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EXPERIMENTAL INVESTIGATION OF SOLAR POWERED COFFEE MAKER BASED ON SCHEFFLER REFLECTOR

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ABSTRACT

In this paper, the coffee making using Scheffler reflector has been proposed. Scheffler reflector of 1.54 m^2 has been used for generation of steam in the receiver of 0.030 m^2. The steam is generated at the temperature of 120°C. This steam is directly mixed with coffee in the coffee container. The temperature of 500ml of coffee increased from 18.9°C to 95°C. The steam production is greatly affected by the solar intensity, air velocity and quantity of water.In 3hr of duration the system was able to produce steam at pressure of 2 bar having overall system efficiency of 25%.

Keyword: Scheffler Reflector; Coffee Maker; Steam Generation;

I INTRODUCTION

Humans need energy usually at elevated temperature to cook food, to maintain the temperature of living space, to operate devices, to operate vehicles and to generate electricity. Fossil and Biomass fuels are excellent sources of the high temperature of current century but harmful in some case because of always producing smoke and undesirable pollutant. Solar energy is a source of all sources of energy used by humankind and nature. All alive are driven by the sun directly and indirectly, but only a few sources of the energy directly from the sunlight. It is necessary to concentrate the heat from the sun in a small area for producing high temperature to ease for human's application. It can be achieved by use of magnifying glasses and curved mirrors, but in long terms, it becomes challenges because of solar declination angle varies -23.5 to 0 to 23.5 in a year. So it is necessary for maintaining high-quality focus through year some engineering efforts require like tracking of the sun.

The Scheffler solar concentrator is a single fixed focus solar concentrator. Namesake engineer Wolfgang Scheffler introduced it. The core idea behind this to produce a high quality fixed focus which requires reducing tracking mechanisms and structures so that it could be easily constructed, maintained, and operated in the whole world. The Scheffler reflector achieves these goals because it maintains a fixed focus by using only single daily axis tracking.

Wolfgang Scheffler [2006] described and developed some ideas about the intricate design of the Scheffler reflectors. The construction and fabrication of the Scheffler Reflector were done in-country plants in India and in Kenya, to assure the resulting technology would be within the range of everybody who would require it in future.Ajay Chandak et.al [2009] created and tested with multistage evaporation system for generation of purified water. Two Scheffler reflectors of 16 sqm each were used for producing steam in the initial stage to 8 bar pressure, and the pressure is slowly brought down to 1bar, in four step distillation system. The total yield achieved in the project was 2.4 times that of single stage distillation. Temperature reduction in every subsequent stage was designed to 25-degree centigrade. The heat of condensation in the last step was dissipated in a solar dryer to enhance its performance. The system has high inherent in food processing industry for applications of juice thickening, sauces, jams, salt gathering systems and distilled water applications. Results of the project are very encouraging.A. Munir et. al [2009] introduced the innovative arrangement of solar renewable power and environmental technologies in the area of farm engineering and food processing by producing a solar distillation system for essential oil extraction from herbs. The development of decentralized agro-based industries on using innovative solar reflectors can start new monuments into rural development particularly within tropical countries. Essential oils extraction of herbs through distillation method is one of the medium temperature agro-based industries. These oils are utilized in food, medicines, fragrances, perfumery and cosmetics. All kinds of herbs were processed successfully by using solar distillation system.Christoph Müller et. al [2009] shows that bakery oven is designed for an 8 m² Scheffler reflector. The latitude of the place is 22° south. Beside a resulting focus elevation of 78 cm, the oven was put on a base of 40 cm, giving a suitable way to the baking case. The baking case measures 60 x 60 x 60 cm³. The oven operates without sufficient ventilation. The temperature held inside the oven increases up to 360°. It was resolved that through the use of the solar community ovens a large reduction in fuel is achieved.Gregor Schapers [2009] revealed agave syrup generation using the Scheffler reflector. The six Scheffler reflectors of 10 m2 are situated outdoor, and they woman can cook inside the kitchen. The solar agave syrup is lighter than the syrup prepared with gas which is darkened because more sugar is caramelized. The taste of the sun agave syrup is sweeter and can be utilized for cooking and sweating without replacing the original taste of the food. So the new solar-agave-syrup is a new product with new properties, and a better quality and cost of the product is lowered.A. Munir et al. [2010] described the design principle and construction details of an 8 m2 surface area Scheffler reflector. The mathematical computations to design the reflector parabola curve and elliptical reflector structure about Equinox by selecting a particular lateral part of a paraboloid are listed. Simple tracking mechanism is used for daily and seasonal monitoring of sun. The design system is simple, flexible and does not need any particular computational setup, thus offering a tremendous potential for application in domestic as well as industrial configurations.A. Munir and O. Hensel [2010] developed an on-farm solar distillation system for working, environmental and financial analyses. A Scheffler fixed focus reflector is used for the solar distillation system. The system comprises a primary reflector (8 m2 area), secondary reflector, distillation still, condenser and Florentine flasks. The average power including efficiency of the solar distillation system was determined to be 1.548 kW and 33.21% sequentially. Various medicinal and aromatic plants like Rosemary, Melissa, Peppermint, Cloves and, Cumin, etc. were prepared successfully by utilizing the solar distillation system, and their process curves were drawn. Rupesh J. Patil et. al [2011] examined the performance of Scheffler reflector of 8 m2 including the aid of single large diameter drum of 20-litre capacity which helps the double purpose of absorber tube and storage tank. Average power and efficiency examined the performance of Scheffler reflector regarding boiling test conducted at Bangalore. The maximum temperature attained by water is 98 °C on the clear sunny day, and ambient temperature varying from 28 °C to 31 °C. Dimensional analysis and mathematical modelling was done to correlate dependent and

