Study of Secondary Reflector Using two different Reflective Materials in Scheffler Reflector

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Abstract—*This paper presents a study of secondary reflector of scheffler reflector using different reflective materials. In the experimental system the solar radiations after reflecting from the scheffler reflector are directed towards secondary reflector placed in the receiver. The profile and arrangement of Secondary reflector is such that it reflects the radiations upward towards the bottom of a vessel containing water. Three different types of reflecting material for secondary reflector studied are galvanized iron sheets wrapped with aluminium foil and reflecting mirror. It was found that the temperature of water in case of Galvanized iron sheets wrapped with aluminium foil, highly reflecting aluminium sheet and reflecting mirrorreached 82 ^{0}C and 100 ^{0}C respectively in just one hour.*

Keywords*: Thermal Performance, Scheffler Reflector, Secondary Reflector, Receiver.*

1. INTRODUCTION

In the last decades, the increasing energy crisis in developing countries and climate change hazards has created awareness to promote the renewable energy technologies. A number of studies have been done on different types of solar collector and solar reflectors. Beyond the low temperature applications, there are several fields of application of solar thermal energy at a medium and medium–high temperature level. From a number ofstudies on industrial heat demand, several industrialsectors have been identi fied with favourable conditions forthe application of solar energy.

Few researchers have worked on scheffler reflector of different size for different application but no study has been done on secondary reflector.The objective of this paper is to study the thermal performance of secondary reflector of scheffler reflector using different types of reflecting materials. The experimental setup is installed at NITKurukshetra, India (29° 58´ (latitude) North and 76° 53´ (longitude) East).

2. EXPERIMENTAL SETUP

The experiment is performed to investigate the thermal performance of secondary reflector of scheffler reflector using different types of reflecting materials. The experimental setup consists of scheffler reflector, receiver, secondary reflector, vessel as shown in Fig. 1. The experimental setup consists of following components:

- Scheffler Reflector
- Receiver
- Secondary Reflector
- Vessel

2.1 Scheffler reflector

The reflector is a small lateral section of a much larger paraboloid. The inclined cut produces the typical elliptical shape of the Scheffler reflector. The sunlight that falls onto this section of the paraboloid is reflected sideways to the focus located at some distance of the reflector. The focus is located on the axis of rotation to prevent it from moving when the rotates. The tracking of the scheffler is done by the cal clock which continuously rotates the scheffler and thus tracks the sun. Specifications of the scheffler reflector are shown in Table 1.

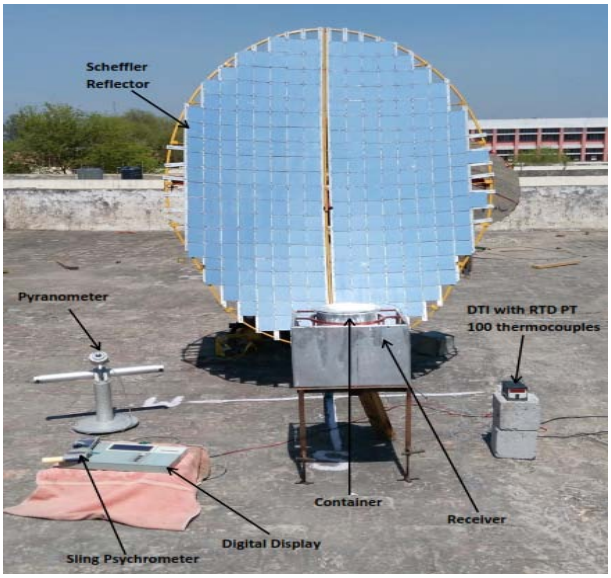

Fig. 1: Experimental Setup

2.2 Reciever

The receiver is of dimensions 410mm*380mm*280mm (Fig. 2). The receiver is covered by aluminium sheet from all sides except front, top and bottom. The secondary reflector is placed inside receiver such that all the light falling on it is reflected upwards. The opening at top ofreceiver is of270 mm diameter. The container is placedinside it.

Table 1: Specifications of the scheffler reflector

Major axis	2.2 m
Minor axis	1.6 m
Focal length of reflector	2.45 m
Aperture area of reflector	2.7 m2
Concentration ratio of reflector	135

Fig. 2: Photograph of receiver

2.3 Secondary reflector

Secondary reflector is placed inside the receiver (Fig. 4). The rays coming after reflecting from scheffler reflector falls on the secondary reflector. The profile of Secondary reflector is such that all the rays falling on it are reflected upwards i.e. at the bottom of container. In this paper three secondary reflector with different reflecting materials are studied. The three different reflecting materials are as follows (Fig. 3):

- Galvanized iron sheets wrapped with aluminium foil.
- Reflecting mirror

(a)

(b)

Fig. 3: Secondary reflector with (a) Galvanized iron sheets wrapped withaluminium foil(b) Reflecting mirror

Fig. 4: Secondary reflector placed inside receiver

2.4 Container

A container of aluminium is used to heat water of 1500 ml (Fig. 5).

