Enhancement of Heat Transfer Performance For Parabolic Trough Solar Collector with Pin Fin Arrays Inserting

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Abstract

Heat dissipation is one of the main problems which we come across while dealing with high load and high speed machines. Because of the work they perform, some amount of heat is generated inside the machine. This heat has to be transferred outside the system to obtained efficient output. If it is not done, then this heat may cause damage to machine parts. To do this, fins are used. Main purpose of fins is to increase surface area of machine so that heat can be transmitted in atmosphere. Tube receiver with pin fin arrays inserting was introduced as the absorber tube of parabolic trough receiver to increase the overall heat transfer performance of tube receiver for parabolic trough solar collector system. The Monte Carlo ray tracing method (MCRT) coupled with Finite Volume Method (FVM) was adopted to investigate the heat transfer performance and flow characteristics of tube receiver for parabolic trough solar collector system.

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Introduction

Solar energy utilization is one of the most effective ways for facing the recent problems in the energy domain which are associated with the global warming, the fossil fuel depletion and the increasing rate of electricity price. Solar energy is abundant energy source which can either to be converted into useful heat and to electricity, the fact that makes it a suitable energy source for numerous applications from domestic hot water production to solar dryers and to electricity production in concentrating solar power plants.

Concentrating solar collectors are the most suitable technology for operation in medium and high-temperature levels (over 150oC) with high thermal efficiency. Among the developed technologies, parabolic trough collector (PTC) is the most mature solar collector type which is used in many applications. PTCs usually operate with thermal oils as Dowtherm, Therminol, Syltherm and Sandotherm, while the last years' applications with molten salts (mainly nitrate salts) have been developed. Thermal oils can operate with safety up to 400oC, while molten salts usually up to 550^{o}C. For achieving higher temperature levels, liquid metals as liquid sodium and gas working fluids (air, carbon dioxide, nitrogen and helium) can be utilized. At this time, the majority of thermal applications with PTC uses thermal oils, as Therminol VP1 and Syltherm 800 because these are the most common and reliable solutions the last years, many techniques have been examined for improving the thermal performance of PTCs. The basic goal of these techniques is to improve the heat transfer conditions between absorber and fluid, increasing the conductivity inside the flow with different ways. Moreover, the increase in the thermal efficiency leads to lower receiver temperature and to lower temperature gradients on it, a fact that reduces the possible deformation problems. In the literature, there are many studies which have been focused on investigating alternative working fluids, as nanofluids for enhancing the thermal performance of PTCs.

METHODOLOGY

Computational Domain

The diagram of the parabolic trough solar collector system with absorbent tube. The linear parabolic concentrators are wont to focus sunlight to heat the pumped-up heat transfer fluid within the absorbent. The good light-weight transmission and heat durability glass envelope are wont to maintain the vacuum house between the absorbent and also the envelope so as to reduce heat loss and prevent corroding. The representation diagram of the parabolic trough solar collector system with PTR is deliberated in Fig. 1. As seen from this figure, the incoming sunlight from the sun is focused on the lowest edge of PTR (red1 area in Fig. 1) by the PTC, whereas the highest edge of PTR (blue area in Fig. 1) is subjected to the non-concentrated solar irradiation. The cross section plan of the PTR is deliberated in Fig. 2

With the aim to enhance heat transfer performance and reduce gradient of PTR, absorbent tube with pin fin arrays inserting is introduced because the absorbent tube of PTR. The structure sketches of absorbent tube with pin fin arrays inserting used for numerical simulation are conferred in Fig. 3.

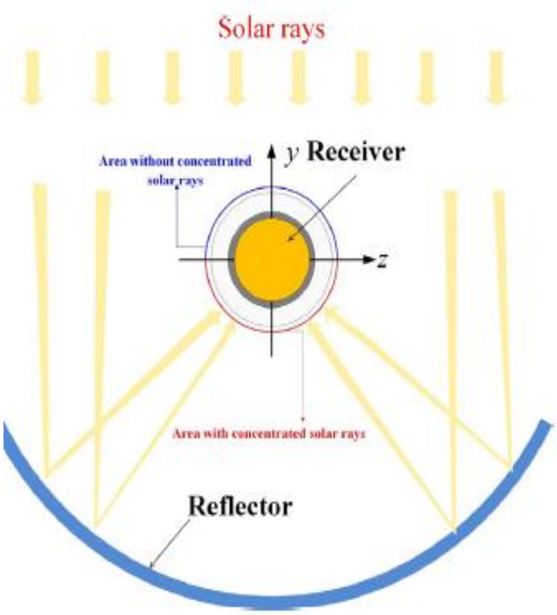


Fig.1 Plan diagram of the parabolic trough solar collector system with Absorber tube

