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NOTES ON NATURAL HISTORY

Performance Evaluation of a Solar Parabolic trough Concentrator

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Study Area: Bhubaeshwar Odisha, India
Coordination: 20.27°N; 85.84°E

Key words: Thermistor module, rim angle, focal length

Introduction

Ending poverty and ensuring sustainability are the defining challenges in recent times. Energy has the answer to both. Access to modern energy services such as electricity, natural gas, modern cooking fuel, etc. is necessary for improved health and agricultural productivity (UNDP, 2001). In order to provide modern energy services to all, clean energy has the answer to both

Clean energy is defined as an energy source or form that when used does not produce negative externalities. Energy derived from sun, wind, water and waves is termed clean energy sources as they generate a very less amount of greenhouse gas.

Jamali (2009) reported the impact of mirror reflectance on the thermal efficiency of solar parabolic trough collector. The main objective of this paper is to use a high reflectance mirror and generally Aluminium and silver were taken as high reflectance mirrors. Alotaibi *et al.* (2020) investigated the performance of steam power plants integrated with a Parabolic Trough collector. The main objective is to remove the low-pressure turbine and to increase the power by 9.8 MW. Singh *et al.* (2012) designed a Parabolic Trough solar water heater which is made up of an Aluminium sheet on which mirror strips were attached for high reflectivity. By taking a focal length of 0.3 m and a manual tracking system the was calculated as 20.25%. Singh & Mishra (2018) has done an analysis of the Solar Parabolic trough collector with CO_2 and ORC cycle as a topping and bottoming cycle. Ahera *et al.* (2013) had done an experiment by taking black epoxy coated Aluminium receiver on PTC and efficiency increased to 52% with a glass cover receiver.

Nomenclature

w= width of the concentrator
d_r= diameter of receiver
CR_G=Geometrical concentrating ratio
CR_O=Optical concentrating ratio
θ_c=Acceptance half-angle of the receiver
θ_R=Rim angle of concentrator
f=Focus point
S=Absorbed solar radiation
$\tau\alpha$=Transmittance absorptance product for the beam radiation
Q_u=Useful heat gain
η_{coll}=Efficiency of collector

Design and mathematical modelling

Here we have calculated the rim angle, focus point, and efficiency of the collector by considering the present value of concentrating ratio. By taking the length of the concentrator as 2 m, a width of the collector = 500 mm, the focal length was calculated as 0.3125 m. The rim angle was taken as 45°.

$$CR_G = w - d_R/\pi d_R$$

$$CR_O = \frac{sin\phi_R}{\pi \sin \phi_C}$$

$$f = \frac{w^2}{16d} = \frac{0.5 \text{ X } 0.5}{16 \text{ X } 0.05} = 0.3125m$$

$$cos\phi_R = 2f/\sqrt{0.5w^2 + (d-f)^2} - 1$$

$$S = I_b R_b (\tau\alpha)_b \left(\rho\gamma + \frac{d_r}{w - d_r}\right)$$

$$(\tau\alpha)_b = \frac{\tau\alpha}{1 - (1-\alpha)\rho_d}$$

$$Q_u = F_R A_a [S - A_r U_L / A_a (t_f - t_a)]$$

$$\eta_{coll} = \frac{Q_u}{A_a \text{ X } H_b R_b} = \frac{M \text{ X } C \text{ X } (T_2 - T_1)}{A \text{ X } I}$$

where M= mass water taken=2 Litres= 4.2 4.2J/kg°C, I= solar intensity=1000W/m² A=area of collector= 2 m² By taking the above data the Instantaneous efficiency was calculated as 25%.

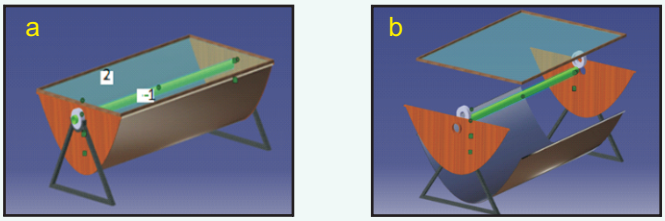

Plate-1:a,b shows the modelling of solar parabolic concentrators by CATIA design. 1. Reflector, 2. Receiver tube.

