Comparative Evaluation of Parabolic Collector and Scheffler Reflector For Solar Cooking

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Abstract

Solar energy is transforming to be the promising renewable energy resource that could be used efficiently for human basic needs like cooking. This study presents the performance analysis of solar cooking instruments based on their geometrical aspects. The main aim is to find the best solar cooking device that can efficiently absorb heat reflecting from its surface. Here we evaluated the performance of parabolic type solar reflector and Scheffler type solar reflector in terms of its thermal efficiency and losses. The main dependent factor for this comparative analysis is the geometry of the reflectors with a diameter of 1.5 m and the radiation of the sun. For better reflectivity in both receiver and concentrator or reflector medium, stainless steel material is used. Depending on these factors, we have evaluated performance of both the reflectors and found satisfactory results. Theoretical and simulated results over various conditions prove that the Scheffler reflector performs well compared to parabolic collector.

Keywords: *Parabolic Collector, Solar insolation, Thermal Efficiency, Scheffler Reflector, Efficiency*

A. INTRODUCTION

In urban areas, the cooking is concentrated on LPG or electric cooking devices. Solar cookers can play a major role both in rural and in urban areas such that use of conventional resources and commercial fuels can be reduced to a certain extent. This could help in improving the economy of the individual as well as the nation. India is surrounded by 70% of the families living in rural areas with 300 sunny days. So utilizing the solar power could be regarded as a best option that could serve in power consumption aspects in India. To safeguard the environment from pollution and without reducing the nutritional value of food, solar cooking is used. Additionally, solar cooking can reduce the consumption or extinction of fossil fuels. Electricity through alternative resources is an alluring thing that could incorporate techniques for concentrating solar energy that includes solar parabolic collector and scheffler reflector [4]. This solar power is concentrated to a particular focal point and that should sufficiently generate power without much wastage. The main drawbacks to get energy from solar radiations are its installation cost, maintenance and operation cost, and reduced efficiency of solar energy conversion rate. Proper placement of cooking devices at the focal point could increase the efficiency, since the solar energy is used efficiently. The preliminary strategy that can use efficiently the solar energy is the geometry of both these instruments with a proper focal point. To make this technology best use for cooking purpose, certain changes needs to be done by setting up an azimuth axis for tracking the solar power. Devising reflector surface with least imperfection that could help in attaining better efficiency with best tracking as well Most of the study concentrates on a single solar reflector type, out of which José Ruelas et al. developed a new mathematical model that estimates the scheffler reflector based on optical and geometric behaviour. Solar parabolic collector was analyzed by Harris and Lenz for finding out its thermal behaviour based upon its geometry and amount of radiation that reaches the reflector. Other researches that concentrated on geometrical shapes includes Shuai et al.

And Badescu determined the thermal irradiance on parabolic solar reflector depending on various geometries. Optimal size for determining the aperture area of parabolic spherical cavity is done through software implementation by Kumar and Reddy. Chin-Hsiang and Hang-Suin studied optimal parameters related to geometry of the parabolic dish for modelling efficiently the thermal parameters. Solar power transmitted from transmitter to receiver is studied theoretically using Duffie and Beckman. Optical and thermal conversion factor for optimizing the solar parabolic collector geometry is studied using Jaffe and Badescu. From the above researches, it is found that to improve efficiency geometry of the dish is concentrated and several theoretical analyses are made to improve the efficiency of the solar instrument. The literature that concentrated on scheffler reflectors are determined here and the performance of solar parabolic trough collector was improved by Qibin et al. using a solar ray trace method. Fresnel concentrator with ray tracing was studied by Lara et al. Linear Fresnel solar reflector was studied by Ya-Ling et al. For analyzing the optical and thermal performance through heat transfer fluid. Sunlight is concentrated using a immobile mirror and receiver that was studied by Rogers et al. For analyzing the ray tracing performance of the system. Studied the receiver design using a parabolic dish though ray tracing software, which is simulated to analyze the efficiency of the system. An experiment is conducted with three parabolic collectors with various aperture entrances was tested and simulated and finally scheffler reflector was designed by Munir et al. For low temperature applications. Soon after reviewing all the literature, it is found that none of the studies concentrated particularly on cooking system. These studies duly concentrated on performance by changing its geometry. Using this, we can compare the geometrical parameters of parabolic scheffler and reflector to find its computational efficiency. In this study a comparative analysis of thermal efficiency and radiation losses is studied by comparing both the solar cooking reflectors. Here the geometry and the parameters required for simulation is kept constant and finally the results were compared for finding out the best cooking solar instrument.

This paper focuses on comparing the performance of both solar parabolic and scheffler reflector in terms of efficiency and loss. Cooking is a major phenomenon, so this paper concentrates on the instrument with best thermal efficiency. The device with best performance is suited for cooking purpose such that it could use the maximum resources available from the sun. Here, the geometry along with radiation of sun is regarded as a major factor that suitably tracked could help in attaining better thermal efficiency and least losses. Since the entire research is based on comparative analysis, performance is compared in terms of various parameters to find the best suited device for cooking in rural areas of India.

