

# Heat Transfer Enhancement in Parabolic Collector Receiver Tube: A Review

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Submitted: 01-06-2022

Revised: 10-06-2022

Accepted: 15-06-2022

**ABSTRACT:** The parabolic trough collector (PTC) is the well-developed and cost-effective solar concentrating technique for medium and high temperature levels (150-400°C). This paper discusses a review of solar parabolic trough collectors, with a particular focus on the various methods of enhancement of heat transfer in solar parabolic trough collector absorber tube by employing artificial roughness at the inner diameter of the collector receiver and compared to smooth tubes. The analysis will be executed with computational fluid dynamics (CFD) method in ANSYS CFX software and designed of collector receiver will be done by PTC Creo 2.0 software.

**KEYWORDS:** Parabolic trough collector (PTC), Twisted tape, Sine Shape, Computational fluid dynamics (CFD), LCR, LS-2, Thermal loss, Aperture

## I. INTRODUCTION

Solar thermal power is the most important renewable energy source which utilize the concentrated solar radiation. A heat engine, works as the main driver for an electric generator which powered by the concentrated solar radiation. As a result, concentrated solar power is conceptually quite similar to conventional and traditional fossil-fuel-based power generation. Both rely on heat energy being transformed into mechanical energy, which is then converted into electrical energy.

The concentrated solar thermal energy can be utilized by four main technologies:

- Parabolic trough systems
- Solar tower systems
- Stirling solar dish systems
- Linear Fresnel systems

The solar collector absorb the sun radiation and convert it to heat, which it then transfers to the working medium. Water, oil, air or organic solvents

may be used as the working medium. The heat energy in the solar collector's working medium, which is in the form of thermal energy, can be used for various applications.

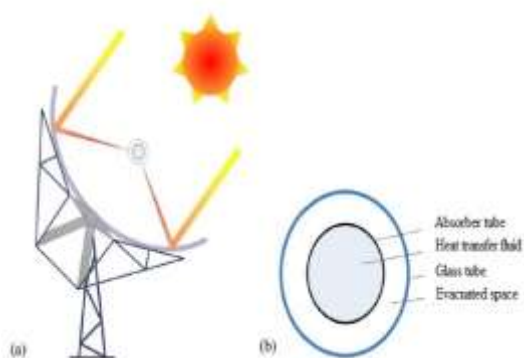
In PTC, the focal line or absorber tube can reach temperatures of 350–400°C. The solar collector efficiency describes with the help of concentration ratio. The concentration ratio is the ratio of effective area of the aperture to the surface area of receiver. The further investigation on the PTC which has a better heat absorption capacity than flat plate collector.

So we need to increase heat transfer rate for the parabolic trough collector by using ANSYS CFX software method, by create artificial roughness in the tube of different size and shape which also improves the overall efficiency of parabolic trough collector.

## II. LITERATURE RIVEIW

The current chapter describes about various researches conducted in the efficiency improvement and design improvement of Parabolic Trough Collector. The methods of investigation used were experimental, dimensional analysis and numerical analysis.

[1] Jian Jin et al (2017) proposed a new method of analyzing the performance of PTC using the principal of similarity principles and dimensional analysis. The method provides new possibilities for solar thermal research by demonstrating that experiments on PTC using reduced scale. The simulation results showed that increasing direct normal irradiance boosted collector efficiency.



**Fig. 1: (a) parabolic trough solar collector unit, (b) Cross section of collector tube (Jian Jin et al., 2017)**

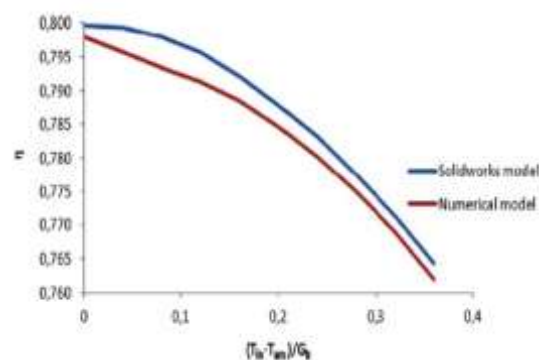
[2] Houcine et al (2017) simulated optically the model of parabolic trough collector (PTC) system using computational method Ray Tracing 3 Dimensional 4 Rays (RT3D-4R) techniques to examine the heat flux distribution along the PTC system receiver tube. In the present study, the local concentration ratio (LCR) and the heat flux density distribution on the absorber tube surface were investigated to validate the proposed method. Also, the effects of the geometric concentration ratio and the rim angle on the heat flux density distribution and on the total intercepted solar energy on the receiver tube were analyzed and investigated.

[3] Wang et al (2017) proposed the on-site method to examine optical efficiency of large size parabolic trough collectors (PTCs). This technique is based on energy balance of heat gain, optical loss, incident solar radiation, heat loss, cosine loss and end loss. The optical efficiency of the 300 KW experimental PTC rig was found to be 76.15 % which agrees with that of LS-3 collector of 77%.