Design and methodology

The main component of the parabolic concentrator is Receiver and reflector with a magnifying glass. The entire collector body is made up of Aluminium material (3 mm, glazing type). The receiver is a tube-like structure having an internal tube made up of copper (diameter=0.05m), and an outer tube made up of glass (diameter=0.08 m). Numbers of magnifying glass strips were inserted into the reflector to

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increase the reflectance. The reflector will focus the incident solar radiation into the receiver. The inlet of the receiver tube was connected with a DC motor which is operated by a solar panel in order to receive continuous circulation of hot water inside the receiver tube. A manual tracking system was used to rotate the concentrator per sun's direction.

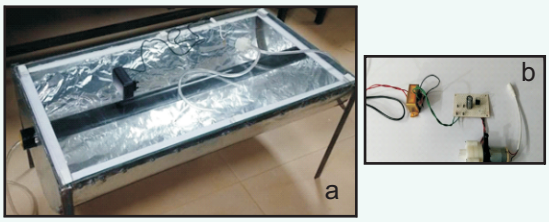

Plate-2: a) Experimental set- up of Parabolic Trough Concentrator, b) Connection of DC motor

The collector is placed in a shadow-free location for testing purposes starting from 9 AM to 4 PM. The main components are transparent glass plate (36 inches×18 inches), receiver tube made as black coated (PVC pipe, diameter as 2 inches), parabolic concentrator (3 feet length, 18 inches width), the diameter of a parabola as 9 inches, Thermostat module with temperature display, 12V DC motor for water supply and 22° as rim angle. A transparent glass plate transmits all the incident radiation into the concentrator. The concentrator is a parabolic shape and is made up of Aluminium and is coated with Aluminium foil. The focuses the incident radiation into the receiver tube. Inside the receiver tube, water is flowing and gets heated. A thermostat module is used to measure the temperature of heated water at a regular interval of time. The experimental set-up of the parabolic concentrator and connection of the DC motor is shown in Plate-2.

Result and discussion:

The test is conducted for three days and temperature is measured by using a thermistor module after one-hour regular interval of time. The temperature profile for three days has been shown in Fig.-1. It has been found that the maximum temperature is obtained as 76°C at 1 PM. The thermistor module is used for measuring temperature.

Conclusively, the PTC can be used for producing steam and cooking purposes which can eliminate the conventional method of cooking. The maximum

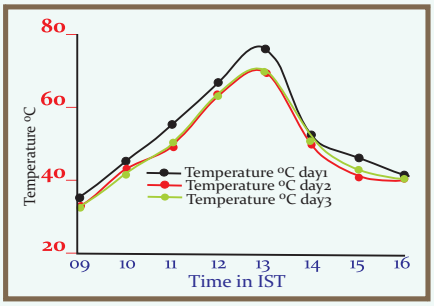

Figure-1: Temperature profile of solar parabolic trough collector

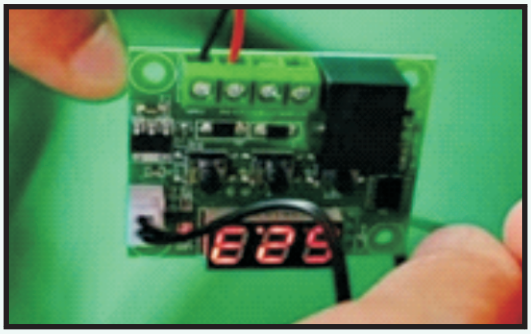

Plate-3: Temperature measuring Instrument as Thermistor module

temperature is achieved at 76°C. Further, the above work can be extended by taking Chrome vinyl as a reflecting surface and also by using a magnifying glass.

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