Development And Testing Of Parabolic Through Collectors For Domestic Applications

Kaustubh Balapure[1], Kaustubh Kedar[2], Raviraj Alandikar[3], Dr. P. S. Patil[4]

[1234]*Student, Dept. Mechanical Engineering, JSPM Rajarshi Shahu college of engineering, Thathawade Pune,Maharashtra, India*
[4]*Professor, Dept. Mechanical Engineering, JSPM Rajarshi Shahu college of engineering, Thathawade Pune, Maharashtra, India*

---***---

Abstract – Global energy demand is expected to increase by more than 60% over the next few decades. Nowadays, home water heaters are getting more and more expensive, and we need to find another reliable way. Solar energy is the most useful source of clean energy to replace fossil fuels. A parabolic trough collector is one of the best ways to sustainably produce hot water. Inexpensive, easy to manufacture and easy to carry, it offers additional cost savings opportunities compared to other available models. The purpose of this research is to harness solar energy for home use. Experiments were performed using grade 204 stainless steel for the reflector and copper tubing for the absorber and mirror. The results show a slight increase in water outlet temperature compared to the simple parabolic trough collector. This document contains comprehensive content. An overview of this simple parabolic trough collector, along with geometric analysis, thermal efficiency, and applications are presented. Applications of PTC include water desalination, water heating, and increasing the power available to generate steam.

Key Words: **Solar Energy, PTC, Household, Reflector, Absorber, Steam.**

1.INTRODUCTION

Solar energy is an important component of renewable resources and is considered one of the best sources of energy available to mankind. In recent decades, the energy demands of the industrial and commercial sectors have continued to grow, resulting in an over-reliance on energy generated using fossil fuel technologies, increasing the release of pollutants into the atmosphere, which contributes to global warming and environmental degradation. human health. It is interesting to note that steam is just one type of water that has changed phases in industry. Steam is used as an economical and simple means of heating in a variety of applications, including plant operations in the chemical, textile, polymer, and paint industries.

There are many ways to convert this solar energy into other forms of energy, such as electricity, hot water, space heating, and desalination. Currently, the most promising technology capable of converting this solar energy into thermal form is the solar concentrator or solar panel. Energy is converted in such a way that the reflected solar rays are linearly focused on the absorber, and heat is transferred from the absorber to the HTF. In general, there are different types of solar collectors, including: B. Parabolic Trough Collector (PTC), composite Parabolic Trough Collector (CPC), and Flat Plate Collector.

Basically, a parabolic trough concentrator that reflects solar energy directly to a receiver or absorber tube placed at the focal line of a parabola is called a parabolic trough, a type of linear concentrating solar collector. Form a light concentrator (PTC). A larger collector opening area concentrates the direct solar energy reflected onto the smaller outer surface of the receiver tube, resulting in the heating of the liquid flowing through the receiver tube. This converts solar radiation into thermal energy in the form of sensible or latent heat in the fluid. This thermal energy can be used to run the Rankine cycle to generate electricity using steam turbines in "solar thermal" power plants or to run industrial activities that require thermal energy (food industry, petrochemical industry, etc.) can. . A parabolic trough concentrator concentrates solar radiation, which is then absorbed by a receiver in the focal line, converted to thermal energy and transported to the HTF. As the man who created the second law of thermodynamics.

1.1 Geometric Description

The geometry of parabolic shape can be defined by the following formula:

$$y = \frac{x}{4f}$$

By using the aperture (W) and the focal distance (f) the rim angle (ϕr) is defined as shown below:

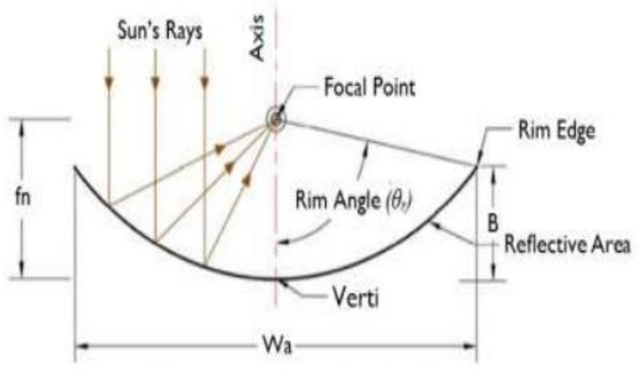

Fig. 1.1 Geometrical Description of PTC

$$\phi r = arctan\left[8\frac{f}{w}\frac{8\frac{f}{w}}{16\left(\left(\frac{f}{w}\right)^2 - 1\right)}\right]$$

