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Heat Transfer Analysis of a Riser Tube in a Flat Plate Collector with Fins

[1]Dr.Narsimhulu Sanke
Director,
Centre for Energy Technology,
Osmania University, Hyderabad-50000, India.
E-mail:cetdirector@gmail.com

[2*]Mohammed Mohsin Shkhair
ME Student,
Dept of Mechanical Engineering,
University College of Engineering,
Osmania University, Hyderabad-500007, India.
*E-mail:qarthe@gmail.com

ABSTRACT:

The paperis focused on the process of energy transition from the collector to the working fluid to improve the efficiency in a flat plate collector byemploying fourhelical fins in the risers to induce a gradient of heat capacitance on CFD modelling of a simplified solar collector was investigated by doing modification inside the riser tube. Flat Plate Collectors (FPC) is widely used for domestic hot-water where fluid temperature less than 100oC. The absorber plate of the FPCtransfers solar energy to liquid flowing in the tubes. The flat plate collector is analysed with helical fins and without fins in a raiser for better heat transfer rates. Heat transfer analysis is done by using CFD ANSYS 14.5 and compares the heat transfer rates on two models of the collector and found optimum geometry of the fin.

Keywords: Flat plat collector, Solar energy, Riser tube fins, Heat transfer, Efficiency.

I. Introduction:

A CFD model is created of a simplified solar collector for the analysis by doing modification inside riser geometry and placing four helical finsinside the tube of a passive system, and the cross section of the raiser is circlewith and without fin.With helicalfins along the tube which represented a segment of the solar collector operating in similar conditions. This design was carried out by Pro-Engineering (version 5) and the analysis has done byCFD ANSYS 14.5 andall possible parametersare taken from Center of Energy Technology, Osmania University, Hyderabad for geometry (Fig. 1) and analysis. The flow is based on thermosyphon effect. The collector efficiency is dependent on the temperature of the plate which in turn is dependent on the nature of flow of fluid inside the tube.

II. Modeling of Flat Plate Collector:

The collector absorber plate with length and width for this design has taken as 1000mm and 2000mm respectively. The riser tube has 10mm in diameter with a thickness of 0.8 mm. The collector has two headers bottom and the top havingsame diameter 22 mm with a thickness of 1.0mm. The profile of riser tubes are in circular that have been enhanced on the inside surface by the addition of helical fins. The fins pattern has been specifically designed to increase the heat transfer area in applications using a fluid with low thermal conductivity. Two models are created without fins and with fins in the riser for the analysis.

Table 1 Size of collector:

Name	Parameter	Dimension
Riser tube	diameter	Ø10mm
	Thickness	0.8 mm
	Number	8
	Spacing between	130mm
Header tube	diameter	Ø22mm
	Thickness	1mm
	Number	2
	Spacing between	1734mm
Housing case	length	2000 mm
	width	1000 mm

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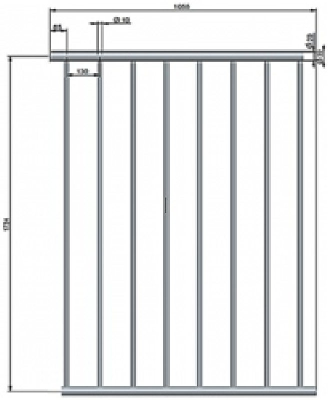

Fig 1 Dimension of the risers and harder tubes(mm).

III.Development of the Geometry of Riser Tube:

Fins are the extended surfaces which are used to enhance the heat transfer rate from heated surface to water. Modeling of a simplified flat plate collector was to be investigated by placing internal fins inside the pipe of a simplified design of a passive system which represented as a part of the flat plate collector operating in similar conditions then analyzed (Fig 2).

symbol	Dimension
p	100 mm
R	2.2 mm
b	2 mm
a	2 mm

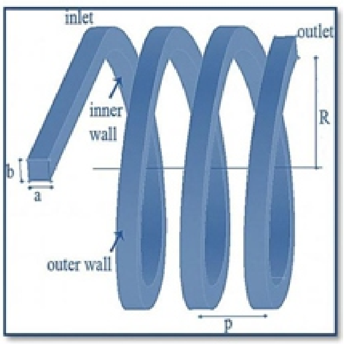

Fig2.Geometry of helical fin.

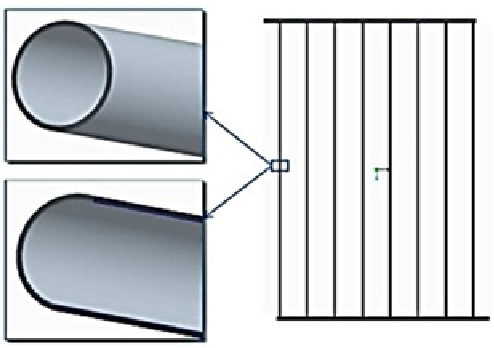

Fig. 3.1 Flat plate collector raiser without fin

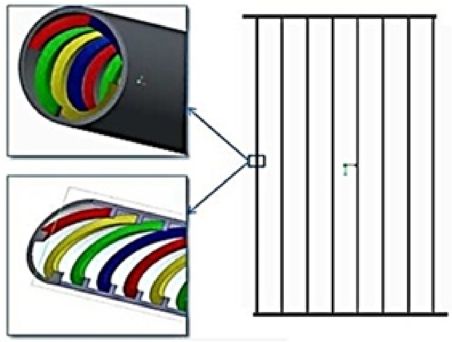

Fig.3.2 Flat plate collector raiser with four helical fins

The model consisted of riser sections made of copper material connected at both the top and bottom headers with four of helical fins are setting inside the riser pipes. There are two cases were investigated, namely without fin and with helical fins in riser (Fig3.1&3.2).

