat flux depends upon the balance between the rate of heat supply and rate of heat up take by the cooker contents.

The heat flux values were found to be in the range of 83,680 to 104,600kJ/hm².

III. CONCLUSION

The Solar cooking technologies can play a key role to reduce or substitute energy consumption from other sources in the near future. Effectively, solar cooking is a best option which offers a promising appliance for solar energy. In addition to its several advantages ,the large-scale diffusion of solar cookers is still limited because of diverse problems. To overcome this limitation and to apprehend more benefits of these systems, more research attempts must be done in future all over the world, to increase their efficiency and enhance their current performance.

REFERENCES

[1] Grupp, M., Montagne, P., Wackernagel, M., A novel advanced box-type solar cooker, Solar Energy, Volume 47, Issue 2, (1991), pp. 107-113.

[2] Funk, P. A. y Larson, D. L., Parametric model of solar cooker performance, Solar Energy, Volume. 62, No. 1, (1998), pp. 63-68.

[3] Kumar, S., Estimation of design parameters for thermal performance evaluation of box-type solar cooker, Renewable Energy, Volume 30, (2005), pp. 1117–1126

[4] Mahavar S, Sengar N,Rajawat P,Verma M,Dashora P. Design development and performance studies of a novel single family solar cooker.Renew Energy 2012;47:67–76.

[5] Mullick S C, Kandpal T C, Saxena A K. Thermal test procedure for box type solar cooker. Sol Energy 1987; 39: 353–60

[6] Joshi J B, Pandit A B, Patel S B, Singhal R S ,Bhide G K, Mariwala K V,et al. Development of efficient designs of cooking systems– experimental. Ind Eng Chem Res 2012;51(4):1878–96.

[7] Ishan Purohit a,*, Pallav Purohit b Instrumentation error analysis of a box-type solar cooker.Energy Conversion and Management 50 (2009) 365–375

[8] michael grupp,* pierre montagne, and mathis wackernagel,a novel advanced box-type solar cooker,solar energy vol. 47, no. 2, pp. 107-113,