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independent variables.A. Munir and O. Hensel [2014] designed, developed and find experimental outcomes of a solar distillery for the extraction of the essential oils from medicinal and aromatic plants. The study was initiated to generate an on-farm solar distillation system for working, environmental and economic reasons. A Scheffler fixed focus reflector is used for the solar distillation system. The system comprises a primary reflector (8 m2 area), secondary reflector, distillation still, condenser and Florentine flasks. The average power and efficiency of the solar distillation system were found to be 1.548 kW and 33.21% respectively. Different medicinal and aromatic plants like Cloves, Peppermint, Rosemary, Cumin, and Melissa, were processed successfully by using the solar distillation system.Vishal R. Dafle et. al [2015] designed, developed and analyzed experimentally the performance of 16 m^2 Scheffler reflectors for 2 bar pressure and 110 °C temperature. The system was intended for the hostel with 500 students at Shivaji University for warm water for bathing and steam for cooking. Scheffler reflector along with mild steel absorber plate was settled in February. It was seen that radiation varies from 620 W/m2 to 937 W/m^2 and maximum temperature achieved by steam is 107 °C. It was resolved that performance of devices using Scheffler technology for water heating and low pressure, temperature steam purposes in industries as textiles, dairies, food industry, etc.

Many researchers have used different design setups for the production of hot water, steam and cooking food with the help of Scheffler reflector. But no research has been reported on production of steam based on Scheffler reflector for coffee making. The objective of this paper is to make solar coffee maker based on Scheffler reflector in Indian climate conditions.

II EXPERIMENTAL SETUP

The experiment has been performed for coffee making by Scheffler reflector. The experiment for coffee making has been conducted at NIT Kurukshetra, India (29°58' North and 76°53' East). The schematic diagram of the experimental setup has been shown in the figure 1.

