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EXPERIMENTAL INVESTIGATION OF DIFFERENT TRACKING MODES OF THE PARABOLIC TROUGH COLLECTOR

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ABSTRACT

A parabolic trough collector with different tracking modes was experimentally investigated. In this experimental setup, the reflected solar radiations were focused on receiver tube which is placed at focal length of the parabolic trough and the temperatures at the various positions of receiver tube are recorded. To enhance the performance of parabolic trough collector, three cases of tracking have been considered; one axis tracking facing southwards, one axis tracking along east-west direction and two axis tracking along east-west direction. It is observed that parabolic trough collector with two axis tracking along east-west direction performs better as compared to other cases. The attained maximum temperatures of receiver tube are found to be 139.5^{o}C, 184.4^{o}C and 162.4^{o}C at right-end, in the middle and left-end respectively.

Keywords: Thermal Performance Analysis, Parabolic Trough Collector, Absorber Tube, Tracking Modes

I. INTRODUCTION

Solar energy is a permanent, free of cost and non-polluting source of energy. It has started receiving importance in the recent past because conventional sources of energy are diminishing day by day. Non concentrating collectors were used for applications which need low temperature, whereas the concentrators are used instead of non concentrating collectors for achieving high temperatures. Also, they show higher efficiency as the receiver area available for heat losses is small. Therefore, parabolic type concentrator received considerable attention during the recent past years.

Seluck M. [1] investigated the thermal performance of the vacuum tube receivers with and without reflectors. Using vacuum tube with reflectors, the value of heat loss coefficient (U_L) was reduced. This was resulted in the increased incident flux on an absorber tube and increased its thermal performance. Rabl A. *et al*. [2] calculated the performance and optimized the design of parabolic trough solar collector. They optimized the different collector parameters like rim angle, concentration ratio and intercept factor. Prapas *et al*. [3] analyzed optical behavior of parabolic trough collectors, based on a ray-tracing technique. The effects on the collector performance were studied by varying angular distribution of the diffuse isolation, scattering of the direct isolation by a transparent aperture cover and the total optical error of the concentrating system. They concluded that the amount of diffused radiations collected were negligible for parabolic trough collectors with high concentration ratio (C.R.>10). Hamad [4] experimentally investigated the performance of a cylindrical parabolic trough collector with novel design of absorber with water as a working fluid. It was observed that there is no significant change in concentrator efficiency when the mass flow rate becomes more than 10 kg/hr. Thomas A. [5] experimentally studied the solar steam generation system that generated steam at a temperature of 150ºC. The average daily efficiency of the system was 33.5%. Kalogirou *et al.* [6] investigated the design and performance characteristics of a parabolic trough solar collector system. They optimized the aperture area, rim angle and receiver diameter of a parabolic trough collector. It was observed that, with a 90° rim angle, the mean focus to reflector distance and the reflected beam spread was minimized. Fend Thomas *et al.* [7] used highly reflective aluminum coil for solar concentrators. Experiments were conducted using standard commercial anodized aluminum sheet of different thickness. They found that highly specular aluminum had an excellent chance to meet the trough requirements. Brogren Maria *et al.* [8] used aluminum polymer laminated steel reflector and tested its optical properties, durability and reflector performance in solar thermal and photovoltaic system. Before ageing, specular reflectance value was 77% and after 2000 h in damp heat, specular solar reflectance had decreased to 42%. This decrease was found to be due to degradation of the polyethylene terephthalate layer, caused by UV radiation and high temperature. Li and Wang [9] investigated the two types of solar evacuated tube to measure their heating efficiency and temperature with fluids of water and nitrogen gas. It was found that water temperature at 90-100ºC provide the better efficiency about 70% with both evacuated tubes. For the high temperature application with ammonia, the efficiency of solar concentrating system with evacuated tube collector decreased to 40%. Reddy and Kumar [10] presented 3-D numerical analysis of the porous disc line receiver for solar parabolic trough collector. The analysis was performed on renormalization-group (RNG) k-ε turbulent model by using therminol-VP1 as working fluid. The introduction of the porous disc in the receiver, improves heat transfer characteristics of the receiver but with a pressure drop as penalty. The maximum heat transfer co-efficient is achieved in top half disc receiver with H=0.5d at θ=30° with reasonable drag. Yashavant *et al.* [11] numerically investigated the performance of parabolic trough receiver with outer vacuum shell and compared with non-evacuated shell receiver. The vacuum shell configuration performs better than the non-evacuated tube even without a selective coating and is significantly better with selective coating. Jin *et al.* [12] investigated the operational performance and energy conversion efficiency of a developed 15 kW solar chemical receiver/reactor for hydrogen production. Solar receiver/reactor was tested at 200-300°C. They found that the solar thermo-chemical process was feasible at this temperature level. Yu Zitao *et al.* [13] designed a U-type natural circulation heat pipe system and experimentally investigated for generating mid-temperature steam. It was observed that thermal efficiency of the system was 38.58% at a discharge pressure of 0.5 MPa during summer time.

