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Design and Optimization of Solar Absorber Tube Using CFD Analysis

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***Abstract*: Parabolic trough solar collector is a solar thermal collector which works on solar energy, the efficiency of this collector depends on the thermal energy of sun. The main objective of this work to present an upto date literature review on the parabolic trough solar collector. During the literature survey from the various research paper related to parabolic trough solar collector it has been observed that there is a lot of research work have been done in the same field and still there is a large scope to work on the parabolic trough solar collector. From the literature review it has been also observed that many authors worked on numerical as well as experimental setups, many of them use various optimization technique which was validate by various simulation tools like ANSYS, computational fluids dynamics tool Fluent and many more.**

Keywords: Parabolic Trough Collector, Cfd Analysis, Solar Radiation, Absorber Tube Etc.

1. INTRODUCTION

A Parabolic trough solar collector is a type of solar thermal collectors which are straight in one dimension and it also curved in parabolic shape.

But in actual practice, these lines are pipes in which liquids are flowing which absorbed the heat coming from solar energy and that heated fluids are used for some specific applications.

The working principle of parabolic trough solar collector is shown in figure no. 1. Parallel rays of sunlight strike on the parabolic concentrator and after reflection it is focused on a point which is called focal point of this concentrator.

Since these concentrated rays are in one dimensional line it produce much more heat of thermal energy which can be used for various application such as to operate heat engines to drive machineries or to generates electricity, it can also used in process industries for drying food products and many more.

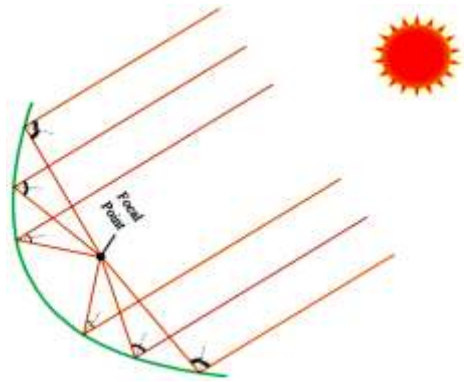

Figure 1: Working Principle of Parabolic Trough Solar Collector

2. LITERATURE REVIEW

Fadi A. Ghaith, Haseeb-ul-Hassan Razzaq [1] addresses the potential of integrating the Parabolic Trough Collectors with a double effect absorption chiller for the purpose of space cooling in residential buildings. A bio mass heater was used in absence of sun as an auxiliary heating source. The obtained results from the numerical simulation were analyzed to identify the optimum configuration in terms of feasibility and potential savings.

Seyed Ebrahim Ghasemi, Ali Akbar Ranjbar [2] in this paper, A forced convection heat transfer from nano fluid flowing inside the receiver of solar parabolic trough collector is numerically simulated. A CFD analysis was performed for nano fluid and find thermal efficiency of the solar system. The results reveal that by increasing of the nano particle volume fraction, the average Nusselt number increases.

Zhiyong Tian at el [3] To maximize the advantages of flat plate collectors and parabolic trough collectors in large solar heating plants for a district heating network, a hybrid solar collector field with 5960 m^2 flat plate collectors and 4039 m^2

parabolic trough collectors in series was constructed in Taars, Denmark. The thermal performance of both collector fields with weather data of a design reference year was simulated to have a whole understanding of the application of both collectors under Danish climate conditions as well.

Bin Zou at el. [4] this study found that the end loss caused by the incident angle weakens the optical efficiency. Larger aperture width and smaller absorber diameter will cause greater end loss for constant incident angle.

Fahim Ullah, Min Kang [5] the experiment was carried out with the three levels of air mass flow rates, F_1, F_2 and F_3 and two levels of a diameter of the absorber, D_1 and D_2 with the concentration ratio of 60. it has been observed that the highest mean efficiency of 23 % was recorded with the air mass flow rates of at F_1 = 3.50 kg.min^{-1} and the mean minimum efficiency 19.6 % was noted for the air mass flow rate at F_3 = 1.5 kg.min^{-1}

Hongbo Liang at el.[6] In this work four different optical models (Monte Carlo, FEM, Change Photon Energy Method & MCM) were constructed with a novel coupled method which was suited to carry out a mass of optical simulations of collectors with different geometrical parameters rapidly and accurately.

Wanjun Qu at el. [7] In this work a 300 kWth solar parabolic trough collector with north-south and rotatable axis tracking is originally presented. The experimental results show that by using the rotatable axis tracking the daily average efficiency can be enhanced from 43% to 48%.

Hongbo Liang at el. [8] A transient heat transfer model was established for the parabolic trough solar collector. The dynamic performance of a PTC was simulated for three different sun-tracking systems in various climate regions according to building thermal design and solar energy distribution in China. It has been observe that the annual efficiency and net heat gain is much better by using system with two axes sun tracking were 1.63~1.75 and 1.70~1.93.