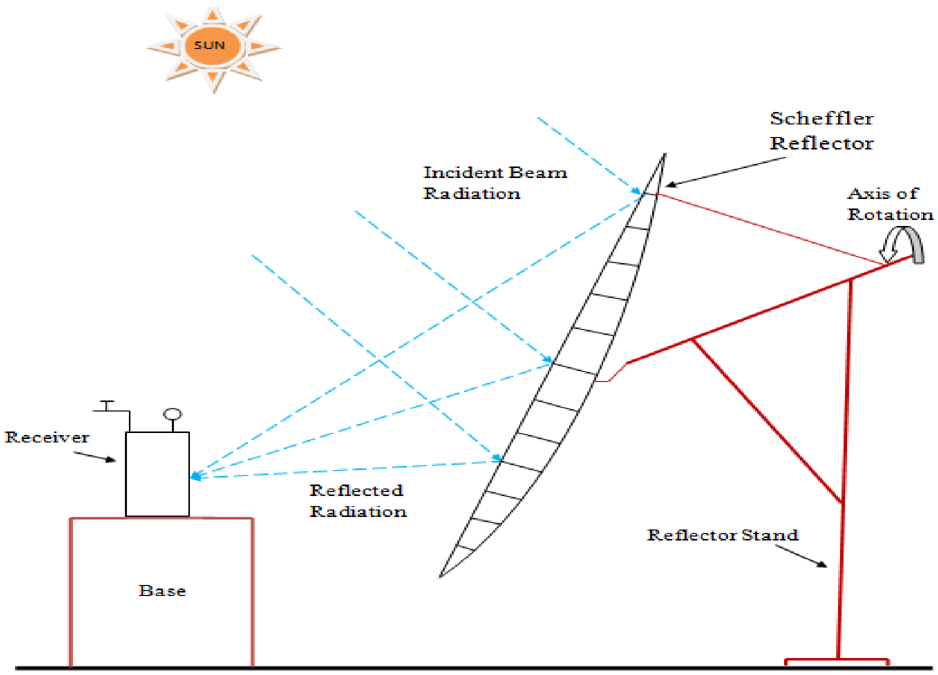

Figure1: Schematic diagram of experimental setup

The experimental setup consists of the following three parts:

i. Scheffler reflector

ii. Receiver

iii. Coffee container

i. Scheffler Reflector

The Scheffler reflector as shown in figure 2 refers to a point focusing device which concentrates the solar radiations to a receiver. The Scheffler reflector of 1.54 m^2 is used for coffee making. The tracking of the Scheffler reflector is done manually after every 10 minutes. Instead of mirror, anodized aluminium sheets are used as a reflecting material.

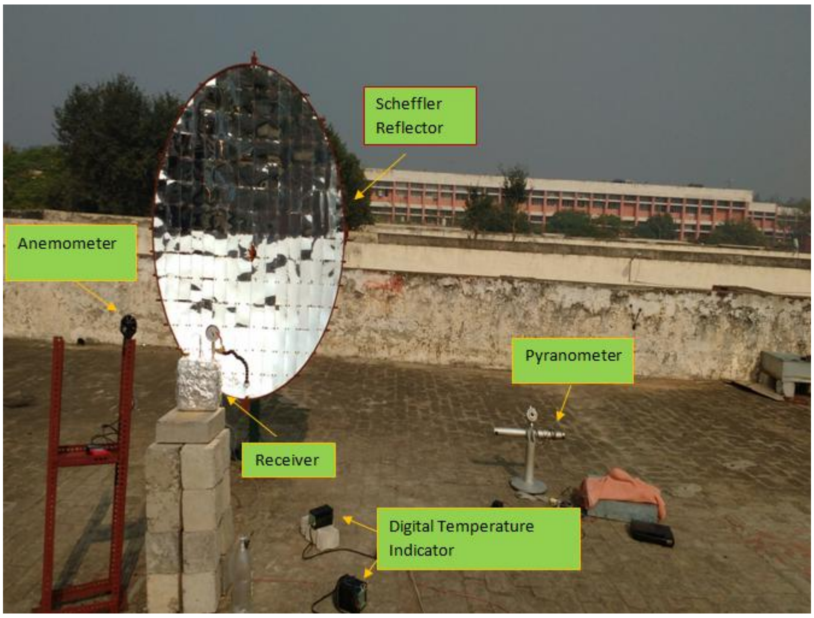

Figure2: Photographic view of experimental setup

ii. Receiver

The receiver of area 0.030 m^2 is used for heating the water. The receiver is made up of stainless steel for steam production. The figure 3 shows the photographic view of the receiver.