[4] Bellos et al (2015) investigated the use of various internal longitudinal fin configuration in the absorber tube of the LS-2 PTC by varying their lengths and thickness and simulated in Solid works Simulation software to evaluate their heat transfer characteristics. This leads that both higher length and thickness fins having higher thermal enhancement and higher pressure losses. The effect of heat transfer enhancement and pressure drop both are studied with varying the number of fins and also its geometrical configurations. The maximum thermal efficiency was determined to be 68.80% with Nusselt number 1.682 times greater than the smooth case while pressure drop and friction factor were found to be twice as compared to smooth case.

[5] C. Tzivanidis et al (2015) simulated the small parabolic trough collector model to determine the optical and thermal efficiency using Solidworks

software which simulates complex problems with the help of finite element method and compared the efficiency curve to one-dimensional numerical model. The collector efficiency and optical efficiency were determined to be 80 % and 75% which are verified using numerical model.



**Fig. 2: Efficiency curve of the collector and comparison with the numerical model (C. Tzivanidis et al., 2015)**

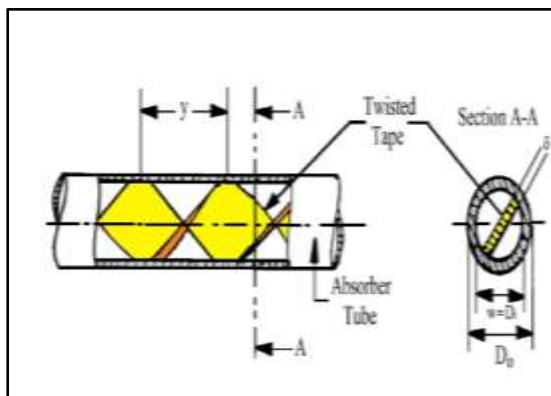
[6] W. Fu et al (2017) used ANSYS CFX software to simulate the effect of wind load on the deformation of the reflecting mirrors for the PTC with torque box and modified the design to reduce torque box weight. The simulation result showed that the collector's performance has improved, its weight has been reduced by 5.8% and its maximum deformation has been reduced by 4.6% with the proposed new design.

[7] Abad et al (2015) investigated the performance of PTC with absorber tube filled with metal foam in order to optimise the thermal efficiency and enhance the heat transfer rate. The experiment was carried out at varied volume flow rates ranging from 0.5 to 1.5 Lit/min, with the ASHRAE 93 standards utilised to evaluate the results. In addition, the Friction factor and Nusselt number for both cases were calculated. The efficiency increased as the mass flow rate was increased, and the same thing happened when the absorber was filled with metal foam. Metal foam reduces the overall loss co-efficient by 45%, resulting in increase in heat transfer rate.

[8] Bellos et al (2017) used  $Al_2O_3$  and  $CuO$  nanofluids, as well as the thermal oil Syltherm 800, to evaluate the application of nano fluids in PTC. A detailed thermal model is developed in EES (Engineering Equator Solver) and its results are validated with experimental results for various inlet temperatures from 25°C to 325°C for the cases mentioned. The analysis showed that both

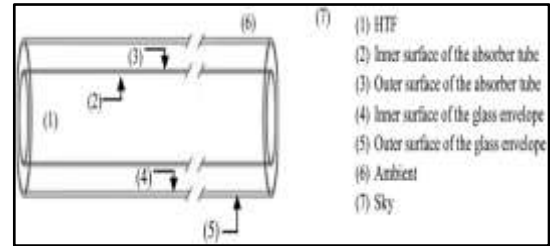
nanofluids perform better with CuO nanofluids, with Syltherm 800 coming out on top. The use of nanofluids instead of thermal oil resulted in a 50% increase in heat transfer, which was observed to rise with increasing temperature. When the concentration ratio is maximised and the flow rate is low, CuO increases efficiency by 1.26 percent, whereas  $Al_2O_3$  increases efficiency by 1.13 percent.

[9] Jaramillo et al. (2016) implemented the twisted tape inside the tube to enhance the heat transfer rate in the receiver tube. A twisted tape is inserted in the receiver tube to augment the heat transfer rate as a passive way, so that the flow rotates in an axial direction which modifies the Reynolds and the Nusselt numbers of the flow in order to produce a high convection heat transfer rate between the receiver and the thermal fluid as shown in fig. 3.



