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PERFORMANCE ANALYSIS OF PARABOLIC TROUGH SOLAR COLLECTOR FOR THREE DIFFERENT FLOW RATES

Anil Kumar[1], Kanhaiya Saw[2], Shabbir Ali[3]

[1,2,3]*M.Tech student, Department of Mechanical, Indian School of Mines, Dhanbad (India)*

ABSTRACT

The influence of various parameters such as concentration ratio, optical efficiency and thermal efficiency on the performance of the trough solar collector was analyzed in this experimental work. Nowadays every country concerns about the environmental pollution and its effect but they need energy for the growth and development of their country. The conventional techniques especially where coal, fossil fuels and some kind of organic matter is used to get required amount of energy leads to a high amount of air pollution that is the main cause for global warming. The non-conventional way of producing energy is the better option as far as pollution is concern but it is not economical and this is the main reason to not to introduce this kind of non-conventional technique by the underdeveloped and developing nation. The geographical condition is also a major factor for such nonconventional source like solar energy, wind energy etc. In this study, analysis was done for the performance of solar trough collector and efficiencies were calculated.

Keywords: Concentration ratio, nonconventional energy, optical efficiency, solar collector, thermal efficiency

I. INTRODUCTION

The renewable source of energy became the necessity of the present age for every nation. As non renewable sources are limited and also cause pollutions that lead to global warming. Solar energy is widely accepted as a sustainable form of energy and due to that it attracted the maximum nation to implement this source in recent years [1]. India is the country where sunlight is present in abundant and can be utilised for generating solar power that may cost more initially but later with the developments of new techniques and increase in the performance of the devices will helps to use solar light for generating energy in a better and economical way. Solar energy is the best suited to the nation like India, where sunlight is available in abundance in summer season, but some states are there where availability of this source is the very high whole year especially the states like Tamilnadu, some regions of south and Rajasthan. Parabolic trough collector (PTC) is having various advantages such as in industrial steam generation [2] and hot water production [3]. There are nine large commercial scale solar power plants installed in USA [4-5] as it is most proven solar thermal electric technology in the world. Earlier researchers were also analyzed for the performance of parabolic trough solar collector.

Numerical analysis for the performance of modified evacuated tube solar collector was done by A. Padilha et al. [6]. Computational Study of Hybrid Water Heater with Evacuated Glass Tube Solar Collector and Rice Husk

Combustion was done by Piyanun Charoensawan et al. [7]. Gang Pei et al. [8] studied the performance of evacuated tube solar water heater systems and was compared with and without a mini-compound parabolic concentrating (CPC) reflector (C<1). Simulation of a solar power absorption system and dynamic modelling of an evacuated tube solar collector was done by J.P.Praene et al. [9]. Avadhesh Yadav et al. [10] studied experimentally on evacuated tube solar collector for heating of air in India. Performance characteristics of parabolic trough solar collector for heat generation were analyzed by A. Valan Arasu et al. [11]. Thermal analysis of parabolic trough solar collectors for electric power generation was done by S.D. Odeh et al. [12]. Conduction heat loss from a parabolic trough solar receiver with active vacuum was analyzed by direct simulation Monte Carlo technique by Matthew Roesle et al. [13]. A simplified methodology was developed for designing parabolic trough solar power plants by V. Padilla et al. [14]. Wind flow around a parabolic trough solar collector was analyzed by N. Naeeni et al. [15].

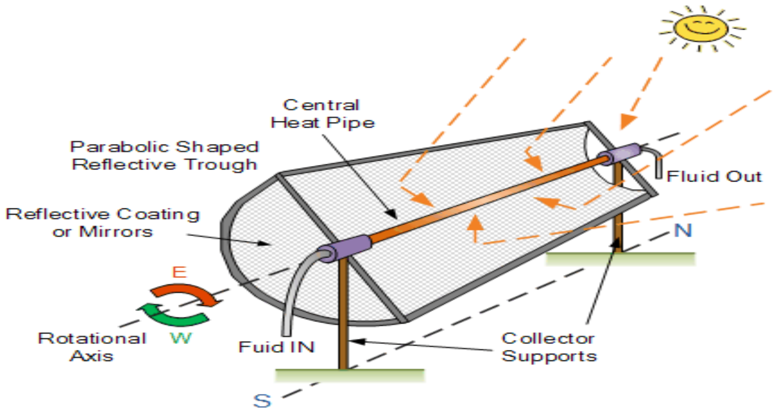

Fig. 1: Parabolic trough solar collector system

In the present study, a parabolic collector was designed and fabricated. The experiments were performed in the same instrument and measurements were recorded. The recorded data were calculated and analyzed for the optical efficiency and thermal efficiency.

II. EXPERIMENTAL SETUP

The design of parabolic trough collectors are structurally simpler than other types of but it requires continuous tracking so as to make sure that solar radiations are concentrated on the absorber tube throughout the day. The design of PTSC should be precise and the dimensions on x, y directions must be accurate to ensure the better optical efficiency of the system.