Figure 3: Photographic View of Receiver

iii. Coffee container

A coffee mixed with milk is contained in the container. A thermocouple is also used to measure the temperature of the coffee. The outlet steam pipe is inserted into the container.

III MEASURING DEVICES AND INSTRUMENTS

Surface temperature of receiver, steam temperature and coffee temperature was measured with PT100 type thermocouple connected with a digital temperature indicator that show the temperature with a resolution of 0.1°C.

The solar radiation intensity was measured during the coffee making process using a Pyranometer model CM11 (Kipp and Zonen, Holland).

The wind velocity is measured by Anemometer with an accuracy of ±0.1m/s.

A pressure gauge of 2 bar is used for measuring pressure inside the receiver.

IV SYSTEM OPERATION

The main objective of this experimental setup is coffee making. In this experimental setup, Scheffler reflector is connected with receiver (focus of Scheffler reflector). During sunshine hours solar radiations which are falling on the Scheffler reflector, concentrated on receiver. The focus of the receiver is fixed because sun is tracked manually. This concentrated solar radiation at the focus produce very high temperature and this energy is transferred to the receiver which contains water. 2 litre of mineral water is used in the receiver for heating by Scheffler reflector. The water is heated and when the temperature of water is reached at 100°C, the steam formation started. When the pressure inside the receiver is reached at 2 bar, then the steam is released into the coffee container. All the performance parameters such as solar radiation, surface temperature and weight of the sample are measured with measuring instruments with an interval of one hour. 500 ml of coffee mixed with milk is used for coffee making. The steam is directly condensed in the coffee container and temperature of coffee is increased. When the temperature of coffee is achieved in the range of 90-95°C, then the system is stopped. After that the heated coffee is used for drinking purposes.

V EXPERIMENTAL RESULTS AND DISCUSSIONS

In this experimental investigation, the main concern was on the coffee making by the Scheffler reflector and the coffee temperature was remained in the range of 90-95°C. The experimental data were collected in clear sky days in December 2016.

5.1 Variation of solar intensity and surface temperature

The experiment was conducted on December 21, 2016. Figure 4 shows the variation of surface temperature and solar intensity during the experimental day. The solar intensity was in the range of 500-725 W/m^2. The maximum surface temperature of receiver was 108°C. During starting of experiment solar intensity was 500 W/m^2 and when it start increasing, the surface temperature was also increased.