Jian Jin, Yunyi Ling & Yong Hao [9] Six dimensionless numbers for the PTC are derived and are used to build a scaled PTC model. Experimental data from the literature are employed to calibrate the numerical model. Compared with the results of four typical cases of non-scaled experimental data obtained from the literature, differences in average efficiencies of the scaled-down models are within 0.75%. The simulation results indicate that the collector efficiency increases with the augmentation of the DNI whereas it decreases with the increase in DTab.

Seyed Ebrahim Ghasemi & Ali Akbar Ranjbar [10] three dimensional turbulent flow for Syltherm heat transfer fluid in absorber tube of solar system with turbulators is simulated. The results show that the heat transfer characteristics of PTC enhances by inserting the porous rings in tubular solar absorber.

Syed Ameen Murtuza at el.[11] evaluate the performance of a designed 5m length PTSC model. It was observed that March to May yielded better outlet temperatures ranging from 93 °C to 103 °C. It was seen that February to May gave good surface and outlet temperatures with laminar flow of liquid.

Michael Andre at el.[12] in this work researcher perform both one way and two way coupled fluid structure interaction simulations corresponding to rigid and aero-elastic models. They find that significant self excited vibrations occur for certain pitch angles.

G. Kumaresan at el. [13] detailed review of the experimental and numerical works carried out on heat transfer enhancement techniques focus to minimization of heat loss. Use of turbulators, addition of nano fluid and selective coatings in the receiver tube of a solar PTC are presented.

Gong Xiangtao at el. [14] to validate the feasibility of the developed MCRT and FVM combined method; the numerical results have been compared with experimental results conducted in the DISS test facility in Spain. The numerical results indicated that by using absorber tube with pin fin arrays the overall heat transfer performance factor can be increased up to 12.0%.

Camilo A. Arancibia-Bulnes at el. [15] A review of the optical characterization techniques that have been developed for solar concentrators is presented. The strengths and possible vulnerabilities of the techniques are also discussed. Finally an analysis of the available information about the accuracy and precision of the different methods is carried out.

L. Salgado Conradoat el. [16] This report presents an up-to-date review on the thermal performance of PTC collectors. Various types of mathematical models and experimental setups of the Parabolic Trough Solar Collectors were reviewed. The heat loss, environmental conditions, temperature and heat flux have been studies with cost analysis and economic strategy is presented.

Ahlem Houcine at el. [17] A detailed computational method Ray Tracing 3Dimensions-4Rays of parabolic trough collector system based on the ray tracing techniques is presented and developed to determine the heat flux distribution along the PTC system receiver tube. a one axis tracked and dual tracked PTC system were investigated for different geometric concentration ratio and rim angle for the Monastir city, Tunisia.

Aggrey Mwesigye, Zhongjie Huan & Josua P. Meyer [18] a thermodynamic analysis using the entropy generation minimization method for a parabolic trough receiver tube making use of a synthetic oil–Al_2O_3 nano fluid as a heat transfer fluid are presented. result shows that using nanofluids improves the thermal efficiency of the receiver by up to 7.6%.

Sourav Khanna, Suneet Singh & Shireesh B. Kedare [19] Using the distribution of solar flux on the absorber tube incorporating the effects of Gaussian sun shape and optical errors, explicit expressions for finding the absorber's temperature distribution and corresponding deflection in the central axis of absorber tube are derived in the current work. Two conditions are considered: (i) the ends of absorber tube are allowed to rotate in the planes passing through focal line of the trough and (ii) rotation is not allowed.

P. Mohammad Zadeh at el. [20] this work focuses on the development of an efficient modeling and optimization of solar collector. The optimization problem used in this study involves maximization of a non-dimensional correlation consisting of Nusselt number and pressure drop with Reynolds and Richardson number which are used as design constraints.

Aranzazu Fernandez-García at el. [21] This study addressed the specific design of a small sized industrial PTC with a flat transparent cover in the aperture plane. Three different PTCs with the same basic geometry were analyzed by numerical simulation. Two of them had glass receiver tube covers, one with an additional flat cover in the aperture plane and the other one without it.

Yacine Marif at el. [22] two fluids was considered, liquid water and Therminol VP-1™ synthetic oil. The intensity of the direct solar radiation was estimated by monthly average values of the atmospheric like turbidity factor for different tracking systems. According to the simulation findings, the one axis polar East–West and horizontal East–West tracking systems were most desirable for a parabolic trough collector throughout the whole year.

Ramchandra G. Patil at el. [23] this paper contains a numerical study of heat loss from a non-evacuated receiver typically used in parabolic trough collectors. The mechanisms of heat loss considered in this study are (1) pipe to glass tube by conduction, convection and radiation and (2) glass tube to surrounding by convection and radiation. Comparison of heat losses in non-uniform and uniform temperature cases shows that the values of heat losses in the two cases differ only by 1.5%.

Yanjuan Wang at el. [24] In this work a three-dimensional simulation based on Finite Element Method is established to solve the complex problem coupling with radiation, heat conduction and convection in the PTCs. it can be found that the circumferential temperature difference of the absorber increases with the rising of the direct normal irradiance and decreases with the increase of heat transfer fluid inlet temperature and inlet velocity. With the velocity of the molten salt in the range of 1 m/se4 m/s, the DNIs of 500 W/m2e1250 W/m2 and the inlet temperature of 623 K e825 K, the CTD of the absorber can reach 12 Ke42 K.