Many researchers have worked and analyzed the parabolic trough collector for different applications i.e. water heating etc. But none of them worked on effect of different modes of tracking on the performance of parabolic trough collector. The objective of this paper is to study the performance of PTC with different modes of tracking. The experimental setup is installed at NIT, Kurukshetra, India [29° 58' (latitude) North and 76° 53'(longitude) East].

II. EXPERIMENTAL SETUP

The aim of the experiment is to study the thermal performance of a parabolic trough collector with different tracking modes. The objective of this study is to investigate the temperature at the different positions in the receiver tube. Parabolic trough collector having an aperture area 1.4884 m^2 and focal length 0.305 m is used for this experiment. The experimental setup of parabolic trough collector in different tracking modes is shown in figure 1.

(a) **(b)** **(c)**

Fig 1: Photograph of The Experimental Setup: (A) One Axis Tracking Facing Southwards (B) One Axis Tracking Along East-West (C) Two Axis Tracking Along East-West

The specifications of parabolic trough air heater are shown in Table 1.

Table 1: Specifications of the Parabolic Trough Collector

Parameter	Dimension
Length of PTC frame (m)	1.22
Breadth of PTC frame (m)	1.22
Aperture area of PTC (m^2)	1.4884
Linear diameter of PTC (m)	1.3999
Focal length of PTC (m)	0.305
Rim angle (degree)	90°
Absorber tube inner diameter (m)	0.030
Absorber tube outer diameter (m)	0.032
Concentration ratio	12.14

The system consists of following parts:

2.1 Reflector

2.2 Absorber tube

2.3 Glazing

2.1 Reflector

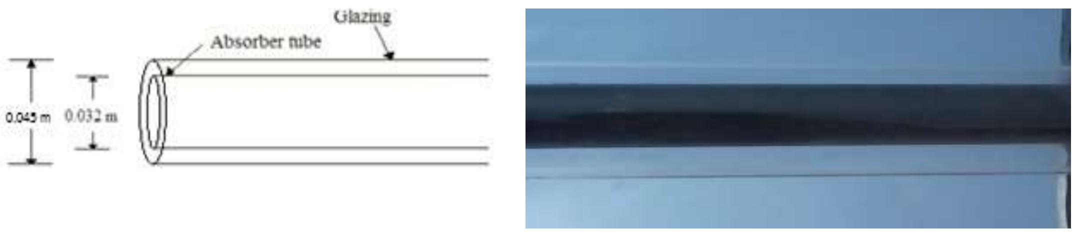
Reflector is one of the vital part of the parabolic trough collector as it decides the fraction of solar irradiance to be focused on the absorber tube. Hence optical efficiency of parabolic trough collector is largely affected by the reflectivity of the material used for reflector. A parabolic reflector reflects and concentrates all the sun rays on the absorber tube. The reflector is a parabolic shaped galvanized aluminium sheet with a reflectivity of 86% at clean surface.