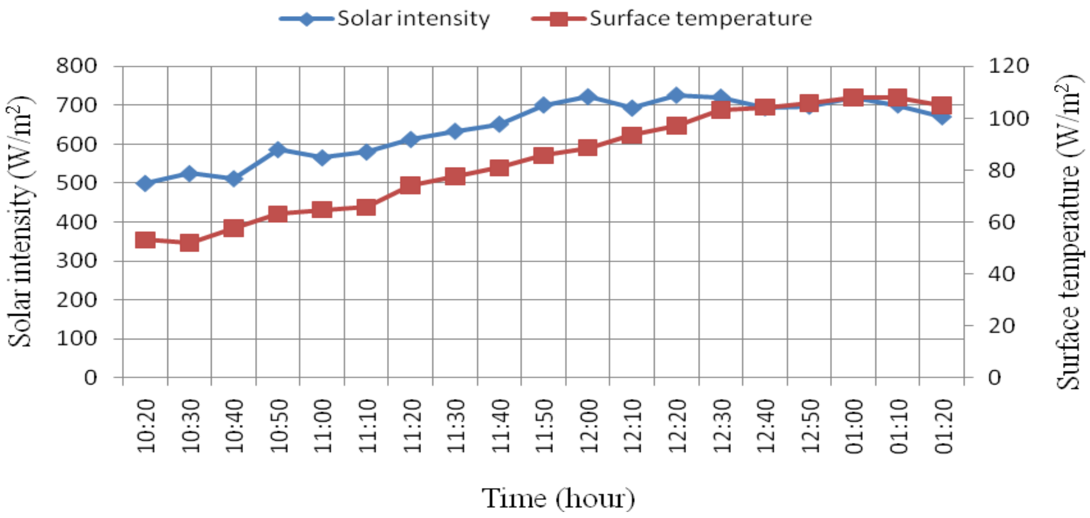

Figure 4: Variation of solar intensity and surface temperature with time

5.2 Variation of air velocity and surface temperature

Figure 5 shows the variation of air velocity and surface temperature with the time during the experimentation on December 21, 2016. The air velocity was in the range of 0.4-1.1. There is less impact of air on the surface temperature during the experimentation.

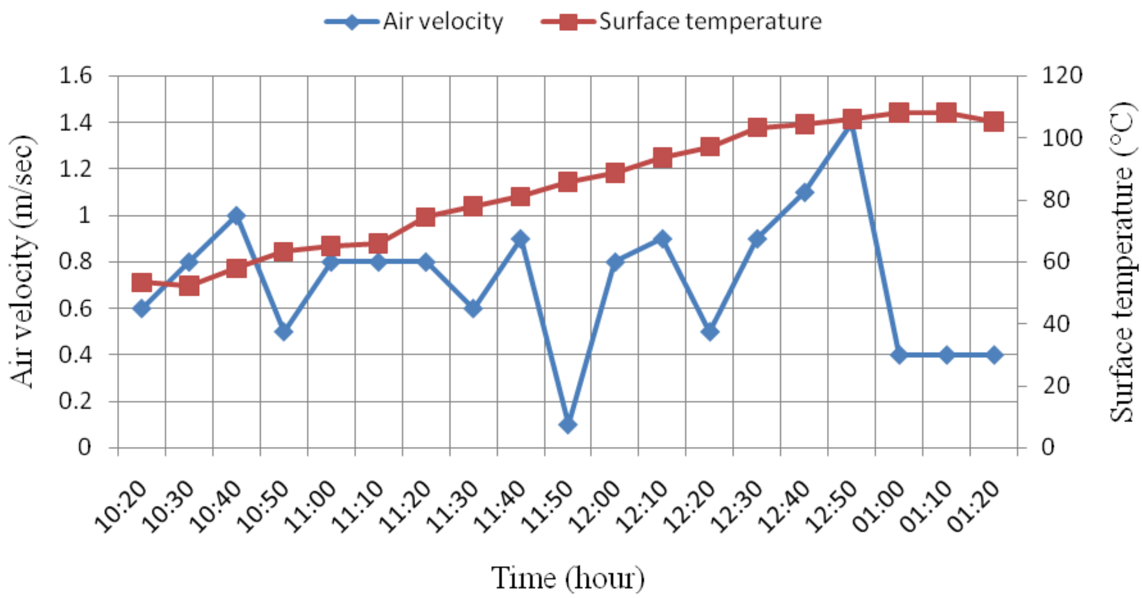

Figure 5: Variation of air velocity and surface temperature with time

5.3 Variation of surface temperature and water/steam temperature

Figure 6 shows the variation of surface temperature and water/steam temperature of receiver with the time during the experimentation on December 21, 2016. As the surface temperature was increased then the water temperature inside the receiver was increased. The surface temperature directly affects the temperature inside the receiver.

