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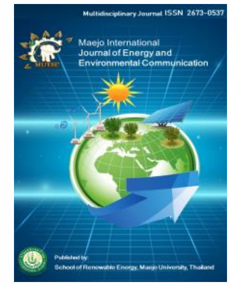

ARTICLE

Performance of cylindrical parabolic solar collector with the tracking system

M. Anil Kumar[1*], K. Sridhar[1], B. Devika[1]

[1]Department of Mechanical Engineering, Kakatiya Institute of Technology and Science, Warangal 506015, India

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ABSTRACT

A parabolic solar collector collects the radiant energy emitted from the sun and focuses on a point. Parabolic trough collectors are the low-cost implementation of concentrated solar power technology that focuses incident sunlight onto a tube filled with a heat transfer fluid. However, the fundamental problem with the cylindrical parabolic collector without tracking was that the solar collector does not move with the sun's orientation. The development of an automatic tracking system for cylindrical parabolic collectors will increase solar collection and the efficiency of devices. The present study of this project work presents an experimental platform based on the design, development, and performance characteristic of water heating by tracking solar cylindrical parabolic concentrating system. The tracking mechanism is to be made by stepper motor arrangement to receive the maximum possible energy of solar radiation as it tracks the sun's path. The performance of the parabolic trough collectors is experimentally investigated with the water circulated as heat transfer fluid. The collector efficiency is calculated.

1. Introduction

Energy is the primary and most universal measure of all kinds of work by human beings and nature (Bhuyar et al., 2021). Everything that happens in the world expresses the flow of energy in one of its forms. More specifically, the sun's energy is produced and radiated; the term refers to the solar energy that reaches the earth. Solar energy, received in the form of radiation, can be converted into other forms of radiation and converted directly or indirectly into other forms of energy, such as heat and electricity, which man can utilize. The point of view of solar energy utilization received at the earth surface than in the extra-terrestrial energy. Solar energy is received at the surface of the entirely different due to various reasons. Solar energy has the most significant potential of all the sources of renewable energy, and if only a small amount of this form could be used, it is one of the essential supplies of energy, significantly when other sources in the country have depleted (Rizwan et al., 2014). Non-conventional energy resources can be a great alternative to these problems in nearby future. Some of these are energy from various sources like sun, tidal, wind, ocean, biofuels, etc. Among all these, solar energy can be a promising source for future energy needs. Solar energy is a vast, inexhaustible source of energy (Souvannasouk et al., 2021). The power from the sun intercepted by the earth is approximately 1.8*1011 MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could continuously supply all the world's present and future energy needs. This makes it one of the most promising in the world continuingly, making it one of

* Corresponding author.
E-mail address: mak.me@kitsw.ac.in (M Anil Kumar)

the most capable unconventional energy sources (Nirunsin et al., 2017).

Energy comes to the earth from the sun. The solar power where the sun hits the atmosphere is 1017 watts, where the solar power on the earth surface is 1016 watts. The total worldwide power demand of all needs of civilization is 1013 watts. Therefore, the sun gives 1000 times more power than we need. If we can use 5% of this energy, it is 50 times more powerful than the world requires (Price et al., 2002).

The energy radiated by the sun on a bright sunny day is approximately 1kW/m^2. Fossil fuels are non-renewable, i.e., they draw on finite resources that eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. An inevitable consequence of the prolific use of fossil fuel is the certainty that these resources eventually run out. Coupled with the growing concern over these diminishing resources, with the present methods of utilizing these fuels, the atmosphere's carbon dioxide content is increasing, leading to adverse effects on the environment. The combustion of fossil fuels has caused severe air pollution problems in many areas because of the localized release of large amounts of harmful gases into the atmosphere. It has also resulted in global warming, which is now a matter of great concern (Saengsawang et al., 2020).

Similarly, the release of large amounts of waste heat from power plants has caused thermal pollution in lakes and rivers, leading to the destruction of many plants and animal life forms. In nuclear power plants, there is also concern over the possibility of radioactive being released into the atmosphere in an accident and over the long-term problems of disposal of radioactive wastes from these plants. The gravity of most of these environmental problems had not been foreseen.