The total collector aperture (A_a) is calculated as

$$A_a = W \times L$$

The absorber (A_{ro}) is the outer area of the tube:

$$A_{ro} = \pi D_{ro} L$$

The ratio of collector aperture (A_a) to the absorber area (A_b) i.e., concentration ratio can be calculated as:

$$C = \frac{A_a}{D_{ro}}$$

1.2 Thermal Analysis

The useful heat production from modified parabolic trough collector can be defined as:

$$Q_u = m.c_p(t_{out} - t_{in})$$

The solar irradiation falling on the collector can be calculated by the product of aperture area (A_a) and direct beam solar irradiation (G_b)

$$Q_s = A_a.G_b$$

The thermal efficiency of the solar collector (η_{th}) can be calculated as the ratio of useful heat to the solar irradiation.

$$\eta_{th} = \frac{Q_u}{Q_s}$$

2. EXPERIMENTAL SETUP AND WORKING

2.1 Selection of Materials

A crucial component of the design and construction of parabolic trough collectors (PTCs) is the material choice. The chosen materials should have characteristics that satisfy the demands of PTC components, such as reflectors, support structures, receiver tubes, and heat transfer fluids. It's crucial to think about things like mechanical and thermal qualities, cost, availability, durability, compatibility with other components, and environmental considerations while choosing materials. Materials should also be assessed for their ability to be manufactured, maintenance needs, and possibility for recycling or reuse.

2.2 Components of PTC

Experimental setup includes –

1. Parabolic Trough Reflector
2. Wooden Supports for Trough Reflector
3. Receiver Tube
4. Tap/Valve
5. Pipes/Elbows

Parabolic Trough Reflector

It is a metal sheet that is often composed of steel and bent into a parabola shape. A stainless-steel sheet could be employed in the experimental setup. It belongs to the (SS 204) grade. The sheet can be coated with mirrors because it will be used to reflect solar light, making the surface extremely reflective. By screwing the sheet to plywood sheets with round plywood cuts, it is bent and supported. A heat transfer fluid (HTF) is included in the receiver tube, which is where the concentrated solar radiation is directed after being reflected by the parabolic trough reflector. The concentrated solar energy is absorbed by the HTF, which then heats up and reaches high temperatures. Following that, a heat exchanger is used to transmit the thermal energy of this heated fluid.

Fig -2.1: Reflector

Wooden Supports for Trough Reflector

The parabolic reflector can be supported using a variety of materials. Typically, plywood sheets are utilized because they are lightweight and shield the reflector from the wind. To preserve the bending support for the parabolic sheet, the plywood sheets are cut into a semi-circular form. The material also makes up the stand that is below the reflector. The stand could be disassembled for travelling purposes because of the way it was built. The reflector's weight and stress must be supported by wooden supports that are strong enough to handle them. The reflector, especially in windy places, can be large and subject to wind loads. To ensure that the wooden supports can effectively withstand the load, careful engineering and design considerations must be made.

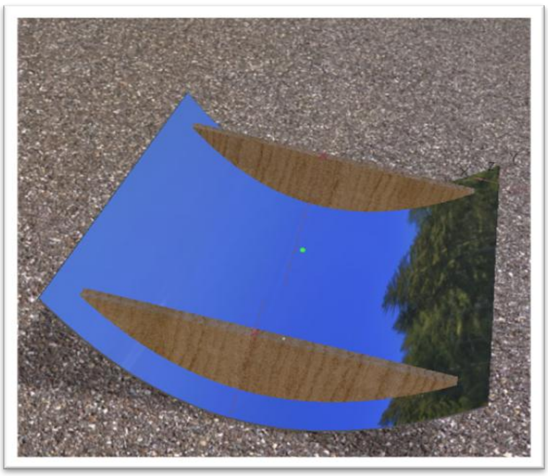

Fig -2.2: Reflector Upper Support Stand for Parabolic Shape

Fig -2.3: Reflector Support Stand Extended View

Receiver Tube

The receiver tube is the part that absorbs thermal energy and transmits to the flowing fluid. Focusing requires special attention. The material of the receiver tube affects the optical and thermal performance of the collector. The receiver tube can also be coated with a matt black heat resistant PU paint. A copper tube is used for the receiver. Receiver tubes are exposed to high temperatures, typically 300°C to 550°C, depending on the specific application and PTC system design. So the receiving tube must be able to do this and can withstand such high temperatures without deforming or compromising its structural integrity. Here is the CAD model of the assembly and the actual model.

