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Role of reflector material in performance of compound parabolic concentrator

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ABSTRACT : *The reflector of a compound parabolic concentrator (CPC) play an important role in the solar thermal system. The solar reflector is continuously exposed to environmental conditions, result in the reflectance losses and structural degradation. The research has been done to give real-life time estimation at an affordable cost. The main focus has given towards the optical efficiency and temperature variation on receiver obtained from the different reflective material. At the initial stage reflectivity of the mirror material is more as compare to anodized aluminum sheets. After some months optical efficiency of mirror material decreases due to atmospheric condition whereas anodized aluminum it decreases slightly. The temperature variation obtained on receiver tube surface is compare when mirror reflector and anodized aluminum reflector are used.*
Keywords – *Aperture area, CPC, Receiver area, Reflectivity.*

I. INTRODUCTION

Solar energy is a non-exhaustible form of energy which used for many applications from industrial hot water supply to power generation. The solar thermal collectors are classified by United States energy information administrators as low, medium and high-temperature collectors. The commonly used solar thermal technologies are compound parabolic concentrator (CPC), parabolic trough collector and Scheffler dish. Compound parabolic concentrators are able to produce high temperature with high thermal efficiency. The parabolic trough collector is one of the mature solar thermal systems the reason behind it covers 90% of total CSP [1].

Compound parabolic concentrator (CPC) design in such way that parabola curve reflects all incident sunlight on to a focal point, and thus the concentration of solar energy can be maximized. It is a versatile solar collector due to the number of applications and geometries that can be used. The Reflector is made by small mirror strips into parabolic shape and an evacuated tube is located in the central focus line of a parabola. To heat the working fluid, a reflection of the solar radiation from parabolic concentrators is to be focused at the evacuated tube. One of the major issues with solar mirror reflectors of a compound parabolic concentrator is it permanently exposed to humidity, dust, wind and high radiation fluxes that cause stress and decrement of physical properties. Mirror reflective materials can lose reflectance due to high temperature, ultraviolet wavelengths and insufficient cooling of mirror surface [2]. Reflectivity is an optical property of a material, which describes how much light is reflected from the material in relation to an amount of light incident on the material. Reflectivity depends on the wavelength of light, the direction of an incident and reflected light, polarization of light, type of the material (metal, plastic, etc) chemical composition and structure of the material, and state of the material and its surface (temperature, surface roughness, degree of oxidation and contamination). The optical properties of solar energy materials are essential for their function.

Cost effective compound parabolic concentrator (CPC) for various industrial, agricultural and residential applications were designed which has average efficiency 25.7%. [3]. Stainless steel sheets are used as the reflective surface to compromise between cost and efficiency. The results reveal a robust design of the dish concentrator [4]. Aluminum reflector material gives the maximum efficiency with a view angle of 450 as compared with stainless steel reflector (SSR) [5].

Compound Parabolic Collector (CPC) system is designed, fabricated and installed for turmeric processing at SGGSIE&T to fulfill the demand of researchers working in the area. In the current system, mirror strips are used as reflecting material. A reflectivity of mirror material decreases due to atmospheric conditions; hence Mirror reflector results in less life. In this study, a parabolic trough collector is investigated with different reflecting material in order to analyze performance evaluation. The observing phenomena including solar beam radiation, Theoretical maximum optical efficiency, temperature variations on receiver surface are compared under mirror reflecting surface and anodized aluminum reflecting sheet (MIRO-SUN).