2. Materials and Methods

2.1. Geometric design of parabolic trough collector

The principle of the parabolic trough collector, which is often used in concentration collectors, is a principle of geometry that a parabolic reflector pointed at the sun reflects parallel rays of light to the parabola's focal point (Kumar et al., 2013). A parabolic trough is a one-dimensional parabola that focuses solar energy onto a line. The collector is designed with a simple parabolic equation and merged with the solar radiation method to optimize the fabrication with local material. According to the size limitation of the highly polished Aluminum sheet, 2400 mm long, 1000 mm wide and rim angle of 180°, makes the focal line is in place with the cord line (Parashar et al., 2014). The Solar Parabolic Trough Collector (SPTC) system are presented in Table 1.

Table 1 SPTC system specifications.

Item	Value
Collector length	1.5m
The perpendicular distance from the vortex	0.2m
Rim angle	90^0
Parabola width	0.8m
Tube diameter	0.0125m
Tracking Mechanism Type	Manual & Automated

The simple parabolic equation can be applied to solve the above condition, where x is axial to parabolic curve, y is the centre line of focal, R is the radius of the parabolic curve, and f is a focal line, as shown in Figure 1 and Figure 2.
Consideration the simple parabolic equation (Eq. 1 y 2):

$$X^2 = 2 R Y \quad (1)c$$

$$f = R/2 \quad (2)$$

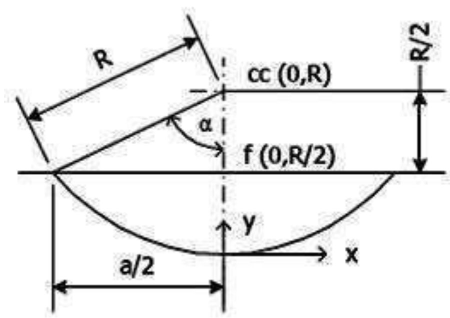

Figure 1 Schematic representation of a parabolic system.

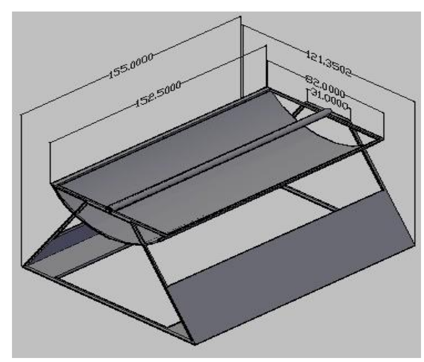

Figure 2 Solar Parabolic trough Collector.

2.2. Fabrication

A typical thermal solar utilization system consists of two or more solar collectors connected to a storage and distribution system. A solar collector is a device that utilizes solar radiation to heat a fluid, which can then be used for suitable domestic applications. The collector we have worked on thermal utilization of the solar intensity is steel strips bent into the evacuated parabolic structure (Tayade et al., 2015).

2.2.1. Supporting frame of SPTC

The frame modelled was L' cross-section and made of Mild Steel (Figure 3). The specifications of the support frame are given in Table 2.

Table 2 Specifications of the Support frame.

Dimension	Value
Length of the Support Frame	160cm
Breadth of the Support Frame	120cm
The thickness of the Support frame	5cm

Figure 3 Model of supporting frame.

2.2.2. Support stand of SPTC

The entire prototype is supported utilizing the stand made by the fusion of the Iron bars, i.e., welding, and this stand can also be made with the help of the wood to reduce the strength to weight ratio, but as the black body is a good absorber of heat, stand preferred to be made of Iron bars of required lengths.

Table 3 Specifications of support stand.

Dimension	Value
Height of the support stand	0.70 m
Distance between the two stands	1.6 m
Width of the stand	0.9906 m
The thickness of the stand	0.025 m

As far as a collector is concerned, it does not just mount only on the stand statically, but the main equipment absorber (copper tube with the thermal conductivity of 384 w/m²k) is placed upon parallel to be concentrated with the foci (focal point), to the end at which the collector is balanced equally with the help of Journal bearing (Figure 4).

Figure 4 Supporting stand.

2.2.3. Sun tracking mechanism

- Most concentrators would collect so little energy in a fixed position that they must be provided with the capability to daily track the sun from morning (East) to sunset (West) to be cost-effective.
- The sun travels 360° in 24 x 60 minutes.
- We are using a rope–pulley drive mechanism; with the help of a rope, we can also do manual tracking (Odeh et al., 2013).
- The parabolic shaped collector perfectly concentrates the rays that are incident in 2- dimensions, and this run automatically with the help of a rope-pulley drive Mechanism.

Figure 5 Rope-Pulley Drive Mechanism.