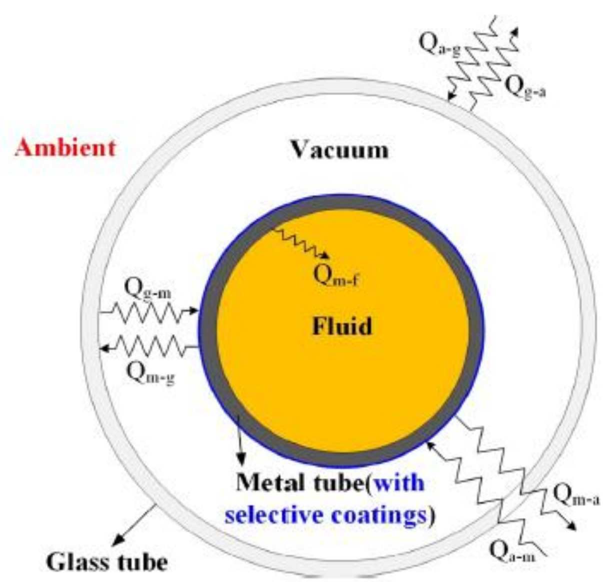


Fig.2: diagram of cross section of the PTR

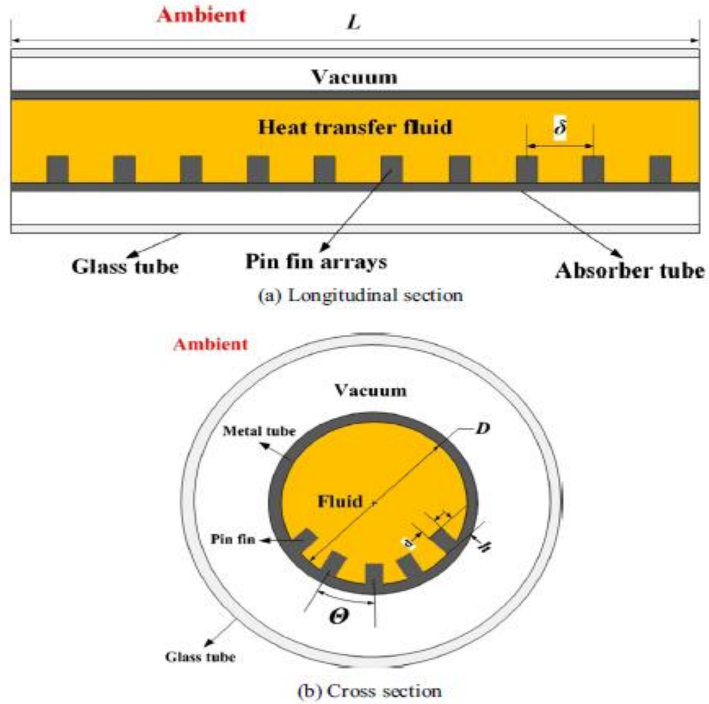


Fig.3 Sketches of absorber tube with pin fin arrays inserting (PFAI-PTR)

CFD MODELLING

Commercially available ANSYS FLUENT v 15.0 was the computational fluid dynamic software working to resolve the anxious general differential equations arithmetically. This software statistically simulates by means of FEM.

Construction of Geometry

The geometry was constructed in Ansys workbench. Firstly, an overview of the pure mathematics while not ribs were created in x-y plane with acceptable dimensions (in mm) so surface was generated from the "built sketches" choice. Then another sketch that concerned the interface between absorbent material plate and fluid was developed. The surface at the start created was split into 2 faces with the assistance of "face-split" choice by selecting the second sketch because the tool pure mathematics. The face-splitting choice was followed by the generation of surfaces from the faces with the assistance of "create surface from faces" choice. Finally, all the sides and surfaces were named consequently.

