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Experimental Analysis of Cylindrical Parabolic Collector with and without Tracking System

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ABSTRACT

The present study of this project work presents experimental platform based on the design, development and performance characteristics of water heating by tracking and non-tracking solar cylindrical parabolic concentrating system. The performance of the concentrator is experimentally investigated with the water circulated as heat transfer fluid. The tests will be carried out with both tracking and non-tracking mechanisms of cylindrical parabolic collector. The collector's efficiency will be noted. The collector's efficiency for both tracking and non-tracking system is compared. It was observed that for non-tracking system efficiency was 11.58%, for tracking it observed 18.8%. Obviously efficiency for tracking system was more and percentage of increase in efficiency was approximately 35%.

Key Words*- CPC, tracking and non-tracking system, solar energy.*

1. INTRODUCTION

Development of single axis universal automatic tracking system for used in solar devices like flat plate collector, Cylindrical Parabolic Collector and photovoltaic module will increase solar collection as well as efficiency of devices. In this work two experimental setups used simultaneously are tracking and non-tracking arrangement systems. Tracking system with CPC tracks according to sun movement from east to west direction. But in the non-tracking system of CPC no tracking takes place with sun movement. Two identical CPC with same specifications were used for conduction of experiments and observed the output of cylindrical parabolic collector with tracking and non-tracking arrangement systems with the variation of time. P. Rhushi Prasad et. al. [1] conducted an experiment on cylindrical parabolic collector with and without tracking system in winter and partly cloudy days, it was found by tests that collector with tracking system was of higher efficiency than non-tracking system, the percentage of efficiency increased of average 37%. There is a considerable scope for increase in efficiency for automatic tracking mechanism. Abdul jabber et. al. [2] worked on effect of 2-axis sun tracking on the performance of compound CPC. An experimental study was performed to investigate effect of two axis sun tracking system on performance of CPC; the tracking collector showed a better performance with an increase in collected energy up to 65% compared with identical fixed collector.

2. METHODOLOGY

Experimental set up for the CPC model are located at BGS R-D center, Department of Mechanical Engineering, SJCIT, Chickaballapur.

2.1 Cylindrical parabolic collector on non-tracking arrangements

- Tank and parabolic collector are to be filled with water completely.
- The inlet water temperature of the collector is to be noted by using calibrated digital indicator.

- The outlet water temperature of the parabolic collector to be by using calibrated digital indicator at an interval of every one hour between 9.30am to 4.30pm.
- Efficiency of the parabolic collector is to be calculated.
- Same procedure is repeated for different days.

The below Fig.1 shows the setup of Cylindrical parabolic collector on non-tracking arrangements.

Fig 1: CPC non-tracking setup at SJCIT

2.2 Cylindrical parabolic collector with tracking arrangements

- Initially parabolic collector is to be placed at an angle of 45^0 facing east in such a way that sun rays should fall at an angle of 90^0 on collector at 9am.
- The inlet water temperature of the CPC is to be noted by used calibrated digital indicator.
- The outlet water temp of the CPC to be noted at an interval of every one hour between 9.30am to 4.30pm by used calibrated digital indicator with respect to movement of collector.
- Efficiency of the CPC is to be calculated.
- Same procedure is repeated for different days.
    - The CPC with tracking system setup as shown in below Fig.2

Fig 2: CPC with tracking system at SJCIT

3. EXPERIMENTATION AND CALCULATION

Here we used the setup of same specifications for both tracking and non-tracking system. In the non-tracking arrangement system parabolic collector is placed on shaft, which is inclined at an angle of 23^0 to horizontal and facing towards south and do not tracks them according to sun movement. In case of tracking system collector is placed on shaft, which is inclined at an angle of 23^0 to horizontal and facing towards south. One end of the shaft is connected to big worm & worm wheel [reduction ratio 1:10] and small worm & worm wheel with reduction ratio 1:324 is connected between the motor and bigger worm & worm wheel of reducing motor speed. The motor is connected to timer circuit which monitors the speed of the motor in such way that the motor run every 5 minutes for 5.6seconds. The power is supplied to the circuit by photovoltaic cell through battery. The other end of shaft is mounted on a bush, a pin-pointer is welded to the end of the shaft which moves over the angle gauge, which is fixed to the stand and it will shows collector movements at time of tracking. In this system tracks the sun by tilting the collector by 1.2^0 per every 5min, the system starts at 9am with an angle of 45^0 from horizontal facing the sun, at 4pm the angle turned through will be 135^0 at this position panel will continue to face sun. After sunset this collector reverts 't' the original position and this is repeated on daily basis.