2.2 Absorber Tube

The absorber tube is placed at the focal length of the parabolic trough collector which is made of aluminium. The outer diameter and inner diameter of absorber tube are 0.032 m and 0.030 m respectively along with a length of 1.22 m. The solar radiations reflected by the parabolic trough collector are collected by the absorber tube.

2.3 Glazing

The glazing is a concentric tubular glass cover which surrounds the absorber tube. The purpose of the glazing is to minimize the convection losses from the surface of the absorber tube. Glass tube is transparent to the radiations of short wavelength (coming from sun) and opaque to the radiations of long wavelength (emitted by the absorber tube). The outer diameter and thickness of the glass tube are 0.045 m and 0.002 m respectively, having length equal to 1.22 m, as shown in figure 3 (a) and (b).



(a) **(b)**

Figure 3: (A) Schematic of Absorber Tube With Glazing (B) Photograph of Absorber Tube With Glazing

III. MEASURING DEVICES AND INSTRUMENTS

The parameters which are measured in this work; these includes:

- Temperature of absorber tube on inner surface
- Intensity of solar radiations

These parameters are measured by the following devices:

The temperatures at different points are measured using RTD PT100 thermocouples. A digital temperature indicator is connected with the thermocouples that give the temperature with a resolution of 0.1^0C.

The solar radiation intensity is measured during the day using a Pyranometer (model CM11), supplied by Kipp and Zonen, Holland.

IV. SYSTEM OPERATION

The parabolic trough collector is manually tracked on each day before the reading starts so that the solar radiations fall normal to the plane of aperture area. When the solar radiations fall on the aperture area of the parabolic trough collector, these radiations are concentrated on the absorber tube. At the different positions of the receiver tube temperature are measured using thermocouples.

Different cases are studied with different modes of tracking of parabolic trough collector. These are as discussed below:

4.1 One Axis Tracking Facing Southwards.

4.2 One Axis Tracking Along East-West.

4.3 Two Axis Tracking Along East-West.

4.1 One Axis Tracking Facing Southwards

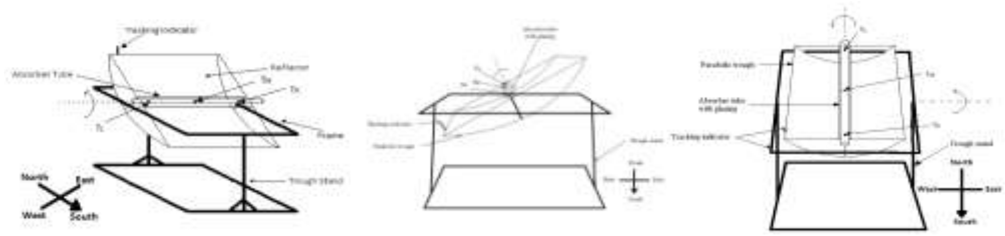
In this mode of tracking the parabolic trough collector is placed such that, it faces towards the south whereas the receiver tube is placed along the east-west direction as shown in figure 4 (a). The collector is tracked once in a day in the beginning of the experiments.

4.2 One Axis Tracking Along East-West

In the second mode of tracking as shown figure 4 (b), the receiver tube is placed along the north-south direction and the collector is tracked along the east-west axis, after an equal interval of 15 minutes throughout the day.

4.3Two Axis Tracking Along East-West

In case of two axis tracking, the collector was tracked on two different axis i.e. once about its east-west axis in the starting of the day and also about its north-south axis after every 15 minutes throughout the day. The two axis tracking is shown in figure 4 (c).



(a) **(b)** **(c)**

Figure 4: Schematic Diagrams of Different Cases (A) One Axis Tracking Facing Southwards (B) One Axis Tracking Along East-West (C) Two Axis Tracking Along East-West

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this experimental setup, the main concern is focused on the different modes of tracking of parabolic trough collector. The experimental data is collected in mostly clear sky days. The results are taken in the month of January 2014. In most of the days, ambient temperature is in the range of 12 °C to 22 °C. The readings are taken from 9:00hr to 17:00hr and noted at an interval of 30 minutes each. Three cases are considered and various results are obtained.