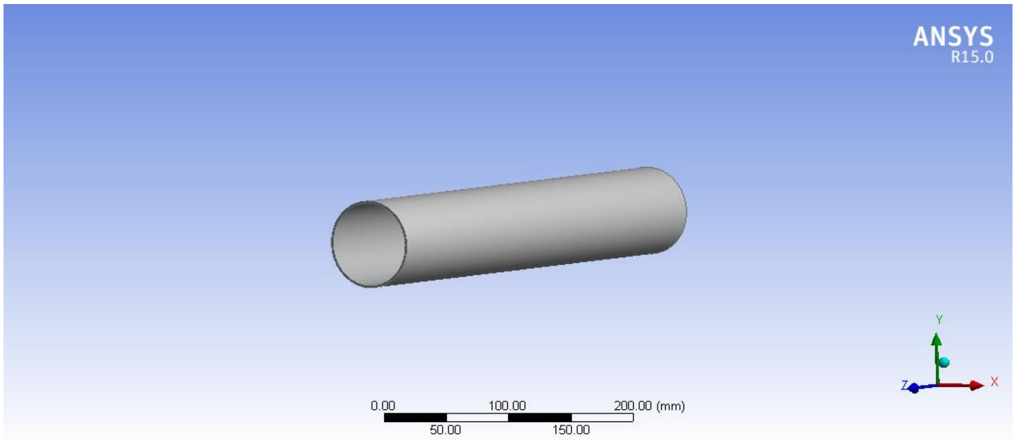


Fig. 4: Model with no rib

Meshing of the Domain

The meshing work was accomplished on commercially offered ANSYS meshing software. The geometry created was imported in ANSYS meshing. The desired variety of divisions and therefore the variety of "bias" were allotted to every edge. Accordingly as to acquire regular rectangular designed mesh cells with the most effective orthogonal quality, planned facing choice was stimulated. To conclude, mesh was produced by clicking on "Generate Mesh" button.

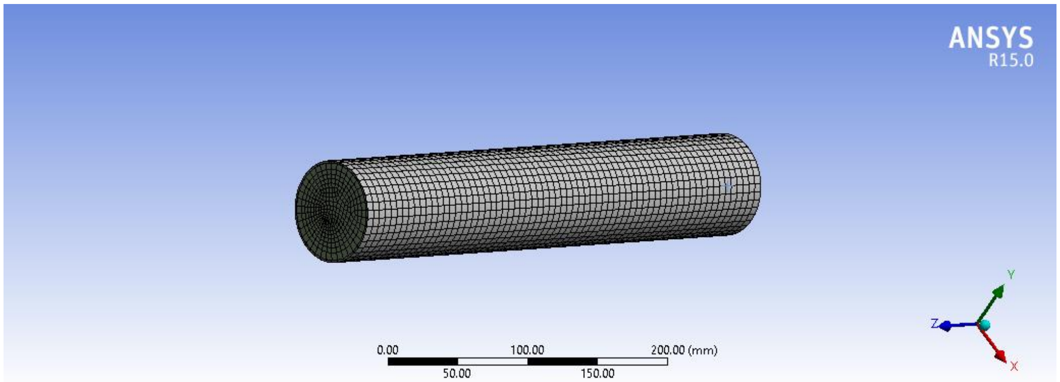


Fig. 5: Mesh model with no rib

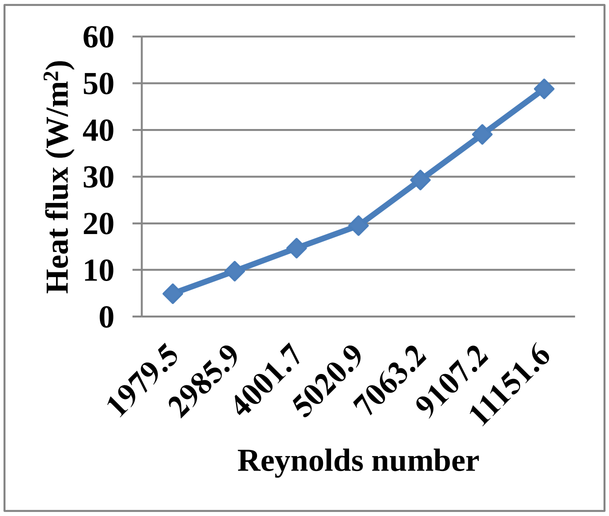
RESULT AND DISCUSSION

Heat Transfer Performance of Smooth Absorber Tube

Investigation on the heat flux distribution on the absorbent tube is vital to induce elaborated data on a way to improve efficiency with the aim to enhance the general heat transfer performance. Energy is that the energy of electromagnetic waves which may travel through house. The amount of energy will be calculated by integrating flux (or power) with regard to time. The collector will concentrate rather more solar rays on all-time low boundary of the absorbent tube, which implies there's rather more thermal energy regenerate from energy on all-time low surface of absorbent tube.