Nomenclature and units

A	Area, m^2
G_b	Solar beam radiation, W/m^2
L	Tube length, m
T	Temperature, ℃
W	Width, m

Greek symbols

η	Efficiency
ρ	Reflectance
τ	Transmittance
α	Absorptivity

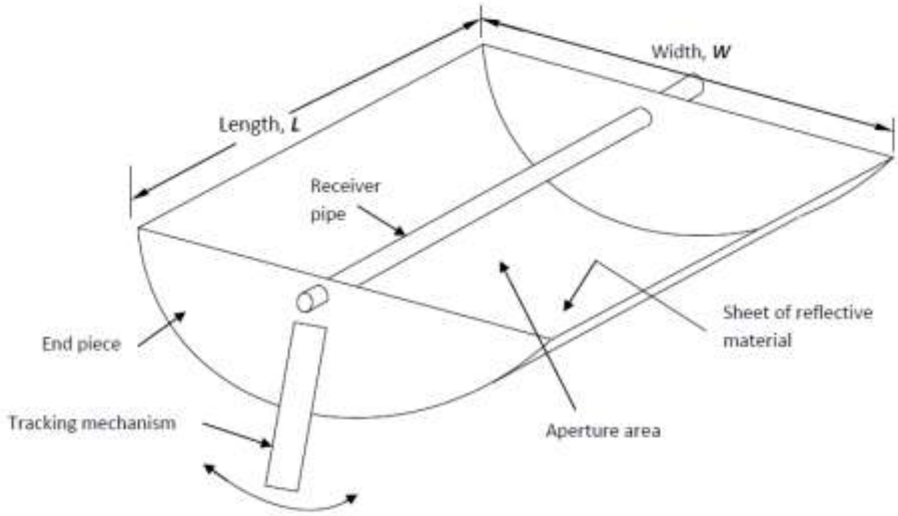

Fig.1. Schematic view of compound parabolic concentrator

II. EXPERIMENTAL SET UP

Experiments were conducted at SGGSIE&T Nanded in a solar lab (19°06'41.2"N 77°17'40.6"E). A single unit of the CPC system is considered for the experimentation. Mirror and anodized aluminum reflectors are used during the experimentation. Mild steel receiver with evacuated tube cover is positioned at the focal line of the reflector. The experimental setup is shown in Figure 2 and Figure 3.

Before beginning the experiments irradiance meter with temperature data logger verified and calibrated according to solar standards. A surface temperature of the receiver, ambient temperature, and solar intensity recorded using data logger (Seaward solar survey 200R series). Data were recorded first seven days using mirror reflector material and then mirror reflectors are replaced by anodized aluminum reflector and data recorded for seven days.

Table 1 Dimension of Compound parabolic concentrator

Dimension	Value
CPC width, W	2 m
CPC Tube length, L	3 m
Surface area, A	7.90 m^2
Outer diameter of MS pipe	50 mm
Absorber Tube outer diameter, D_o	70 mm
Absorber Tube inner diameter, D_i	68 mm

Fig.2. CPC with mirror as reflector material (Image)

Fig.3. CPC with anodized aluminum (MIRO-SUN) as reflector material (Image)

III. RESULT AND DISCUSSION

The experimental data recorded from 29 to 31 January 2018 for mirror reflector material and from 9 to 12 February 2018 for anodized aluminum (MIRO-SUN) reflector material. Radiation intensity, ambient temperature and temperature variation of the receiver surface recorded for above two reflector material, between 11 to 13 hours of each day. Three days average intensity variation with daytime during experimentation of mirror and anodized aluminum (MIRO-SUN) reflector material is shown in figure 4. The below graph shows the radiation intensity increases from 11 AM to 13.