The analysis depends on the parameter of the collector and dimensionsare shown in Fig 2. The common fins used extensively to increase the rates of heat transfer by convection are straight fins because such fins are simple.

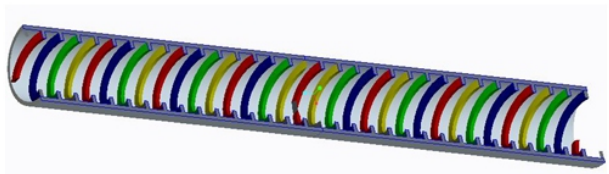

Fig.4Section of riser tube with helical fins.

IV. Meshing by ICEM CFD:

The three dimensional computational domain is modeled using Tetrahedronsmesh (Fig 5.1 & 5.2) this type of mesh is refer depend on the shape of the risers ,the triangle shape mesh is used at the corners and other type of meshes are not suitable in the corners for 3D.

The mesh is used ANSYS ICEM CFD tetrahedrons for collector without fin the numbers of elements are 2372068 and nodes are 518217. The number of element for collector with fins 2766362 and the nods 676312.

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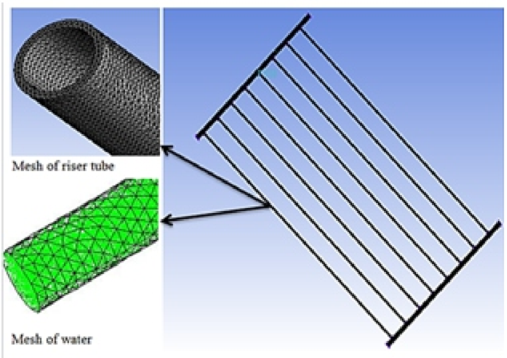

Fig. 5.1 Mesh of flat plate collector raiserwithout fin.

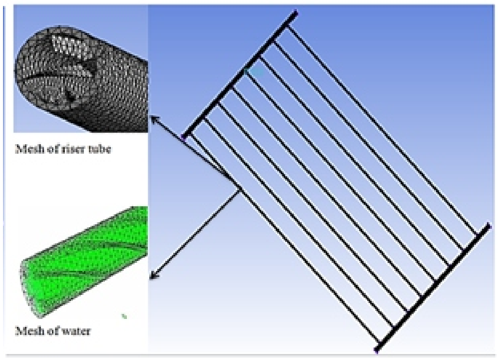

Fig 5.2 Mesh of flat plate collectorraiser with four helical fins.

V. Boundary Conditions and Operating Parameters

Assumptions:

• Water is a continuous medium and incompressible.
• The flow is steady and possesses laminar flow characteristics.

• The thermo-physical properties of the absorber plate and absorber tube are constant with respect to the operating temperature.

• The bottom portion of the absorber tube and face of the absorber plate is assumed to be adiabatic.
Boundary condition

• Inlet temperature to inlet riser 303˚C

• Heat flux of average day of August is 950W/m2

• Mass flue rate is 0.016Kg/s

• Working fluid is water has density 1000 Kg/m3

VI. Analysis:

Steady state simulations are carried out with a 2m2 flat plate solar collector panel. The geometrical dimensions are shown in Table 1.Due to the large difference in the dimension of absorber tube length (1734 mm) and tube hydraulic diameter (10 mm), a very fine grid distribution is needed in the cross-section of the riser tube. The model is imported to Fluent solver 14.5 after meshing is done and entered the boundary condition for both the models (with helical fins and without fin) to do analysis for heat transfer and compare between two cases.

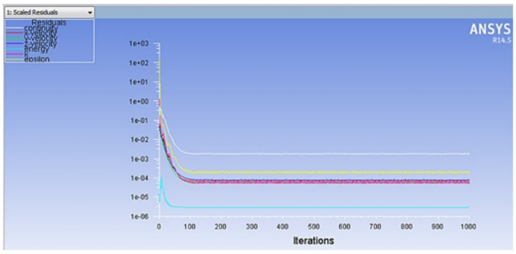

Figure 6 Turbulence (kinetic energy KE) with accumulated time diagram.