Table: 1 Heat flux with different Mass flows and corresponding Reynolds number

Mass flow (Kg/s)	Reynolds number	Heat flux (W/m^2)
0.054	1979.5	4.926
0.107	2985.9	9.761
0.161	4001.7	14.691
0.214	5020.9	19.521
0.321	7063.2	29.287
0.428	9107.2	39.056
0.535	11151.6	48.815



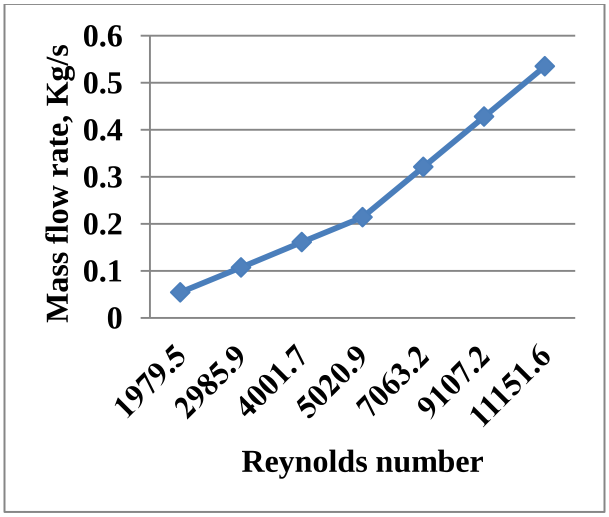


Fig.6: Variation of heat flux with Reynolds number

Fig.7: Variation of heat flux with mass flow rate

Temperature Contours

Comparing the seven contours, it's obvious that the higher Reynolds variety a lot of uniform temperature distribution on the absorbent material tube on the flow direction will be obtained. This development is induced by the explanation that the heat transfer fluid flows within the absorbent material tube will be mixed powerfully and also the convective heat transfer constant is increased considerably once the Reynolds variety will increase. The thickness of thermal boundary layer on the close to wall aspect will be reduced by the turbulence intensity enhancing with the rise of Reynolds variety.

Table: 2 Temperature obtained at different Reynolds number and mass flow rate for smooth tube

Mass flow (Kg/s)	Reynolds number	Temperature (K)
0.054	1979.5	308.02
0.107	2985.9	307.05
0.161	4001.7	306.69
0.214	5020.9	306.50
0.321	7063.2	305.63
0.428	9107.2	305.31
0.535	11151.6	305.01

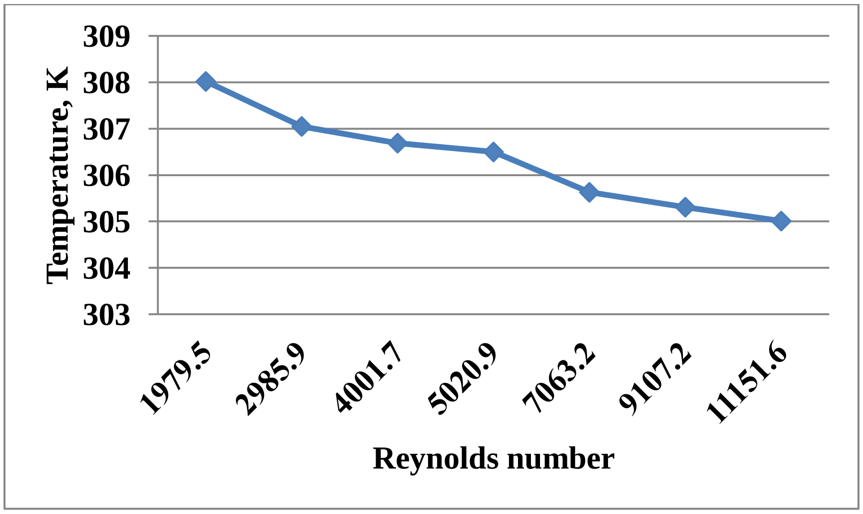


Fig.8: Variation of temperature with increase in Reynolds number

Turbulence Kinetic Energy

The turbulent kinetic energy (TKE) distribution contours of absorber tube of PTR with not the same Reynolds numbers.

Table: 3 TKE obtained at different Reynolds number and mass flow rate for smooth tube

Mass flow (Kg/s)	Reynolds number	TKE (J/Kg)
0.054	1979.5	0.0308
0.107	2985.9	0.0301
0.161	4001.7	0.0468
0.214	5020.9	0.0637
0.321	7063.2	0.0984
0.428	9107.2	0.1342
0.535	11151.6	0.1725