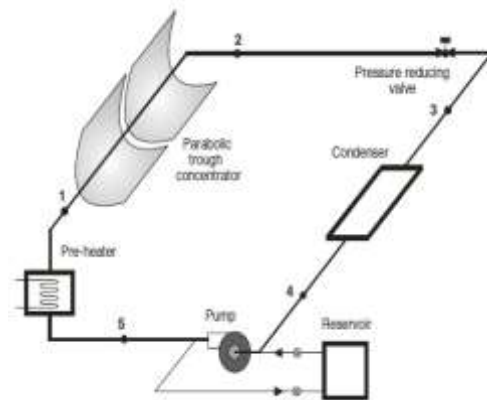
**Fig. 3: Schematic representation of the Twisted Tape insert (Jaramillo et al., 2016)**

[10] Siqueira et al (2014) used a mathematical model to compute the flow parameters and heat transfer in solar parabolic trough collectors, as well as determine the optical and thermal efficiency, thermal losses, and the radial and axial temperature profiles. The one-dimensional analysis system showed in Figure 4 covers all of the parameters of the energy balance between the HTF and the atmosphere that are required to estimate the terms of this balance, which can vary depending on the type of solar collector, the condition of the HCE, optical properties, and environmental conditions.



**Fig. 4: Schematic of a fragment of HCE (De Oliveira Siqueira et al., 2014)**

[11] Filho et al (2014) presented the technique and results of a small-scale parabolic trough collector's thermal losses experimental and numerical analysis. The examined collector is 3 metres wide and 4 metres long, having evacuated tubes with selective coatings. However, small changes in operational conditions and deformation of the parabolic trough's axis had a significant impact on system performance. The fundamental design of the solar parabolic trough system in Figure 5 is a closed circuit with auxiliary equipment that supplies water at a controlled pressure, temperature, and mass flow rate at the collector intake.



**Fig. 5: Parabolic trough systems with pre-heater (Filho et al., 2014)**

[12] Bellos et al (2016) used Solidworks flow simulation method to analyse how nanofluids can improve thermal efficiency, and they looked at three distinct working fluids (thermal oil, thermal oil with nanoparticles, and pressured water) to see how they compare in terms of heat transfer efficiency. As illustrated in Figure 6, the second design of the absorber tube offers a wavy form with sine shape to enhance the inner surface of the tube and therefore increases the heat transfer rate. The turbulence and mixing of the flow inside the tube is improved by this unique design, resulting in a more uniform temperature profile. Furthermore, the sine form aids

in the creation of vortices within the flow, which improves the heat transfer rate.

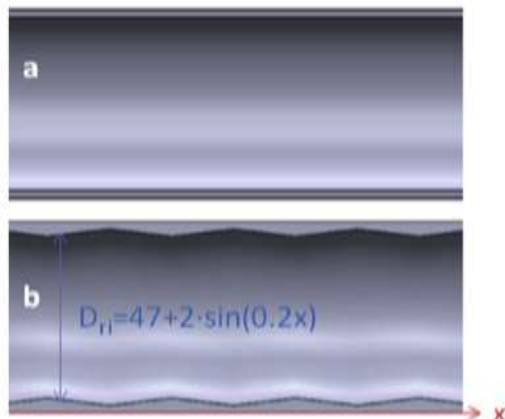


Fig. 6: Converging-diverging tube with sine shape (Bellos E., 2016)

### III. CONCLUSION

I have presented the information about the types of the solar collector and modification of solar parabolic trough collector by using present status.

Related to my study I learned more about the theory of solar collector and its practical application in the real world. I have study more about to parabolic trough collector and the modification done on collector receiver using computational fluid dynamics (CFD) analysis. To heat transfer enhancement of solar parabolic collector receiver, I learned about the ANSYS-CFX and PTC Creo 2.0 software.

There are many different designs of solar collector system in the seminar. Researchers have modified the solar collector system to get a better performance, such as using Monte Carlo method, 3-d ray tracing method and create artificial roughness in the tube to increase the heat transfer rate and also increase the temperature of fluid.

This paper highlights the factors that influence the yield of solar collector. The most important factors include climate, design, and operational parameters. The productivity of the solar collector was determined to be directly correlated to total solar radiation, ambient air temperature and wind speed.

In addition, I have learned about the applications of parabolic trough collector such as air heating system, desalination process, refrigeration system and industrial purposes. The productivity of the collector depends on the types of material which is used for collector to provide effective sun radiation reflection, types of fluid flow in heat collecting element or receiver and also depends on tracking system of solar PTC.

In this paper, I learned wide investigation on solar collector. We discussed modification types of solar collector with different part modifies and different technique. Productivity and efficiency of solar collector improve by researcher using different investigation. On the basis of learning experience in this seminar, I will be doing work on create artificial roughness inside the tube by using CFD analysis in ANSYS-CFX software and CAD modelling will be doing on PTC Creo 2.0 to increase heat transfer rate of PTC receiver.

The future scope of work seeks to benefit researchers employing experimental methods for the testing of the parabolic trough solar collectors for validating their results with the numerical and simulation techniques and widening the applications of parabolic trough collectors for newer applications.

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