Review on Thermal Analysis of Solar Collector

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Abstract— Solar thermal power is one of the most important renewable sources that utilize the concentration of solar radiation. In this aspect the solar collector geometry plays a significant role in improving thermal efficiency of heating device. The current work studies the various researches conducted in optimizing design and material of solar collector geometry used in heating applications to improve its overall performance. The paper also discusses about numerical, experimental and analytical methods used in the study of solar collectors.

Keywords: Solar Collector, Design optimization, Numerical method

I. Introduction

Solar thermal power is one of the most important renewable sources that utilize the concentration of solar radiation. The concentrated solar radiation drives a heat engine that works as the prime move for an electric generator. Thus, concentrated solar power is very close in concept to conventional and traditional forms of power generation that are based on fossil-fuel combustion. Both rely on the conversion of thermal energy to mechanical energy then to electrical energy. Currently, there are four main technologies that utilize the concentrated solar thermal energy: (a) parabolic trough systems, (b) solar tower systems, (c) Stirling solar dish systems, and (d) linear Fresnel systems. Many studies discussed the best performance, design, the parabolic trough (the receiver) to achieve the required temperature. The concentrated energy is then used to boil water into steam, which is usually used to drive conventional electrical generators. The design of parabolic trough relies on many parameters such as solar distribution flux, reflector material of the concentrator, diameter of the parabolic trough concentrator, sizing the aperture area of concentrator, focal length of the parabolic trough, the focal point diameter, sizing the aperture area of receiver, absorber material of the receiver, geometric or area concentration ratio, and rim angle. A solar parabolic trough is described as a long, trough-shaped reflector that has a parabolic cross-section with a slope affected by the rim angle. The trough focuses the reflected sunlight radiation along a line running the length of the trough. In order to collect this heat, a pipe, which is called a receiver, is positioned along the length of the trough at its focus and a heat collection fluid is pumped through it. The receiver tube is designed to absorb most of the energy focused onto it to heat the passing fluid to a higher temperature. Receivers can be made of black-coated steel tubing, insulated by a protective glass cover enclosing a vacuum layer to reduce heat loss. An antireflective coating is important and, in some designs, may be added to the outer glass surface to increase efficiency further. Solar parabolic troughs always have a tracking system, which are usually adjusted with their long axes from north to south and they are mounted on structural supports that allow to track the sun from east direction to west direction during the day hours' time. These supports may be made of steel, aluminum, or other material with higher strength. The solar parabolic trough systems have many advantages such as high-power density, high efficiency, modularity, and versatility.

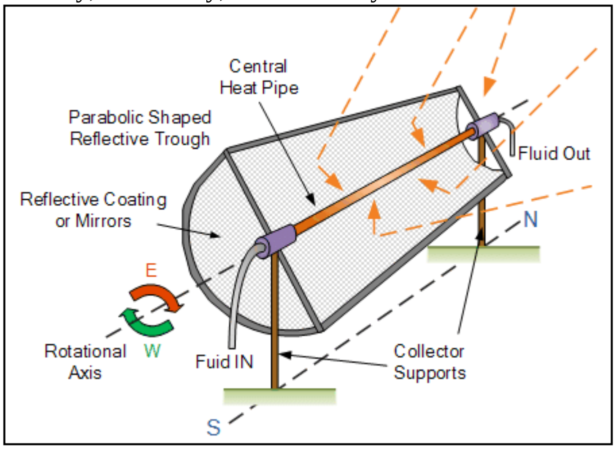

Fig. 1: Solar Parabolic Trough Collector

II. Literature Review

Jian Jin et al[1] proposed a new method of analyzing the performance of PTC using the principal of similarity principles and dimensional analysis. The method provides the new perspective for solar thermal research by demonstrating the possibility of performing experiments on PTC using a reduced scale. The simulation results showed the increased in collector efficiency with augmentation of direct normal irradiance.

Houcine et al[2] simulated optically the model of sun tracking PTC using computational Ray Tracing 3 Dimensional 4 Ray (TR3D-4R) method. The variation of Geometric Concentration Ratio and rim angle on the hourly concentrated solar flux is studied. For the Geometric Concentration Ratio of 50 and an hourly angle of 900, the solar flux was found to be maximum.

Filho et al [3] analysed numerically and experimentally the thermal losses through parabolic trough collector. The One-Dimensional heat transfer model was developed to predict the losses in PTC under steady state conditions.