G.C. Bakos & D.A. Petroglou [25] This paper deals with the technical feasibility and economic viability of a solar thermal power plant using parabolic trough collectors in Greece. The power plant is to be installed in the island of Rhodes and its power output will be 8.55 MW. Power plant simulation is carried out using TRNSYS software. It was found that for the particular investment, considering a 75% of initial investment cost loan, the payback period will be approximately 13 years.

Aggrey Mwesigye, Tunde Bello-Ochende & Josua P. Meyer [26] a numerical investigation of thermal and thermodynamic performance of a receiver for a parabolic trough solar collector with perforated plate inserts is presented. The analysis was carried out for different perforated plate geometrical parameters including dimensionless plate orientation angle, the dimensionless plate spacing, and the dimensionless plate diameter. the modified thermal efficiency increases between 1.2% and 8%.

David H. Lobón, Loreto Valenzuela & Emilio Baglietto [27] this work introduces a computational fluid dynamic simulation approach to predict the behavior of a solar steam generating system, which is located at the Plataforma Solar de Almería, Spain. The STAR-CCM+ code used to implement an efficient multiphase model capable of simulating the dynamics of the multiphase fluid in parabolic-trough solar collectors.

Zhiyong Wu at el. [28] the detailed temperature distribution of a parabolic trough receiver is successfully simulated by combining a MCRT code and FLUENT software. the transient behaviors of parabolic trough receiver under direct concentrated solar irradiance are investigated. The information from this study is of great importance to the design and the optimization of the structure of parabolic trough receiver, as well as to identify the causation of parabolic trough receiver's failure.

A.A. Hachicha at el. [29] a detailed numerical heat transfer model based on the finite volume method for these equipment is presented. In the model, the different elements of the receiver are discredited into several segments in both axial and azimuthal directions and energy balances are applied for each control volume. The optical model is compared with known analytical solutions. The performance of the overall model is tested against experimental measurements from Sandia National Laboratories.

Aggrey Mwesigye at el. [30] This paper presents results of a numerical analysis of entropy generation in a parabolic trough receiver at different concentration ratios, inlet temperatures and flow rates. Results show a reduction in the entropy generation rate as the inlet temperature increases and the optimal flow rates at which the entropy generated is minimum are presented for different flow rate and concentration ratio, and the results are the same irrespective of the inlet temperature considered.

Dongqiang Lei at el. [31] The Institute of Electrical Engineering Chinese Academy Sciences and Himin Solar Co. Ltd. cooperated to develop solar receivers for the first 50MW parabolic trough project in Inner Mongolia, China. This paper presents a new testing method to accurately test the coating emittance. A heat loss comparison between the receiver and other existing receivers provides a reference that enabled further optimization. Theoretical and experimental analysis examines the effects of end loss both with and without a heat insulator and a coil heater.

P. Wang, D.Y. Liu & C. Xu [32] the present numerical simulation investigates the effect of inserting metal foams in receiver tube of parabolic trough collector on heat transfer. The effects of layout, geometrical parameter, and porosity of metal foams on the flow resistant, heat transfer and thermo-hydraulic performance are analyzed. The maximum circumferential temperature difference on the out surface of receiver tube decreases about 45% which will greatly reduce the thermal stress.

K. Ravi Kumar & K. S. Reddy [33] In this work heat transfer enhancement of line focus solar collector with porous disc receiver is studied with water and therminol oil. A three dimensional numerical simulation of porous disc enhanced receiver is carried out using commercial CFD software Fluent evolve the optimum configuration.

Z.D. Cheng at el. [34] a three-dimensional computational model of the whole parabolic trough solar collector system and corresponding numerical simulations by combining the Finite Volume Method and the Monte Carlo Ray-Trace method were presented. Corresponding codes and solving methods were also developed and applied to simulate and analyze the total involutes photo-thermal conversion process of an experimental LS2 PTC system.

Z.D. Cheng, Y.L. He & F.Q. Cui [35] This study presents numerical computation results on turbulent flow and coupled heat transfer enhancement in a novel parabolic trough solar absorber tube, the unilateral milt-longitudinal vortexes enhanced parabolic trough solar receiver where longitudinal vortex generators are only located on the side of the absorber tube with concentrated solar radiation. It was found that the mechanism of heat transfer enhancement of this novel absorber tube can be explained very well by the field synergy principle.

3. CONCLUSION

From the above studies it has been concluded that lot of research work over the world wide on the topic of parabolic trough solar collector have been done and still its technological development is going on. After reviewing the various literatures from the various research paper related to parabolic trough solar collector it has been observed that still there is a large scope to work on the parabolic trough solar collector. From the literature review it has been also observed that many authors worked on numerical as well as experimental setups, many of them use various optimization technique, some of authors worked on flowing fluids for higher thermal efficiency which was validate by various simulation tools like ANSYS, computational fluids dynamics tool Fluent and many more.

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