2.3. Experimental setup

The experimental setup consists of a cylindrical parabolic frame made of iron, having 4 legs is placed on the building. The radium sheet is fixed to the frame as a parabolic trough to reflect solar radiation. A copper tube is used for the absorption of energy from solar radiation (Yassen, 2012). It is located in the midpoint of the parabolic collector. The diameter of the copper pipe is 12.5mm. One end of the rubber tube with the same diameter is connected to the inlet water tank, and the other end is connected to the copper pipe inlet. The inlet to the copper tube is cool water, and the outlet is hot water. This setup is exposed to the sun for 6 hours. During this period, the concentrator reflected the solar insolation was falling on it to the focal line, which means that the solar insulation is concentrated at the focal line, which is nothing but a copper tube. The experimental setup is shown in Figure 6.

Figure 6 Theoretical Setup of SPTC Mount Assembly.

2.4. Experimental procedure

The experimental setup is placed on the top of the building. The reflector is cleaned so that it is free from dust and now check the correctness of thermocouples. Replace the thermocouples if necessary. The water tank is filled with fresh water from an overhead tank, and all other connections are checked and calculated the mass flow rate so that the water flow can be kept at the desired rate. Takedown the initial temperatures of inlet and outlet tubes at the copper tube. The readings of inlet and outlet temperatures should be noted at a regular interval of every half an hour with the help of an Analog thermometer. The experimental setup is exposed to solar radiation for seven hours, and the readings are taken throughout the day. The experiment was conducted over some time, and the readings were taken. But the readings are not continuous due to erratic weather. So, the readings on three different clear days were considered for calculation, and the performance analysis of the concentrator with the copper tube was carried out.

3. Results and Discussion

The following results were drawn from the experimental setup of the solar parabolic trough collector: The setup is modified, and the efficiency is relatively high compared to the flat-plate collector. The significant change in the setup is the replacement of the collector. This new model consists of a parabolic trough collector and copper tube located at the centre of the collector. The heat absorbed with this tube is relatively high than that of a flat plate collector; this was a copper tube, so convection losses were reduced. This yields better absorption of the heat input given to the copper tube.

The significant advantage of the solar parabolic concentrator is that it concentrates all the energy falling on the reflecting sheet, which is termed as concentration ratio and the value of this concentration ratio, was found to be 4.81, which is a high value. The flow of the water should be constant throughout the day to get helpful sound output. The solar concentrator uses only beam radiation to heat the water. It does not take into account global and diffuse radiation. A large amount of heat input that is given to the tube is converted into proper heat. The Aluminium sheet, which is used for reflecting the solar rays, is good, and it reflected a considerable part of solar rays onto the copper tube, which is at the focus of the parabolic trough.

In manual experimentation, in comparison between single tube and multi-tube as time or day progresses, we can see or observe higher heat gain through the multi-tube (Figure 7 and 8).

When we compare the experiment result with a hybrid tube system, we can observe a maximum heat gain through the hybrid system.

- Max Q_{u1} – Single tube = 26 w
- Max Q_{u2} – Multi-tubes = 83 w
- Max Q_{u3} – Hybrid system = 114 w

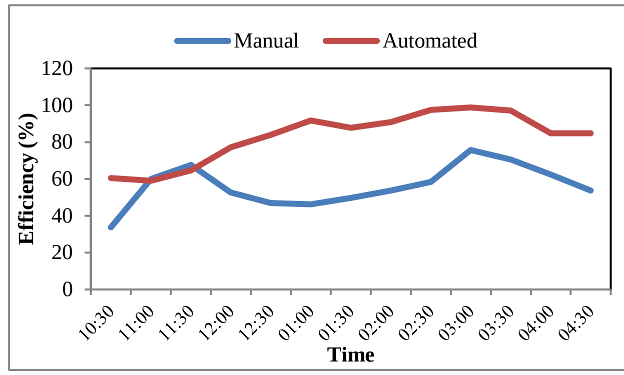

Figure 7 Single tube (Efficiency vs time).

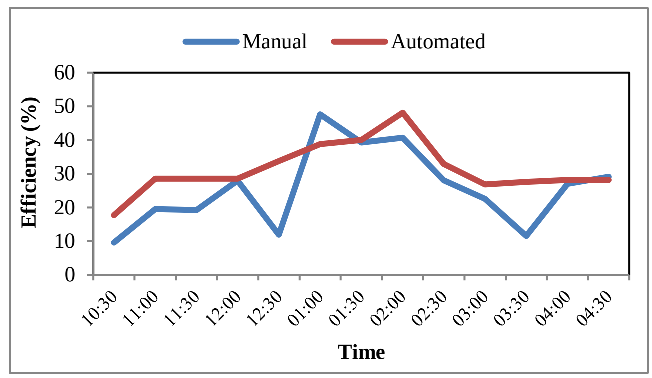

Figure 8 Multitube (Efficiency vs time).