Fig. 5: Photograph of container

3. MEASURING DEVICES AND INSTRUMENTS

Different parameters are measured, these are:

- Water, vessel bottom and surface of secondary reflecting material temperature

- Ambient temperature
- Solar radiation intensity

The temperatures are measured with RTD PT100 thermocouples which are connected with a digital temperature indicator that shows the temperature with a reso 0.1℃.

Dry bulb temperature of ambient air is measured with Sling Psychrometer.

The solar radiation intensity is measured during the day time with a Pyranometer-model CM11, supplied by Kipp and Zonen, Holland.

The experimental data is recorded at an interval of 10 minutes. The experiments were carried out in mostly clear sky days in the month of March 2015.

4. SYSTEM OPERATION

The main objective of this experimental setup is to study the thermal performance of secondary reflector using different types of reflecting materials. In the experimental setup, three different types of secondary reflecting materials were used to heat 1.5 litre quantity of water. Container is placed in the receiver and the system is exposed to solar radiation. Solar radiations after reflecting from scheffler reflector and the secondary reflector are made to concentrate at the bottom of container.

5. EXPERIMENTAL RESULTS AND DISCUSSION

In the experimental setup, cooking was conducted in the daytime as well as in the evening time at different cooking loads using a novel design of solar cooker with dual thermal storage unit based on the parabolic dish type collector. The performance of secondary reflector using different types of reflecting materials was studied at NIT Kurukshetra, India. The experiments were conducted during the month of March 2014. Every day, solar collector was exposed to solar radiation at 11:30 hr and readings were taken from 11:30 hr at an every interval of 10 minutes upto 12:30 hr. Three different cases were studied with different secondary reflector with reflecting material with

- Galvanized iron sheets wrapped with aluminium foil as secondary reflector
- Mirrors as secondary reflector.

5.1 Galvanized iron sheets wrapped with aluminium foil as secondary reflector

During the day, the maximum intensity was 934W/m^2 at 12:30 and the ambient temperature was in the range of 27°C to 28°C. The Fig. 6 shows that the temperature of vessel bottom reached to 158 ℃ while the temperature of water rises to 82 ℃ in one hour.

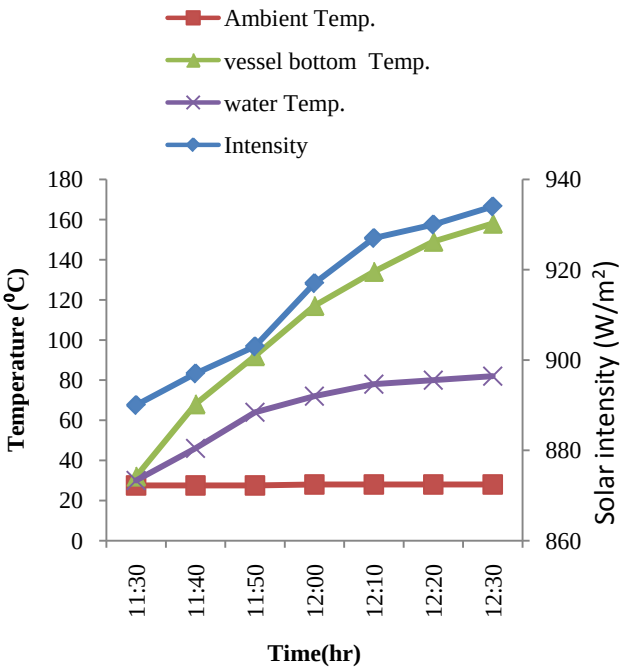

Fig. 6: Variation of temperature and solar radiation intensity with time in case of Galvanized iron sheets wrapped with aluminium foil as secondary reflector

5.2 Reflecting Mirrors as secondary reflector

On this day the temperature was in the range of 28℃ to 29 ℃ and average solar intensity was 907 W/m^2. The Fig. 7shows that the temperature of vessel bottom crossed 200 ℃ in 20 minutes. And the temperature of water reached its boiling temperature in one hour.