Wang et al [4] simulated and experimentally verified the on-site test method and thermo-hydraulic model. This method is based on energy balance of incident solar radiation, heat gain, cosine loss, end loss, optical loss and heat loss. The optical efficiency of the 300 kWt PTC rig was found to be 76.15 % which agrees with that ofLS-3 collector(77%).

Bellos et al[5] simulated the small parabolic trough collector model to determine the optical and thermal efficiency using Solidworks software and compared with 1-

D numerical model. The collector efficiency and optical efficiency were found to be 80 % and 75% which are verified using numerical model.

Bellos et al[6] 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 theie heat transfer characteristics. The effect of pressure drop and heat transfer enhancement both are studied with changing the number of fins and also its geometrical configurations. The maximum thermal efficiency was found to be 68.80% with Nusselt number 1.682 times higher than the smooth case while pressure drop and friction factor were found to be twice as compared to smooth case.

W.Fu et al[7] simulated the effect of wind load on the deformation of the reflecting mirrors for the PTC with torque box using ANSYS CFX software and optimized the design to reduce the weight of torque box. The simulation result showed that the performance of thecollector has improved, the weight of the collector was reduced by 5.8% and the maximum deformation of the collector was reduced by 4.6% with the proposed new design.

Abad et al [8] investigated the performance of PTC with absorber tube filled with metal foam in order to improve the thermal efficiency and enhance the heat transfer rate. The experiment was performed for different volume flow rates from 0.5 Lit/min to 1.5 Lit/min and the ASHRAE 93 standards were used to test the performance. Also, the Friction factor and Nusselt number had been evaluated for both the cases. With increasing the mass flow rate, the efficiency was found to increase and the same occurred while using the absorber filled with metal foam. The use of metal foam decreases the overall loss co-efficient by 45% and thus enhancing the heat transfer rate.

Bellos et al[9] investigated the use of nano fluids in PTC using Al2O3and CuO nanofluids along with thermal oil Syltherm 800. A detailed thermal model is developed in EES (Engineering Equator Solver) and its results are validated with experimental results for various inlet temperatures from 250C to 3250C for the cases mentioned. The result showed that both the nanofluids gives best performance with CuO nanofluid with Syltherm 800 being the best. The heat Transfer enhancement of about 50% took place with the use of nanofluids than thermal oil and is found to be increased with increase in temperature. The use of CuO increase the efficiency by 1.26 % while the use of Al2O3by1.13% when the concentration ratio is maximizing and flow rate is relatively low.

Jaramillo et al. [10] improved the heat transfer in the receiver tube by inserting a twisted tape in the tube to increase its thermal. 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. 2.

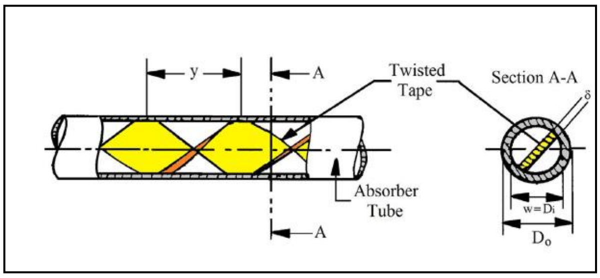

Fig. 2: Schematic representation of the twisted tape insert

Siqueira et al. [11] implemented a mathematical model to calculate the flow parameters and the heat transfer applied to solar parabolic trough collectors and determined the thermal and optical efficiency, thermal losses, among others, likewise present the radial and axial profile of temperature. Fig. 3 described one-dimensional analysis system covers all the parameters of energy balance between the HTF and the atmosphere, necessary to estimate the terms of this balance, which may depend on the type of solar collector, the condition of the HCE, the optical properties and conditions of environment.

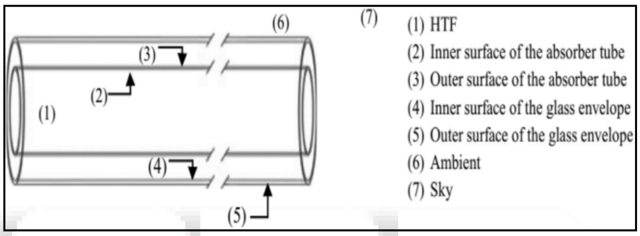

Fig. 3: Schematic of a fragment of HCE

Filho et al. [12] illustrated the methodology and the results of an experimental and numerical investigation of the thermal losses of a small-scale parabolic trough collector. The collector investigated is 3 m wide and 4 m long, with evacuated tubes with selective coatings. However, system performance was very sensitive to small variations in the operational conditions and deformation of the axis of the parabolic trough. The main design of solar parabolic trough system in Fig. 4 consists of a closed circuit where the auxiliary equipment provides water at controlled pressure, temperature and mass flow rate at the collector inlet.