In Automated experimentation, comparing single tube and multi-tube, we can see or observe higher heat gain through the multi-tube as time or day progresses. When comparing the experiment result with a hybrid tube system, we can observe a maximum heat gain through the hybrid system (Figure 9).

- Max Q_{u1} – Single tube = 41.8 w
- Max Q_{u2} – Multi-tubes = 109.7 w
- Max Q_{u3} – Hybrid system = 135.8 w

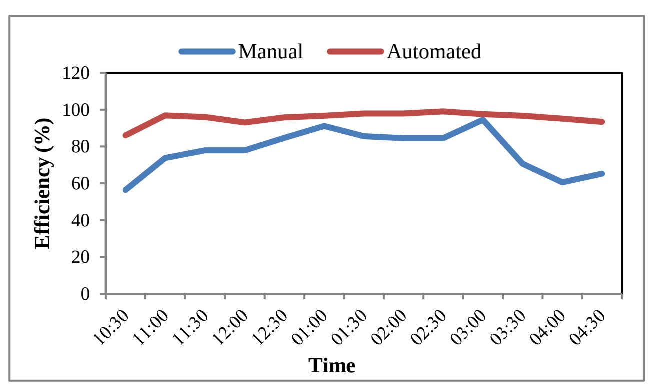

Figure 9 Hybrid tube (efficiency vs time).

Heat gain in hybrid system is comparatively high with other systems, this is why because we are making water to stay for long time at heating zone or receiver tube (Figure 10). It is also observed that Heat gain by Automatic tracking system is higher than the Heat gain by manual system (Table 5).

Finally, we can conclude the result that the performance of modified setup of solar parabolic concentrator with copper tube is satisfactory and can be used in places where the availability of solar insolation is moderate (Math et al., 2014).

Table 5 Variation of heat gain w.r.t time for tracking.

Time	Qus	Qum	Quh
10:30	10.45	**36.5**	57.4
11:00	15.67	47	73
11:30	26.12	47	88
12:00	26.12	52	94
12:30	31.35	62.7	92
01:00	36.57	67.9	114.9
01:30	36.57	73.1	117.5
02:00	41.8	83.6	125.4
02:30	31.35	88.8	135.8
03:00	26.12	109.7	135.8
03:30	26.12	104.5	130.6
04:00	26.12	94	130.6
04:30	26.12	78.3	130.6

Where; Qus- single tube, Qum- multi tube, Quh – hybrid tube

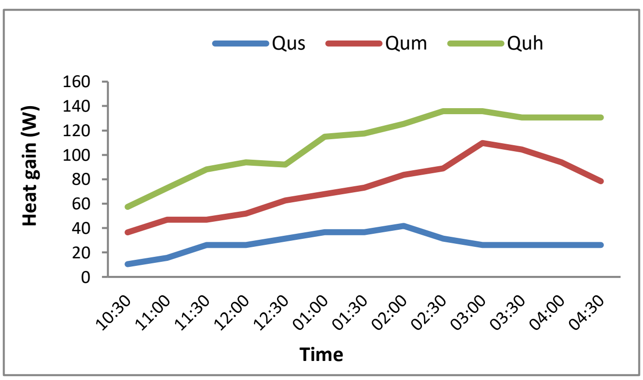

Figure 10 Variation of Heat gain w.r.t time with tracking.

4. Conclusion

The use of solar troughs is limited only to clear sunny days. The Solar trough tilting angle is limited to a maximum of 120°. The steam can produce scaling inside the metal absorber pipe; hence, a non-corrosive coating should be applied. The solar concentrating collector is among the best ways to use solar energy efficiency due to its advantages in converting abundantly available solar energy into an effective and convenient form of heat energy that can be used for various purposes. As per the design considerations of the cylindrical parabolic trough, the collector is fabricated. The experiment is carried out on sunny days. The maximum heat gain by the working fluid is 135.8 W. Finally, and it was concluded that the concentration of Solar Energy on the Parabolic Trough Collector had been intensified compared to Flat-Plate Collector.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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