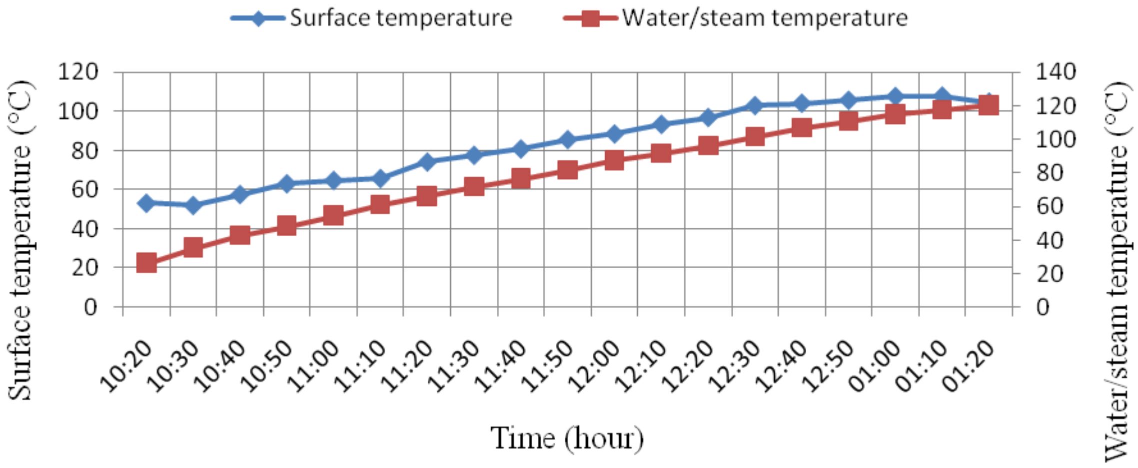

Figure 6: Variation of surface temperature and water/steam temperature with time

5.4 Variation of water/steam temperature and pressure

Figure 6 shows the variation of water/steam temperature and pressure of receiver with the time during the experimentation on December 21, 2016. The temperature rise inside the receiver causes the increase in the pressure also. When the temperature inside the receiver increased above 100°C then the steam formation started. The maximum pressure inside the receiver was 2.068 bar.

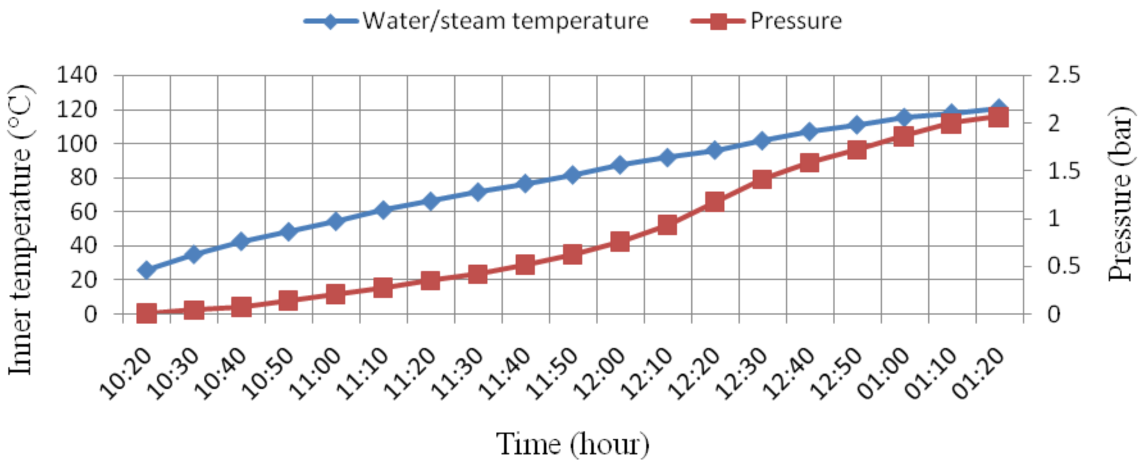

Figure 7: Variation of inner temperature and pressure with time

VI CONCLUSIONS

The main objective of the present research work was to explore the feasibility of coffee making based on Scheffler reflector in north region of India, as an alternative approach to the conventional method of coffee making. On clear sunny day the maximum temperatures of receiver surface achieved with average solar radiations of 642 W/m^2 were 108°C. The temperature of coffee mixed with milk in coffee container was increased from 18.9°C to 95°C. It concluded from the experimental investigation that, the coffee making can be done by Scheffler reflector without use of any high grade energy.In 3hr of duration the system was able to produce steam at pressure of 2 bar having overall system efficiency of 25%.

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