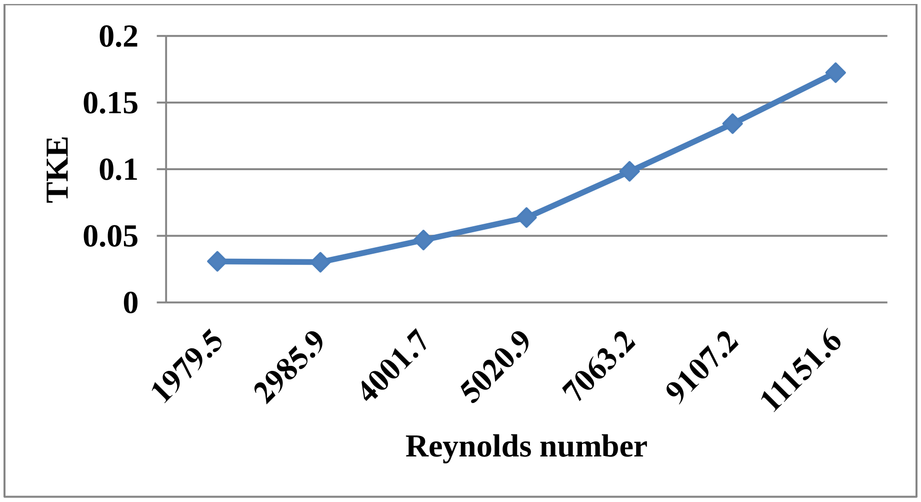


Fig.9: Variation of temperature with increase in Reynolds number for smooth tube

CONCLUSION

In this proposed research, the tube with pin fin arrays inserting was introduced as the absorber tube of PTR (PFAI-PTR) to increase the overall heat transfer performance and decrease the temperature gradient of absorber tube. The following conclusions can be drawn:

1. In the heat transfer performance of smooth absorber tube the contour of heat flux distribution on the periphery of absorber tube of PTR the heat flux is rises wtth increase reynolds number at minimum Re =1979.5 the heat flux is 4.926 and maximum Re=11151.6 the heat flux is 48.815. In this also the mass flow rate is incresaes with increses reynolds number. At minimum Re= 1979.5 the mass flow rate is 0.054 and maximum Re= 11151.6 the mass flow rate is 0.535.
2. In the Contours distribution temperature of smooth tube the temperature is decrease with increase reynolds number. At minimum Re= 1979.5 the temperature is high 308.02 and at maximum Re= 11151.6 the temperature is low 305.01. It is observed that the temperature decreases sharply with the increase of Reynolds number and mass flow rate which is benefit to decrease the thermal stress on the absorber tube.
3. In the turbulence kinetic energy seen that the magnitude of TKE has very little fluctuations on the fluid flow direction for a similar Reynolds number however varies considerably on the radial direction. With the rise of Reynolds number, the magnitude of TKE will increase. At minimum Re=1979.5 the TKE is 0.0308 and at maximum Re 11151.6 the TKE is 0.1725.

REFERENCE

[1.] Gong, Xiangtao, et al. "Heat transfer enhancement analysis of tube receiver for parabolic trough solar collector with pin fin arrays inserting." Solar Energy 144 (2017): 185-202.

[2.] Amina, Benabderrahmane, et al. "Heat transfer enhancement in a parabolic trough solar receiver using longitudinal fins and nanofluids." Journal of Thermal Science 25.5 (2016): 410-417.

[3.] Bellos, Evangelos, Christos Tzivanidis, and Ilias Daniil. "Energetic and exergetic investigation of a parabolic trough collector with internal fins operating with carbon dioxide." International Journal of Energy and Environmental Engineering 8.2 (2017): 109-122.

[4.] Bellos, Evangelos, et al. "The impact of internal longitudinal fins in parabolic trough collectors operating with gases." Energy conversion and management 135 (2017): 35-54.

[5.] Fuqiang, Wang, et al. "Heat transfer performance enhancement and thermal strain restrain of tube receiver for parabolic trough solar collector by using asymmetric outward convex corrugated tube." Energy 114 (2016): 275-292.

[6.] Bellos, E., et al. "Thermal enhancement of solar parabolic trough collectors by using nanofluids and converging-diverging absorber tube." Renewable Energy 94 (2016): 213-222.

[7.] Huang, Zhen, et al. "Numerical investigations on fully-developed mixed turbulent convection in dimpled parabolic trough receiver tubes." Applied Thermal Engineering 114 (2017): 1287-1299.

[8.] Kumar, K. Ravi, and K. S. Reddy. "Thermal analysis of solar parabolic trough with porous disc receiver." Applied Energy 86.9 (2009): 1804-1812.

[9.] Mwesigye, Aggrey, Tunde Bello-Ochende, and Josua P. Meyer. "Heat transfer and entropy generation in a parabolic trough receiver with wall-detached twisted tape inserts." International Journal of Thermal Sciences 99 (2016): 238-257.

[10.] Jaramillo, O. A., et al. "Parabolic trough solar collector for low enthalpy processes: an analysis of the efficiency enhancement by using twisted tape inserts." Renewable energy 93 (2016): 125-141.