Fig -2.4: Absorber tube Strip Placement and Mounting

Fig -2.5: Actual Rod

Tap/Valve

In a Parabolic Trough Collector (PTC) system, valves or faucets are essential components for controlling liquid flow in the system. The specific type and configuration of valves and cocks used in a PTC system will depend on factors such as system design, size, and operating requirements. Common types of valves and cocks used in PTC systems include ball, gate, globe, and control valves. These valves can be operated manually or automatically with a remote control and actuators for precise adjustment. Proper valve and tap selection, installation, and maintenance are critical to ensuring the reliability and efficiency of your PTC system. Material compatibility, pressure and temperature ratings, fluid properties, system safety requirements, etc. must be considered when selecting a valve or faucet for a PTC system.

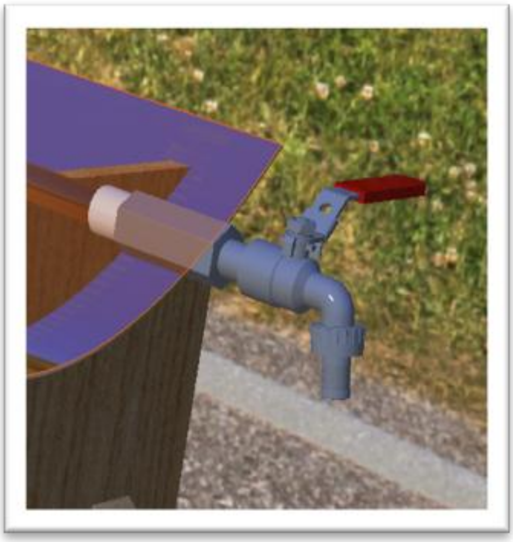

Fig -2.6: Valve/Tap

Pipes/Elbows

A parabolic trough collector (PTC) system's fluid circulation and heat transfer operations depend heavily on pipes. Pipe sizing, insulation, material choice, and pressure drop are the crucial components of pipes and valves include pipe joints and fittings, piping layout, and piping arrangement. When constructing and installing pipes in a PTC system, it's necessary to follow all applicable laws, standards, and safety regulations. To guarantee the dependability, effectiveness, and safety of the piping system, thorough engineering analysis, including pressure drop calculations, thermal modelling, and stress analysis, should be carried out.

2.3 Instruments And Devices for Measurement

A variety of parameters need to be measured in order to observe how the setup operates. A set of precise instruments is required in order to measure anything.

a) Thermocouples for temperature and heat-related parameters.

b) Volumetric tank for mass flow measurement.

c) A stopwatch to check time-related limits.

d) Thermometer

2.4 Assembly

It is significant to keep in mind that the particular assembly procedure can change depending on the manufacturer, design constraints, and project needs. When assembling a PTC system, it is advised to adhere to the manufacturer's instructions and seek the advice of knowledgeable experts to ensure appropriate component installation, alignment, and performance. This will help the PTC withstand strong winds and rain. Body fitting should be improved without sacrificing any components. The fluid should be flowed properly. Water leaks, pipe damage, and other issues need to be addressed. Focusing on solar radiation requires a level mounting surface. Thorough testing and commissioning processes are carried out when the assembly is finished to ensure the functionality and performance of the PTC system. This may include tests to assess solar concentration, thermal efficiency, fluid flow rates, pressure levels, and system safety. Here is the cad model of assembly and actual model.