3.1 Specification of the Cylindrical Parabolic Collector

1. Length of the receiver of the collector = 2m
2. Width of the receiver of the collector = 0.5m
3. Length of absorber pipe = 2m
4. Diameter of the absorber pipe = 25mm
5. Material of the collector = galvanised iron
6. Thermal conductivity of material= 204.2w/mk
7. Density of the material = $2707kg/m^3$
8. Material of the absorber pipe - copper
9. Thermal conductivity of the pipe= 386 w/mk
10. Density of the material pipe = $8954kg/m^3$
11. Thickness of the collector = 10 mm
12. Focal length of the collector = 300 mm
13. Location of the collector = Chickaballapur
14. Latitude and longitude of place = $13^0$24'9", $77^0$43'49''

The experimental data obtained as below table, the readings were taken in the months of March, April and May at R&D centre SJCIT, Chickaballapur.

3.2 Day wise readings

Day 28: 25-04-2014, Chickaballapur, Average global radiation 711 W/m^2, Average wind speed 4.3 km/hr
The experimental temperature readings are given below in Table.1

The day wise reading was taken on 25/04/2014 was given in the below table1. The reading started at morning at 9.30am to evening 4.30pm on hour basis.

Nomenclature:

A = Area of the collector
A_r = Area of the receiver pipe
Aa = Aperture area of the collector
T1 = Temperature of water at inlet in ^{0}C
T2 = Temperature of water at outlet in ^{0}C
M = Mass of the water flowing in the absorber pipe
C_p = Specific heat of water
R = Input radiation
Q = Energy output of collector
H = Efficiency of collector
CPC = Cylindrical Parabolic Collector
PV = Photo Voltaic

Time in hours	Outlet temperature of stationary collector $T_2{}^oc$	Outlet temperature of tracking collector $T_2{}^oc$
9.30	31	32
10.30	45	53
11.30	55	62
12.30	67	77
01.30	59	71
02.30	52	65
03.30	46	60
04.30	40	55
Avg. temp	44	60

Table 1: temperature readings on 25/04/14

3.3 Day average Efficiency calculation: day 25/04/2014

Average solar radiation received by the earth in terms of energy R = 711 w/m^2

T1 = temperature of water at inlet 31^{0}C

T2 = temperature of the water at outlet 44^{0}C (non-tracking), 60^{0}C (tracking)

M = mass of water flowing in the absorber pipe 50kg

Cp = specific heat of water 4.182 KJ/k

Area of the collector $A = A_a + A_r$

Where, A_a is Aperture area of the collector

A_r is area of the receiver pipe

Area of the receiver pipe $A_r = 2\times \pi \times 0.025 = 0.1570m^2$

Aperture area of the collector A_a = width× length of CPC = 1×2 = 2m^2

Area of the collector $A = A_a - A_r = 2 - 0.1570 = 1.843m^2$

Solar radiation received by the earth in 7hrs in terms of energy

I.e. input radiation = radiation received by collector × Area
= 711×3600×7×1.843 = 33021399.6 joules

Energy output of tracking collector Q = M×Cp× (T_2-T_1) = 50×4.182×1000× (60-31) =6063900joules

Efficiency of tracking collector (η) = output of collector / input radiation = 6063900/33021399.6 = 18.4 %

Energy output of Non tracing collector Q = M×Cp× (T_2-T_1) = 50× 4.183×1000(44-31) = 2718950joules

Efficiency of non-tracking collector (η) = output of collector / input radiation= 2718950/ 33021399.6 = 8.21%

Increase in % efficiency of tracking collector = (18.4-8.21)/18.4 ×100 = 45.34%

3.4 Discussion on Tracking Accuracy and Error

The measurement of tracking accuracy is measured by using standard scale. The scale is fixed perpendicular to the parabolic collector, a point pin is fixed normally to the plane of collector and whole collector rotates under the scale. A point pin shows the angle deviation of the collector at the time f rotation. The collector starts at angle of 45^0 in morning at 9am and moves towards sun movement and finally reached at an angle of 135^0 in evening 4pm. It can be seen that error in the shaft rotation is increasing over a period of time. The probable reason of the inaccuracy can be due to following facts.

- Back lash (gear & coupling)
- Unequal teeth dimension of the gear

The maximum deviation being about 5^0 over a day, this much of devotion does not lead to any significant effect on collector.