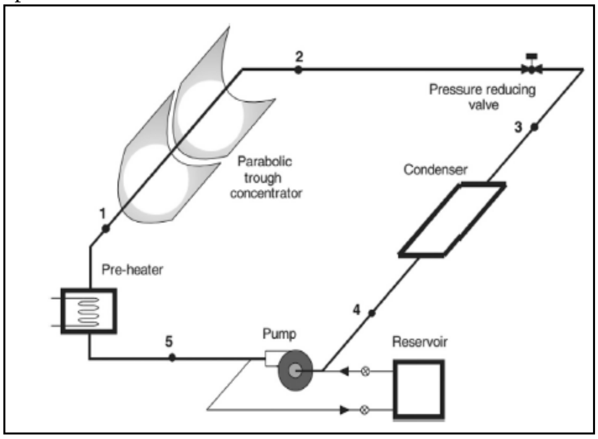

Fig. 4: Parabolic trough systems with pre-heater

III. CONCLUSION

The current study presents researches conducted on various types of solar collectors using experimental and numerical techniques. The findings have shown that collector geometry, inclination angle, absorber tube geometry and thickness of absorber tube have significant effect on heat transfer characteristics like temperature, heat flux and heat dissipation rate.

REFERENCES

[1] Jian Jin, Yunyi Ling, Yong Hao, 2017.Similarity analysis of parabolic-trough solar collectors- Applied Energy 204: 958–965.
[2] Ahlem Houcine, Taher Maatallah, Souheil El Alimi, Sassi Ben Nasrallah.2017.Optical modeling and investigation of sun tracking parabolic trough solar collector basing on Ray Tracing 3Dimensions-4Rays-ustainable Cities and Society 35:786–798.
[3] Victor C. Pigozzo Filho, Alexandre B. de Sá, Júlio C. Passos, Sergio Colle.2014. Experimental and numerical analysis of thermal losses of a parabolic trough solar collector-Energy Procedia 57: 381 – 390.
[4] Ruilin WANG, Wanjun QU, Jie SUN and Hui HONG.2017.An on-site test method for optical efficiency of large-size parabolic trough collectors", Energy Procedia 105: 486 – 491.
[5] C. Tzivanidis, E. Bellos, D. Korres, K.A. Antonopoulos, G. Mitsopoulos.2015. Thermal and optical efficiency investigation of a parabolic trough collector- Case Studies in Thermal Engineering 6 :226–237.
[6] Evangelos Bellos, Christos Tzivanidis, Dimitrios Tsimpoukis.2017. Multi-criteria evaluation of parabolic trough collector with internally finned absorbers-Applied Energy 205: 540–561.
[7] W. Fu, M.C. Yang, Y.Z. Zhu, L. Yang.2015. The wind-structure interaction analysis and optimization of parabolic trough collector-Energy Procedia 69 :77 – 83.
[8] Milad Tajik Jamal-Abad, Seyfollah Saedodin, Mohammad Aminy.2015. Experimental investigation on a solar parabolic trough collector for absorber tube filled with porous media-Renewable Energy 107: 156-163.
[9] Evangelos Bellos, Christos Tzivanidis.2017. Parametric investigation of nanofluids utilization in parabolic trough Collectors -Thermal Science and Engineering Progress 2: 71–79.
[10] Jaramillo OA, Borunda M, Velazquez-Lucho KM, Robles M. Parabolic trough solar collector for low enthalpy processes: an analysis of the efficiency enhancement by using twisted tape inserts. Renew Energy 2016;93:125–41. http://dx.doi.org/10. 1016/j.renene.2016.02.046.
[11] De Oliveira Siqueira AM, Gomes PEN, Torrezani L, Lucas EO, Da Cruz, Pereira GM. Heat transfer analysis and modeling of a parabolic trough solar collector: an analysis. Energy Procedia 2014;57:401–10. http://dx.doi.org/10.1016/j.egypro. 2014.10.193.
[12] Filho VCP, De Sá AB, Passos JC, Colle S. Experimental and numerical analysis of thermal losses of a parabolic trough solar collector. Energy Procedia 2014;57:381–90. http://dx.doi.org/10.1016/j.egypro.2014.10.191.