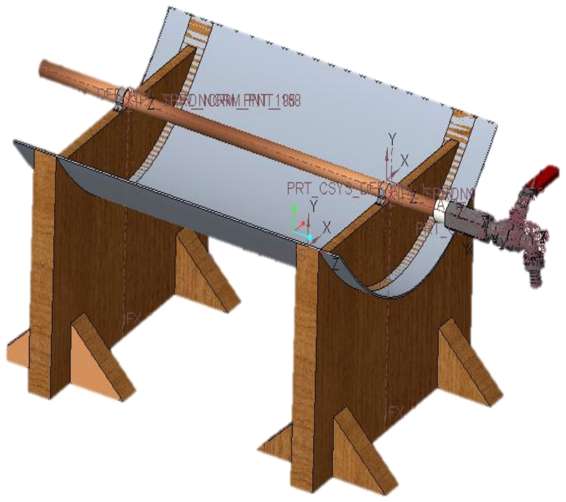

Fig -2.7: Assembly

Fig -2.8: Actual Model

Table -1: Technical Specification of solar parabolic trough Collector

Parameters	**Specifications**
Reflector Material	Stainless Steel (Grade – 204)
No. of Mirrors	1
Focal Length	360.12 cm
Linear Diameter	1199.08 cm
Diameter	1100
Depth	210
Volume	99784836.66
Focal Length / Diameter	0.33
Area	950331.8 cm2
Absorber Material	Copper
Absorber length	91.44 cm

2.5 Working

A PTC is a line-focusing type of reflector that directs sunlight into a straight line after it hits a parabola-shaped reflector. The parabola's focal point is where the sun's radiation is concentrated. By placing a receiver tube near the focal point, it is possible to extract the thermal energy contained in solar radiation. The material used to construct this receiver has good heat conductivity. It transports the fluid inside with heat from the sun's rays. A metal or wooden stand supports the entire setup. To capture the most solar radiation, the reflector's acceptance angle is manually adjusted. The deflected light from the reflector is focused first on the supporting mirrors, then on the collector. This boosts the sun's energy intensity.

3. BILL OF MATERIAL/COSTING

Table -2: Overall Cost of PTC

Sr. No.	Name Of the Component	QTY	COST
1	Wooden Stand	4	500
2	Wooden Supp. Frame	2	800
3	Wooden Upp. Frame	2	300
4	Flow Control Valve	1	100
5	Cupper Rod	1	300
5	Pipes/Elbows	2	150
6	Metal Pipe Holder	2	50
7	Screws	4	50
			Total- 2250

4. RESULT

The experiment, aimed at creating an inexpensive parabolic trough collector for home use using specular reflectors, copper tube absorbers and a mirror assembly, was considered successful and allowed water to drop significantly to 75 degrees Celsius. can be accomplished without major problems. Consider that not so high quality materials were used due to budget constraints. Our parabolic trough collector is very light and portable, allowing us to record heating phenomena at different locations, under different weather conditions and time frames. Below are the test results.

The wind speed was 9 km/hr. and the weather was clear and sunny, humidity on 31.7% and outside temperature was 38°C and cloud coverage was 10%. at Nagpur Maharashtra.

Table -3: Temperature variation wrt to time of water and absorber pipe.

Time (in Hour)	Tw (water temp in deg. Cel.)	Tp (absorber pipe Temp in deg. Cel.)
10:30	27.3	27.3
11:00	37.1	39.2
11:30	45.6	47.8
12:00	54.3	55.8
12:30	65.1	67.5
01:00	66.2	68.9
01:30	68.6	71.3
02:00	70.5	73.5

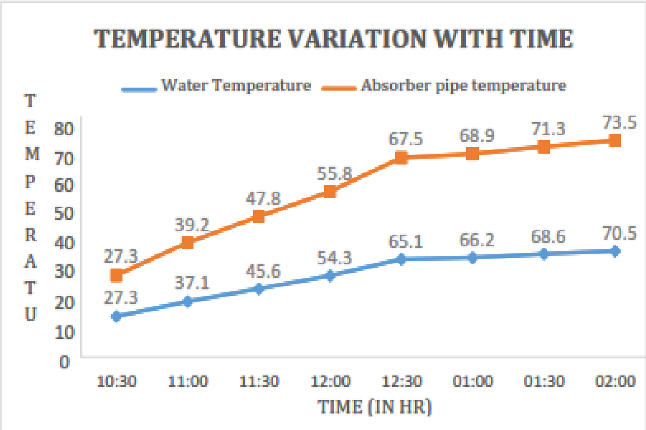

Chart -1:: Theoretical estimation of performance of PTC assisted with mirrors on November 23, 2022