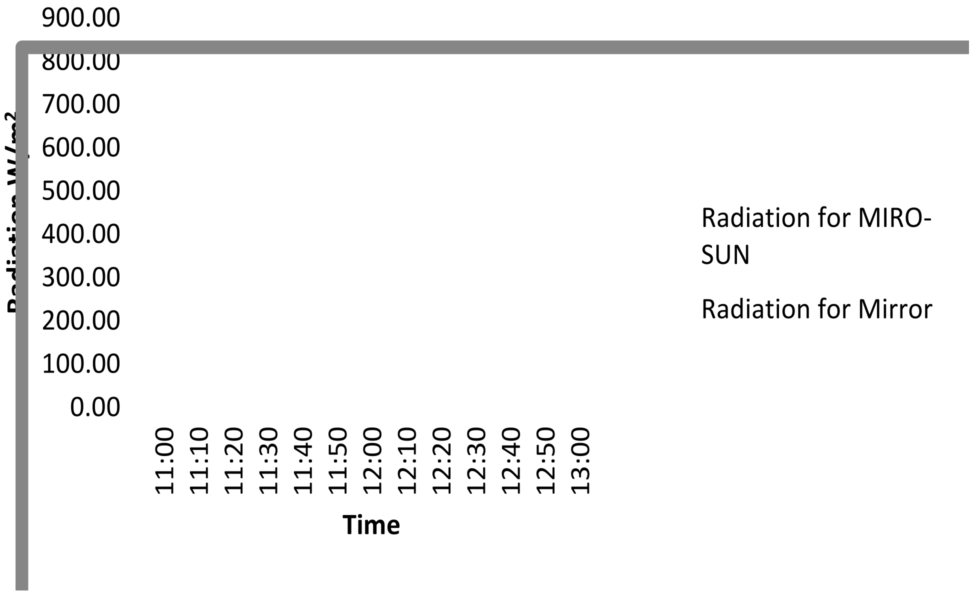

Fig.4. Average Radiation intensity variations during experimentation

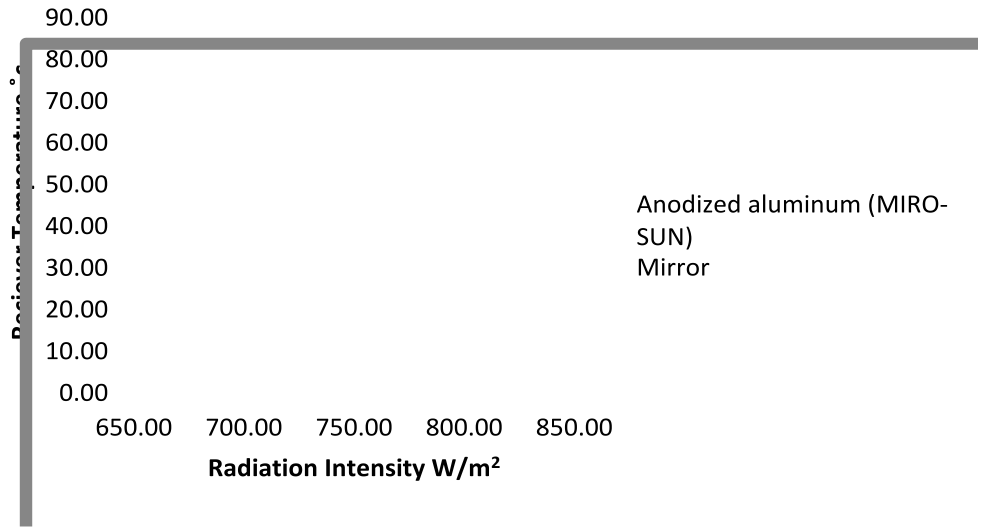

Fig.5. Comparison of temperature variation

From the result, it found that temperature at receiver surface is more when anodized aluminum (MIRO-SUN) reflector as compares to mirror reflector. The efficiency of CPC system is increased due to increase in temperature. Surface temperatures of a receiver with respect to radiation intensity are presented in figure 5. It was observed that receiver surface temperature of anodized aluminum (MIRO-SUN) is higher than mirror reflector material. When radiation intensity was 775 w/m2 the surface temperature in case of mirror reflector found to be 58˚C and for anodized aluminum (MIRO-SUN) 68˚C.

IV CONCLUSION

Effect of the reflector material on receiver temperature in the compound parabolic system presented. Effect of two different reflector materials discussed and it has been found that anodized aluminum (MIRO-SUN) reflector is better than the mirror reflector material. The result also shows time required to achieve the desired temperature is less in case of anodized aluminum (MIRO-SUN) as compare with mirror reflector. The CPC system can be work efficiently when the radiation intensity is less, due to its higher reflectivity and long life of anodized aluminum (MIRO-SUN).

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