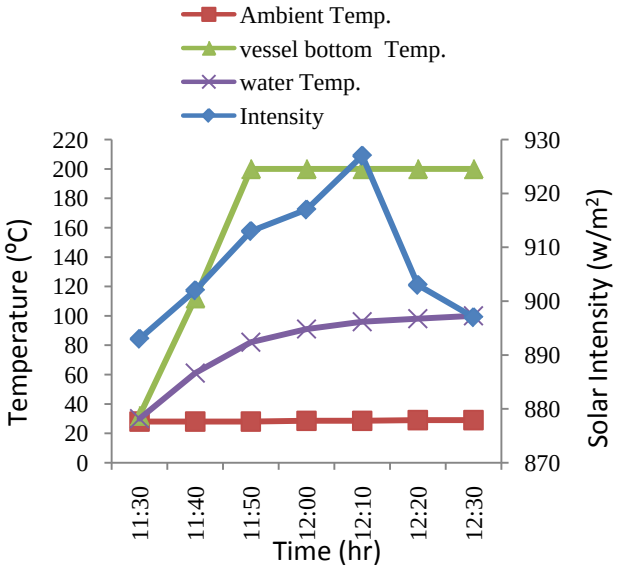

Fig. 7: Variation of temperature and solar radiation intensity with time in case of Mirrors as secondary reflector

6. THERMAL ANALYSIS

The system is exposed to solar radiation from 11:30 hr to 12:30 hr. Solar radiations after reflecting from scheffler reflector and the secondary reflector are made to concentrate at the bottom of container.

The solar radiations received at the aperture area (see table 1) of the scheffler reflector is calculated by the formula:

$$I_R = I \times A_a$$

In the above equation average solar intensity during charging time is taken.

The radiations after falling on scheffler reflector are reflected towards the secondary reflector. Highly reflective mirrors with reflectivity of 95% are used. The solar radiation reflected by the scheffler reflector is given as:

$$I_{RR} = I_R \times \rho_R$$

The radiations after reflecting from scheffler reflector are received at the secondary reflector. But, there are some losses of radiations as few radiations could not reach the secondary reflector. In this case, there are approximately 20% of radiations losses. The system has radiation receiving factor of 0.8. Radiations received at the secondary reflector:

$$I_{SR} = I_{RR} \times RRF$$

The radiations after falling on secondary reflector are reflected upwards towards the container. Two different secondary reflectors with reflecting material Galvanized iron sheets wrapped with aluminium foil and mirrors are used. The solar radiation reflected by the secondary reflector is given as:

$$I_{RSR} = I_{SR} \times \rho_{SR}$$

The container is made up of aluminium material of absorptivity 75%. Radiations absorbed by container:

$I_{abs} = I_{RSR} \times \alpha_{cont.}$
Efficiency of scheffler reflector system:

$$\eta_{system} = \frac{Q_{output}}{Q_{input}}$$

Where, $Q_{output} = I_{abs}$ $Q_{input} = I_R$

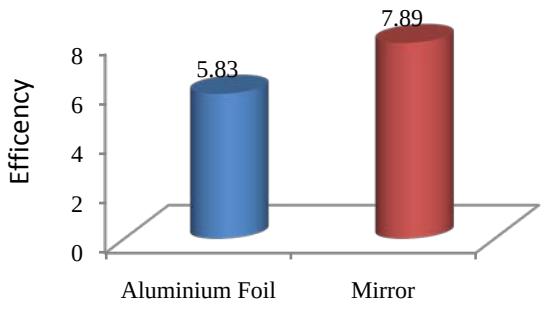

Fig. 8: Efficiency of the receiver for different cases

7. CONCLUSION

It was found that within a short period of half hour the temperature of water reaches 75 ºC.The temperature of water after one hour is 82ºCand 100ºC for case1 and case 2 respectively. It was also observed the temperature of bottom of vessel crossed 200ºC in just short span of 20-30 minutes.The large difference between the temperature of bottom of vessel and the water shows that there is heat loss. So there scope for improvement in receiver to prevent heat loss.

8. NOMENCLATURE

A_a Aperture area of scheffler reflector

A_{abs} Absorber area of scheffler reflector

C Geometric concentration ratio

I_R Solar radiations received at scheffler reflector

I Average solar radiation Intensity

I_{RR} Solar radiations reflected by scheffler reflector

ρ_R Reflectivity of scheffler reflector

I_{SR} Solar radiations received at secondary reflector

RRF Radiation receiving factor

I_{RSR} Solar radiations reflected by secondary reflector

ρ_{SR} Reflectivity of secondary reflector

I_{abs} Solar radiations absorbed by container

$\alpha_{Cont.}$ Absorptivity of material of solar cooker

η_{system} Efficiency of the system

Q_{output} Energy output from the system

Q_{input} Energy input in the system

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