5. COCLUSION

This paper wraps up a succinct analysis of the different geometrical and thermal characteristics of the parabolic trough collector. The structure of the PTC, which can increase efficiency and reduce working costs, is its most crucial component. The working fluid, also known as heat transfer fluid (HTF), is the second-most important factor. Water is typically used as a heat transfer fluid. Although. The reflector has a significant impact on the PTC's performance. Polished SS-204 sheet, aluminium foil, and silver-coated PVC sheet are a few low-cost substitutes. The absorber should be very absorbent with minimal heat loss. The PTC's performance versatility enables it to be applied in a variety of domestic and commercial settings. Mirror integration can also enhance PTC's thermal performance by lowering solar radiation loss.

Based on the literature, we can speculate that nanofluids can be used to improve performance, but this is an emerging area that still needs to be explored. Parabolic trough collectors replace older solar collector designs. It can replace traditional hot water supply methods.

Our experiment is developed with the goal of providing an in-depth examination of PTC and multiple applications utilizing a parabola with a mirror finish and an evacuated tube configuration in mind. The performance of the structural and optical performance, thermal performance, and applications are the essential parameters of a PTC that are summarized in graphical form as shown above. 700 ml of fluid can be produced while it is still in the pipe. In order to execute a constant flow through the pipe and obtain continuous water heating, more research is required. PTC structure is considered to be the most important parameter for PTC design, cost and performance. Structural changes can improve performance and reduce running costs. The heat transfer fluid is his second most important parameter, as our work has shown. Water is the most common working medium. With stainless steel in this case, the reflector would be the most expensive part of his PTC. The receiver should have low heat loss and absorb high levels of radiation. Glass tube covers, selective coatings on receiver tubes, pin-fin inserts, and porous media within the tubes can also be used to improve PTC efficiency. The Parabolic Trough Collector (PTC) is an established technology that harnesses solar energy and converts it into usable heat energy. Throughout this discussion, we have explored various aspects of PTC, including design, components, operating principles, and experimental considerations.

6. REFERENCES

1) Devender Kumar & Sudhir Kumar, 2017, Thermal performance of solar parabolic trough collector at variable flow rates: An experimental investigation.

2) H. Jafari Mosleh a , S. Jahangiri Mamouri a , M.B. Shafii a, 2015, A. Hakim Sima b, A new desalination system using a comb ination of heat pipe, evacuated tube and parabolic through collector.

3) Ali Jaber Abdulhameda,b,⁎ , Nor Mariah Adama , Mohd Zainal Abidin Ab-Kadira , Abdul Aziz Hairuddina, 2018, Review of solar parabolic-trough collector geometrical and thermal analyses, performance, and applications

4) Sunil Nain , Vishal Ahlawat , Sanjay Kajal , Parinam Anuradha , Ashutosh Sharma , Tej Singh, 2021, Performance analysis of different U-shaped heat exchangers in parabolic trough solar collector for air heating applications.

5) Sahil Thappa1 · Aditya Chauhan1 · A. Sawhney2 · Y. Anand1 · S. Anand1, 2020, Thermal selective coatings and enhancement characteristics for efficient power generation through parabolic trough collector.

6) Dinesh Kumar Suppan & R. Siva Subramanian, 2020, Performance analysis of parabolic trough solar collector by varying the absorber surface

7) A.V. Arasu and T. Sornakumar, "Design, manufacture and testing of fiberglass reinforced parabola trough for parabolic trough solar collectors", Sol. Energy, 2007, 8(10): 1273-1279.

8) K.S. Reddy and K.R.K, "Solar collector field design and viability analysis of standalone parabolic trough power plants for Indian conditions", Energy Sustain Dev, 2012, 16(4): 456–470.

9) Kumaresan G, Sudhakar P, Santosh R and Velraj R, "Experimental and numerical studies of thermal performance enhancement in the receiver part of solar parabolic trough collectors,", Renewable Sustainable Energy Reviews, 77(March):1363–1374.