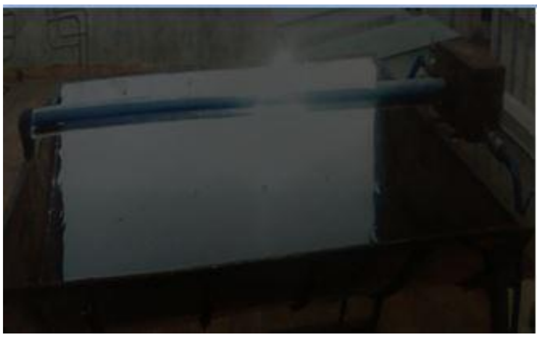

Fig. 2: Reflector with absorber tube

Fig. 3: Support structure for manual tracking

2.1 Design Parameters

The design parameter of a parabolic trough collector can be classified as geometric and functional. The geometric parameters of a PSTC are its aperture width and length, rim angle, focal length, diameter of the receiver, diameter of the glass envelope and the concentration ratio. The functional parameters of PSTC are optical efficiency, instantaneous and overall thermal efficiency and receiver thermal losses. These parameters are largely influenced by the absorptivity of the absorber. The errors are due to the defects in reflector material, support structure, location of the receiver with respect to the focal plane of PSTC and misalignment of PSTC with respect to the sun caused by the tracking errors.

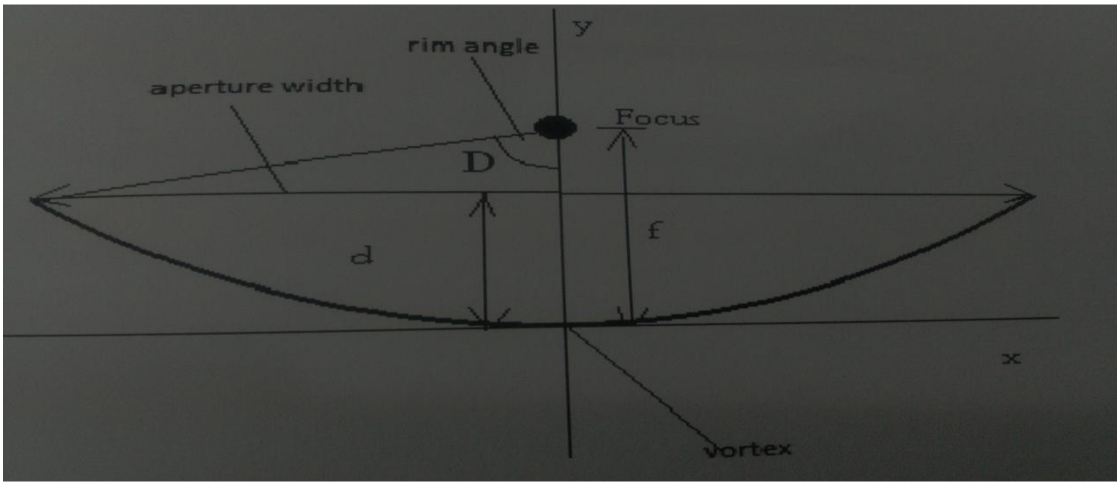

Fig. 2: Design specifications of parabolic reflector

Table 1: Specification of absorber tube

Reflective material	Stainless steel
Reflectivity of mirror	0.9
Absorber tube material	Glass with copper coating
Inside diameter of Copper tube	35mm
Outside diameter of copper tube	45.4mm

Table 2: Different parameters and their values for the fabricated PTSC

Parameter	Value
Collector aperture	1130mm
Collector length	1420mm
Aperture area	$1.54m^2$
Rim angle	90^o
Focal distance	100mm
Receiver diameter	35mm
Water flow rate	30KJ/hr
Tank material	Stainless steel
Tank insulation material	Glass wool
Water pump	25 W

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Formula used for performance testing of hot water generating PTSC

1) **Collector efficiency** $(\eta_{collector}) = \frac{Q_u}{A.I} = \frac{mC_p(T_0 - T_i)}{A.I}$;

Where, Q_u = Useful heat gain (KJ/hr)

A = Aperture area (m^2)

I = Solar Radiation Intensity (W/m^2)

m = Mass flow rate (Kg/hr)

Cp = Specific heat capacity of water (J/Kg-K)

T_i, T_0 = Outlet and inlet temperature of water (°C)

2) **Effective aperture area:** (W - D_{co}) × L;

Where, W = Width of the reflector

D_{co} = Outside diameter of glass cover tube

2.2 Specimen calculation

Flow rate of water = 42 Kg/hr

Area of collector = 1.54 m^2

Total heat available = (pyranometer reading × 60 × 4.186 ×10^4) / (pyranometer constant ×1000)

= (5.2 × 60 × 4.186 × $10^{4)}$ / (5.56 × 1000) = 2349.54 KJ/hr-m^2;

Heat available in collector = Total heat available × area of collector

= 2349.54 × 1.54

= 3618.29 KJ/hr

Heat gained by water = $m_w \times C_{pw} \times \Delta t$

= 42 × 4.187 × (40 - 30)

= 1758.12 KJ/hr

Efficiency = (Heat gained) / (Heat available) × 100 = 48.58%

III. RESULT AND DISCUSSION

The parabolic trough solar collector system is mainly used for the power production as the temperature of steam is very high. It is also used for water heating, air heating and other applications as well.