Case 1: One Axis Tracking Facing Southwards

As shown in figure 5, it is observed that the temperature at receiver is directly related to solar intensity. When the solar intensity is high, temperature at receiver is also high and vice versa. In the forenoon session, the temperature of the right-end is found to be low whereas the left-end temperature is high and in the afternoon session, the right-end temperature is more as compared to the left-end temperature. This is because of the position of sun as it rises in the east and sets in the west. During the day, maximum solar intensity is 612W/m^2 at 12:00hr and maximum temperature is found at the right end (T_R) of the receiver tube, which is 175 °C at 13:30hr. Whereas, the maximum temperatures at left-end (T_L) and in the middle (T_M) of the receiver tube are 122.8°C and 164.3°C respectively.

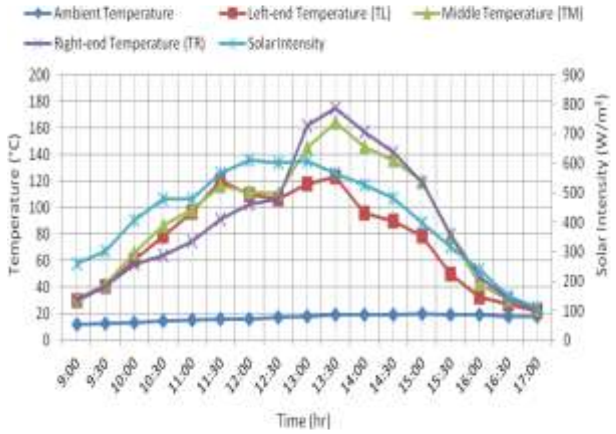


Figure 5: Variation of Various Temperatures and Solar Intensity During the Day With One Axis Tracking Facing Southwards

Case 2: One Axis Tracking From East To West

As shown in figure 6, the left-end temperature is found to be high as compared to the other two temperatures and the right-end temperature is lower than other two temperatures. This is due to the facing of the collector i.e. as the collector is tracked from east to west direction and the receiver tube is kept along the north-south direction. During the day, maximum solar intensity is 835 W/m^2 at 12:30hr and maximum temperatures at right-end (T_R), left-end (T_L) and in the middle (T_M) of the receiver tube are 118.1°C, 166.7°C and 154.3°C at 13:00hr respectively.

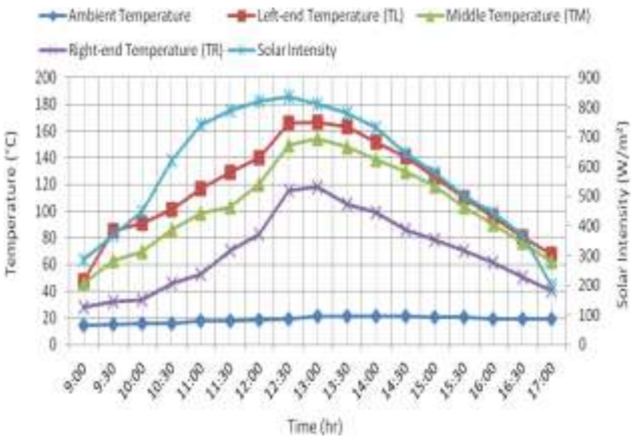


Figure 6: Variation of Various Temperatures and Solar Intensity During the Day With One Axis Tracking Along East-West

Case 3: Two Axis Tracking From East To West

It is observed that the temperature at different positions of the receiver tube varies according to variations in solar intensity. In this case, the maximum temperature at different positions of the receiver tube i.e. at the right-end (T_R), left-end (T_L) and in the middle (T_M) are 139.5°C, 162.4°C and 184.4°C. During the day maximum solar intensity is 852 W/m^2 at 12:30hr as shown in figure 7.