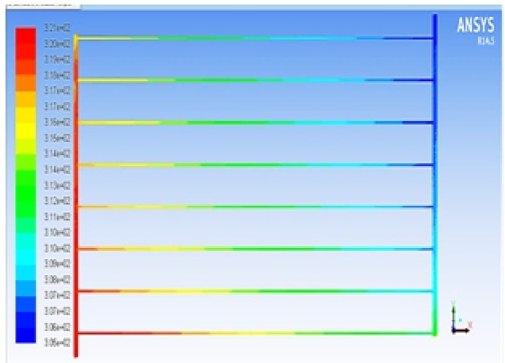

Fig 7.1Temperature distributionsin thecollector (without fin)

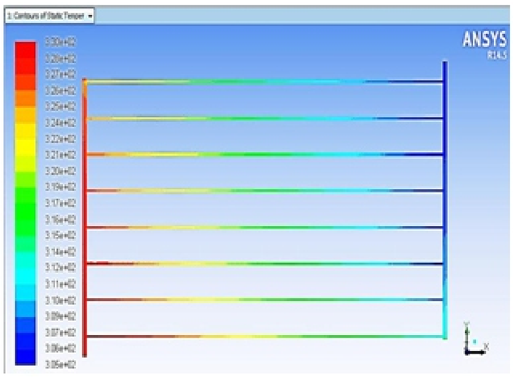

Fig 7.1Temperature distributions in the collector (with fins)

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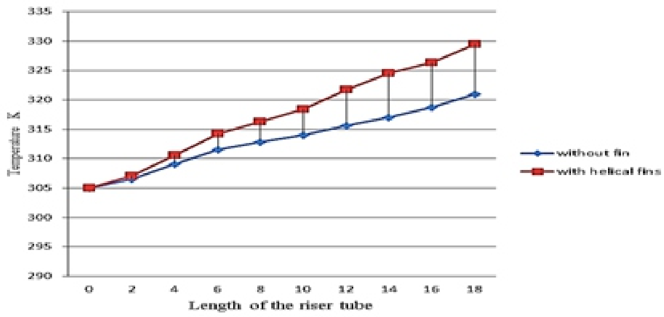

Fig 8 Temperature comparison between riser tubes with and without fin.

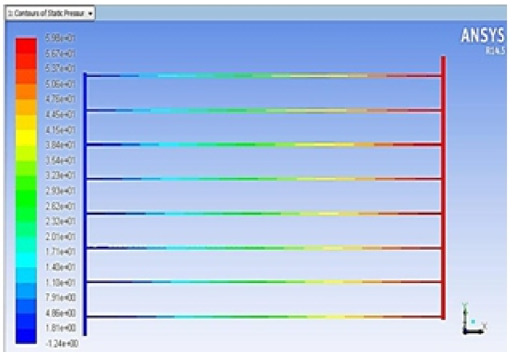

Fig 9.1 pressure distributions in the collector (without fin)

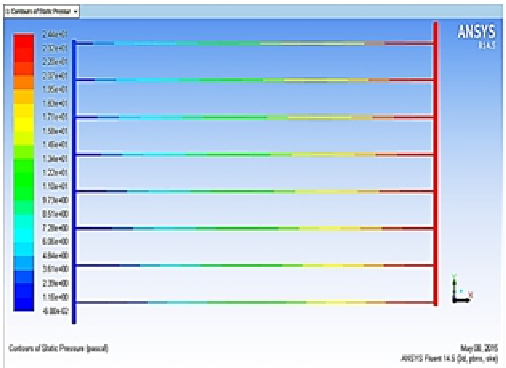

Fig 9.2 pressure distributions in the collector (with fins)

VII. Results and Discussions

CFD simulation is first performed on the risers of flat plat solar collector system for both models(with helical fins and without fin), basically the model is designed to extend the heat transfer area to enhance convective heat transfer coefficient. For this case it has been modified the shape of the riser to improve the performance of the device while the working fluid is water.

Under same boundary condition, which the inlet temperature for both cases is 303K and the heat flux is 950 W/ m2. When the collector fluid enters at 1Ltr/min atthe panel having tilt angle is 30˚.The results are shown that the maximum temperature occurred after the peak solar radiation.In CFD analysis the average temperature of the fluid flow through helical fins traced at outlet header is 330.6K, where as in without fins the outlet temperature is 321.4K for same boundary conditions.

The maximum temperature in modified shape of the risers is progress up to 9.2 K because of turbulence and velocity decreases in raiser tube.The pressure drop in the riser pipe for the given boundary conditions in both cases was relatively high, without fins has 24.2 Pa and that for with helical fins58.2 Pa. Due to do modified on the shape of the risers the pressure of fluid were higher than the simple risers at entrance in this case the temperature of working fluid has been increased. The figure 8.1&8.2 has indicated very clearly the different between in two casesin this study.

Conclusion:

It is traced that, the outlet temperatures of collector without fin is 321.4 K, and with helical fins 330.6 K, for same inlet conditions, the outlet temperature is increased about 9.2 K in helical fins as compared to without fins.

The efficiency ranges depended on the ambient temperatures and the time of the day, the collector with helical fins is 18.2 % more efficient than collector without fin.The pressure drop in the raiser (heating pipe) for the given boundary conditions in both cases was relatively high, being about 24.4 Pa for without fins and 58.2 Pa for with helical fins.

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