The PTSC technology can be very useful for the water heating applications if the cost of the system is reduced to some extent.

Fig. 1 shows the graph between solar intensity in KJ/hr-$m^2$and time in hours. The solar intensity was recorded at time period of 15 min. from 10:15hrs to 14:15hrs and the graph were plotted between them at various flow rate of 30Kg/hr, 42Kg/hr and 60Kg/hr. The solar intensity for different flow rate was measured.

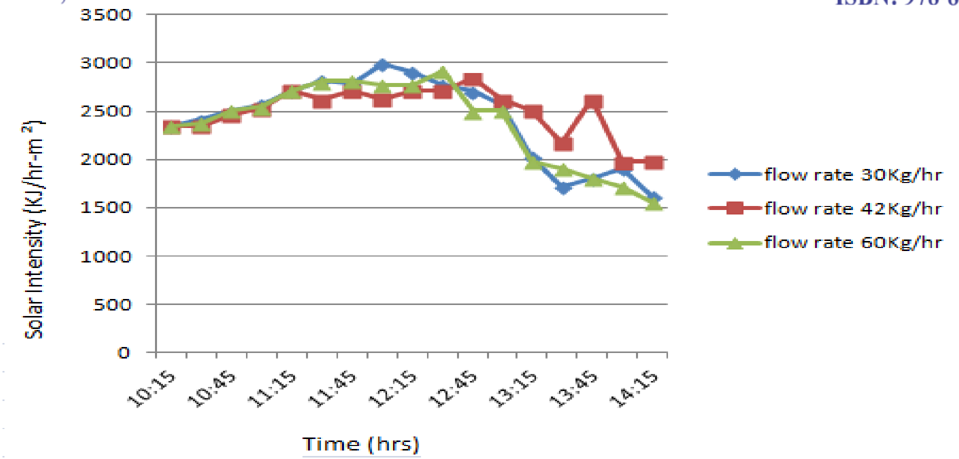

Fig. 3: Graph between Solar Intensity and Time

The fig. 4 shows the graph between collector efficiency in percentages and time in hours. The collector efficiency for different flow rate were calculated and the graph was plotted between them.

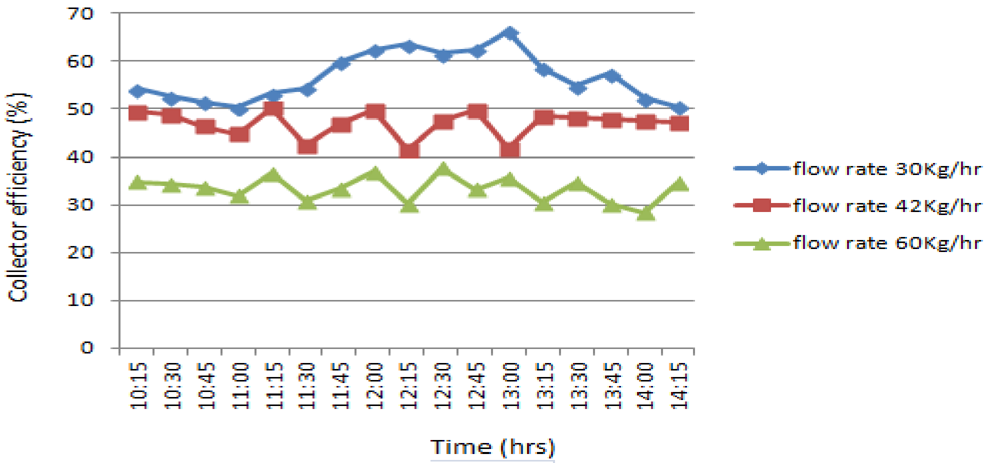

Fig. 4: Graph between collector efficiency and Time

In fig. 3 graph shows that as the time increases solar intensity also increases for certain time but later it decreases continuously. Graph plotted in fig. 4 shows that as time increases collector thermal efficiency also increases because of increase of solar intensity up to peak temperature but later as temperature decreases collector thermal efficiency also starts to decrease.

The calculation was done for total heat availability, heat available at collector, heat gained by water and thermal efficiency for the flow rate of 42Kg/hr and the values were found to be 2349.54KJ/hr-m^2, 3618.29KJ/hr, 1758.12KJ/hr and 48.58 respectively.

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