The below Table.2 presents a typical day measurements of inaccuracy and the results have also shown in Fig 4.

Time 'hr'	**9.30 am**	**10.30 am**	**11.30 am**	**12.30 pm**	**1.30 pm**	**2.30 pm**	**3.30 pm**	**4.30 pm**
Error	1^0	1.3^0	1.7^0	2.3^0	2.8^0	3.6^0	4.5^0	5^0

Table-2: Tracking error with time

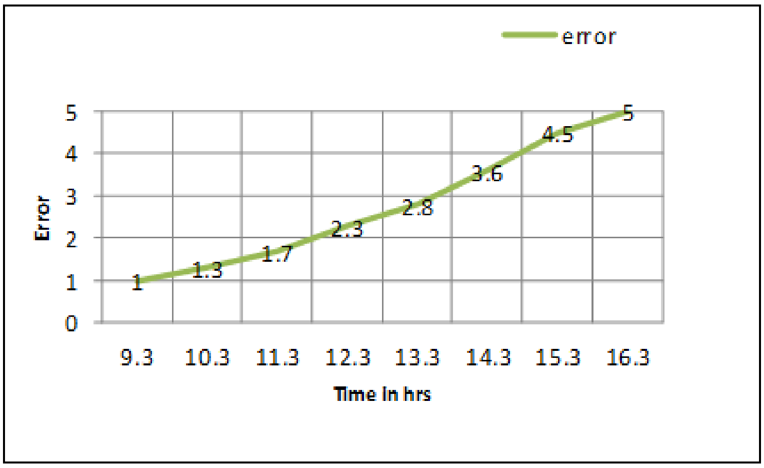

Fig 4: Tracking error with time

4. RESULTS

The result has calculated on daily, weekly and monthly basis. The temperature readings were taken from morning 9.30am to evening 4.30pm for both tracking and non-tracking systems. The efficiency calculations were done as above. Here we considered the average readings for daily, weekly and monthly result. Below Table.3 gives the average results of days, weeks and months.

Days/ weeks/ months avg. base	**Total avg. global radiation in W/m^2**	**Tracking collector efficiency (η) %**	**Non-tracking collector efficiency (η) %**	**Percentage of efficiency increased %**
Day wise (avg. 65 days)	760	20.26	12.57	39.57
Weekly wise (avg. of 8 weeks)	720	16.98	10.85	33.64
Monthly wise (avg. of 2months)	730	17.8	11.19	31.65

Table 3: Results of daily, Weekly and Monthly wise

The temperature variation along with time for daily base was shown in below Fig 5.

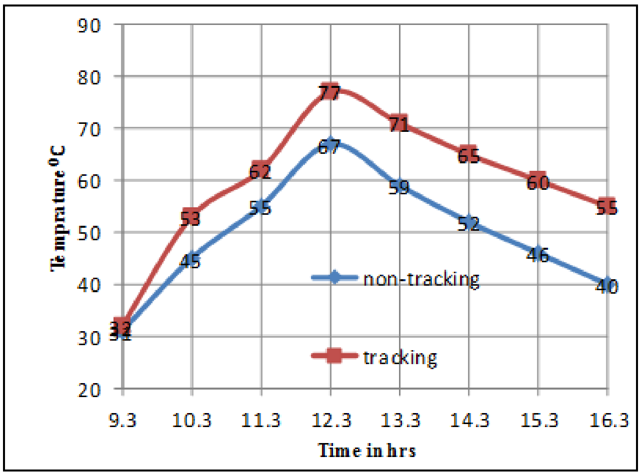

Fig 5: Variation of temperature with time for daily wise

From above calculations, tables and graphs it was observed that the efficiency for the tracking system was higher than that of non-tracking system,

5. CONCLUSION

We have conducted experiment on performance analysis of parabolic collector with tracking and non-tracking system. The efficiency of both tracking and non-tracking is calculated and it is found to higher for the tracking system. Due to unusual weather condition, less radiation was obtained, as it was cloudy and windy. The efficiency would have been further increased if these climatic conditions didn't prevail. There is a consider scope for increase in efficiency for automatic tracking system. The percentage of efficiency increased for tracking system is approximately 36%, hence the CPC with tracking system has found more efficient. In another term, using this solar equipment we can extract eventually 27% of direct solar energy and convert it into thermal energy that can be used directly for several applications such as water heating, electricity generation using Sterling engine, vapor production etc.

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