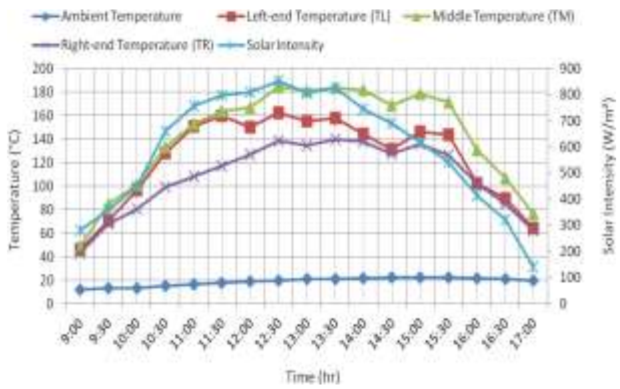


Figure 7: Variation of Various Temperatures and Solar Intensity During the Day With Two Axis Tracking Along East-West

VI. CONCLUSIONS

The following conclusions have been made from the experiments conducted.

1. The maximum temperature of the receiver tube is achieved with two axis tracking along east-west which is 184.4°C at middle of the receiver tube.
2. In two axis tracking along east-west end losses are minimized whereas in the other two modes of tracking these losses are more prominent.
3. One axis tracking facing southwards is easier as compared to other two modes of tracking.

6.1 Nomenclature

T_L	left-end temperature (°C)
T_M	middle temperature (°C)
T_R	right-end temperature (°C)

REFERENCES

[1]. Selcuk M. Kudret., “Analysis, development and testing of a fixed tilt solar collector employing reversible vee-trough reflectors and vacuum tube receivers”, Solar Energy, 22, 413-426 (1979).

[2]. Rabl A., Bendt P., Gaul H.W., “Optimization of parabolic trough solar collectors”, Solar Energy, 29, 407-417 (1982).

[3]. Prapas D.E., Norton B., Probert S.D., “Optics of parabolic-trough Solar-Energy collectors possessing small concentration ratios”, Solar Energy, 39, 541-550 (1987).

[4]. Hamad F.A.W., “The performance of a cylindrical parabolic concentrator”, Energy Conversion Management, 28, 251-256 (1988).

[5]. Thomas A., “Operation and performance of the solar steam generation system”, Energy Conversion Management, 33, 191-196 (1992).

[6]. Kalogirou S.A., Lloyd S., Ward J., Eleftheriou P., “Design and performance characteristics of parabolic trough solar collector system”, Applied Energy, 47, 341-354 (1994).

[7]. Fend Thomas, Jorgensen Gary, Kuster Harald, “Applicability of highly reflective aluminum coil for solar concentrator”, Solar Energy, 68, 361-370 (2000).

[8]. Brogren M., Helgesson A., Karlsson B., Nilsson J., Roos A., "Optical properties and system aspects of a new aluminum/polymer/laminated steel reflector for a solar concentrator", Solar Energy Materials and Solar Cells, 82, 387-412 (2004).

[9]. Li M. and Wang L.L., "Investigation of evacuated tube heated by solar trough concentrating system", Energy Conversion and Management, 47, 3591-3601 (2006).

[10]. Kumar K. Ravi and Reddy K.S., "Thermal analysis of solar parabolic trough with porous disc receiver", Applied Energy, 86, 1804-1812 (2009).

[11]. Yashavant J., Daniel P., Das A. K., "Numerical investigation of parabolic trough receiver with outer vacuum shell", Solar Energy, 85, 1910-1914 (2011).

[12]. Jin H., Hong H., Liu Q., "Operational performance of the development of a 15kW parabolic trough mid-temperature solar receiver/reactor for hydrogen production", Applied Energy, 90, 137-141 (2012).

[13]. Yu Z., Zhang L., Wang W., Fan L., Hu Y., Ni Y., Fan J., Cen K., "An experimental investigation of a natural circulation heat pipe system applied to a parabolic trough solar collector steam generation system", Solar Energy, (article in press) (2012).