B. LITERATUR REVIEW

This section deals mainly with the geometry of solar cooking instrument namely parabolic collectors and scheffler reflector. This gives the primary outline of the efficient cooking instrument through the major geometrical factor with fixed measurement for both the instruments. Initially the geometry of solar parabolic collector with misalignments is discussed and that is followed by its competitor. The parabolic collector considered for analysis consists of a concentrator with an opening diameter of 1.5 m in a parabolic shape. A reflecting layer is placed over the interior surface and the sun rays falling on the reflecting layer, gets reflected on a receiver plate. The reflection over the plate is placed accurately using the focal point made at the concentrator. The reflective material that is used to cover the parabola is taken as steel. The reflective co-efficient of which is taken as 0.85. This concentrator could be defined as a directional medium that provides a best follow up for the sun rays based on axis Scheffler reflector is designed to operate at high temperature because of its frequent variation in focal point and improved handling of its receiver. The main advantage is that it can shift its receiver based upon the reflection from the elliptical cavity. In order to balance the earth’s rotation, reflector rotates with an angular velocity along polar axis from east to west. Thus the reflector’s relative position remains stationary with respect to sun that provides fixed focal axis along the axis of rotation. Advantage of scheffler is that it can also provide seasonal tracking with same focus over rapid changing in solar declination. The following section includes the geometry of scheffler with crossbar reflector.

C. METHOD

Both the instruments were modeled in Simulink and tested with STP conditions. To calculate all the resultant output parameters, the equations that are defined above are used for modelling blocks in Simulink. The experimental conditions are observed in terms of values generated in a range using the equations defined above. Here parabolic collector (fig. 5) is tested without tracking and scheffler reflector (fig. 6.) is tested such that it tracks the sun. The parameters like aperture area, radiation of sun and other coefficients are maintained with same values for both the instruments. Stainless steel material is used as a concentrator for both the instrument with same diameter, thickness and reflection coefficient as stated in previous section. Diameter of both parabola and scheffler is taken as 2 m, depth of both parabola and scheffler is taken as 0.5 m and the focal distance as 0.75 m. Different thermal efficiency formula is needed to calculate both parabolic collector and scheffler reflector. Thermal efficiency of solar parabolic collector is calculated in terms of the geometry and temperature of the sun. Similar to parabolic collector, scheffler also performs the same in terms of medium and material.

The thermal efficiency of the steel material without misalignment attains maximum efficiency than compared with other efficiencies (fig. 11). Optical efficiency of the scheffler is high when compared with parabolic collector and also other thermal efficiencies are found to be relatively high when compared with parabolic collector. From the above results, it could be found that scheffler reflector attains maximum efficiency when compared with parabolic reflector as radiation over the reflector increases. It is seen from the fig. 8 and 10 that the overall efficiency of the scheffler reflector is found to be 79% with steel as reflecting medium and geometry is considered without misalignment. Similarity the efficiency of parabolic collector seems to possess an efficiency of 72% at 10:00 am without considering the misalignment.

When misalignment is considered as a factor, it could be found that efficiency of both the scheffler reflector and parabolic collector seems to get reduced by a factor of β'. The results from the above graph (fig. 9 and 11) for both instruments proved that with steel as a reflecting instrument, the efficiency of the devices increases. The thermal efficiency at 10:00am for scheffler reflector is found to be 48% with steel as reflector and 31% efficiency without steel. Likewise for parabolic collector, the thermal efficiency is found to be 34% with steel as collecting medium and 22% without steel. From the simulated results, it could be obtained that scheffler reflector performs well in terms of thermal efficiency and overall efficiency.

D. CONCLUSION

This research clearly demonstrates the effectiveness of the scheffler reflector and proved its efficiency in terms of heat gain with water as absorbing medium to make it suitable for cooking heat conditions. Thus the scheffler reflector attains maximum efficiency of 79% at 10:00am compared with parabolic collector with 72%. Also, it is observed that the geometry of the device plays a major role in concentrating the heat to the reflector object. Slight misalignment in geometry reduces the obtained efficiency, since the heat is concentrated to uneven space. From the simulations, we could conclude that scheffler reflector outperforms well when compared with solar parabolic collector. This could be proved in terms of scheffler reflector's tracking ability than fixed parabolic collector. Also, we found that reflectivity of the concentrator plays a major role in improving the efficiency such that the concentrator or reflector with better heat coefficient can improve the design. Improvements could be further done by changing the geometric design of both parabolic collector and scheffler reflector with better design for improving its efficiency. Also use of other reflective material can further improve the thermal efficiency and reduced cost design could make it suitable for people to use it for daily use.

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