EFFECT OF SOLAR RADIATION ON RECEIVER TUBE OF SOLAR COLLECTOR

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ABSTRACT-Solar energy is one of the everlasting and promising sources of energy. Solar systems such as solar collector or receiver, solar chimney, solar heater are the wonderful technologies to adapt the solar energy suitable for human utilization. In this work, an effort has been made to analyse the performance of 1.2 m length designed parabolic trough solar collector model. The heat receiving element were made of stainless steel and copper with water as a heat transfer fluid. The heat transfer fluid circulates through a receiver tube that absorbs solar radiation reflected from the reflector of parabolic trough collector. The receiver tube was modeled by SOLIDWORKS modeling software. This model was justified based on the results obtained from an experimental with respect to inlet temperature, surface temperature and thermal efficiency under different solar radiation. The simulation were carried out by CFD using measured meteorological data. Finally, the effect of solar radiation was compared between receiver tubes in both simulation and experimental.

KEYWORDS:**Solar, Thermal collector, Receiver tube, Expeimental investigation, Simulation analysis.**

INTRODUCTION

A standard thermal solar collector can be used both for domestic hot water production and for heating purpose. The solar energy collection as a renewable energy topic has been the primary interests of many engineers and researchers for the last two centuries due to its wide applications such as domestic water heating systems. Today, solar water heating systems are being used for single family houses, apartment buildings, schools, car washes, hospitals, restaurants, agricultural farms and different industries. Solar water heating can reduce domestic water heating costs by as much as 70%. Owners of these buildings have found that solar water heating systems are cost-effective in meeting their hot water needs all over the year. In a parabolic trough collector, the reflector focuses sunlight on a receiver tube through which heat transfer is pumped. Solar parabolic collector with truncated cone shaped helical coiled receiver made up of copper and coated with nickel chrome at focal point, using 3D modeling software Pro/Engineer. Heat transfer analysis was done on the dish collector by applying different temperatures effecting in a particular day. Comparison was done between the two models. CFD analysis was also done to determine the outlet fluid temperature, mass flow rates etc. Heat transfer analysis and CFD analysis was done by using CFD ANSYS [1]. The paper showed comparison between the results obtained from CFD model and those from experimentation. The heat transfer fluid flows in tubes which were configured in a unique arrangement during the charging and discharging processes. Water contained in a cylindrical tank with four tubes coiled inside it was used as the phase change material . Experiments were conducted for both freezing and melting processes. A three dimensional CFD model using ANSYS code was developed and validated with experimental results [2]. Performance of a solar parabolic trough collector focusing on its receiver. The receiver consisting of a glass-shield enclosing a heat collector element with vacuum in the annular space has been subjected to seasonal and diurnal variations of solar radiation along with the concentrated heat flux reflected from the parabolic trough mirror for conditions. The summer conditions exhibit a 2.5 times higher pressure drop at noon compared to the morning conditions. The comprehensive analysis was performed using the finite volume based CFD code of ANSYS FLUENT 12.1 [3]. This paper presents a review of the design parameters, mathematical techniques and simulations used in the design of parabolic trough solar systems, along with a review on their applications. Recent studies that analyze the deployment of solar parabolic trough collectors in different countries and the operational SPTC plants are also presented and discussed. The paper also discusses the different kinds of software and test methods of solar collectors [4]. Mathematical model to predict optical efficiency and thermal losses for any parabolic trough collector . The model was validated through comparison with the experimental results on the prototypes. It was included in a custom built simulation environment to predict yearly performances of a PTC field coupled with an industrial process heat demand. Encouraging results were shown and final considerations were drawn for this application. The mathematical model developed for a PTC was composed of two different parts, an optical model and a thermal model. They carried out annual simulation for the performance of the developed model [5].This paper describes an experimental study of parabolic trough collector. The objective of the paper is to perform parametric investigations of the effect of flow rate and absorber water inlet temperature on the collector's thermal efficiency for different level of solar insolation under the climatic conditions of Assam. The optimum values of the inlet parameters for various solar insolation levels are also found out. From this work, the highest thermal efficiency of the present collector is 65%, obtained when optimum values of input parameters are applied simultaneously [6].

EXPERIMENTAL INVESTIGATION

The receiver tube of solar parabolic trough collector was made up of stainless steel and copper.Figures 1,2 shows the above mentioned absorber tubes.

Fig 1: Stainless steel receiver tube

Fig 2: Copper receiver tube

Table 1. Specifications of parabolic trough collector

Receiver tube materials	Stainless steel, Copper
Receiver tube length	1.5m
Outer Diameter of tube	25mm
Inner Diameter of tube	22mm
Reflector	0.4mm thickness Aluminium sheet
Reflectivity	0.90
Absorptivity	0.85
Aperture	0.6m
Length	1.2m

EXPERIMENTAL SETUP

The reservoir tank was fully filled with water. The ball valve is used to maintain the flow of water from reservoir tank to the receiver tube. The one end of the receiver tube is connected with tank. The heat gained by the heat transfer fluid is observed for mass flow rate of 0.0068 Kg/sec. The experiment was done for stainless steel and copper receiver tube. Table 1 shows the specifications of parabolic trough collector.Thermometer is used to measure inlet and outlet temperature of fluid. In ths work, two collectors with stainless steel and copper receiver tube materials were investigated at same time. Figure 3 shows the experimental setup with stainless steel and copper receiver tube.

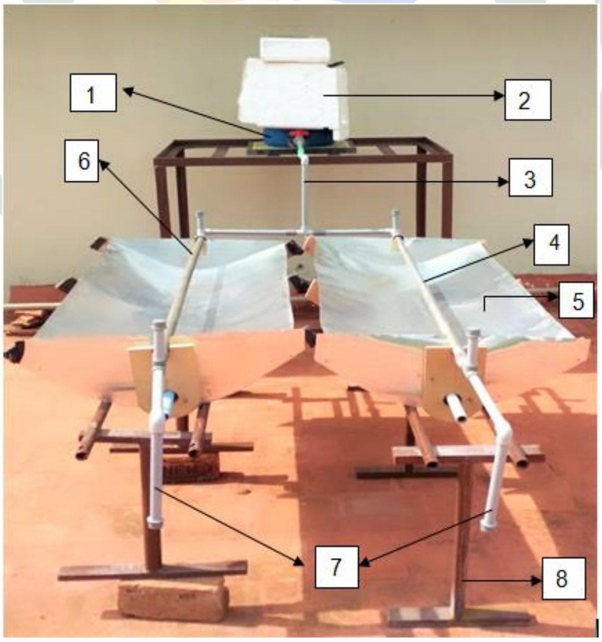


Fig: 3 Experimental setup with stainless steel and copper receiver tube

1. Reservoir or Tank.
2. Polystyrene material.
3. Water Inlet.
4. Stainless steel receiver tube.
5. Aluminium reflector.
6. Copper receiver tube.
7. Water outlet.
8. Collector stand.

EXPERIMENTAL PARAMETERS

Location = Coimbatore.
Latitude = 11.01° N.
Longitude = 76.95°E.
Mass flow rate of water = 0.0068 Kg/sec.
Trough fixed position= North-South.
Experiment period = March 27.

An experiment was done by stainless steel and copper receiver tubes in the day of March,2018 at 10 AM, 12 noon, 02 PM.From experimental investigation the following results were obtained.

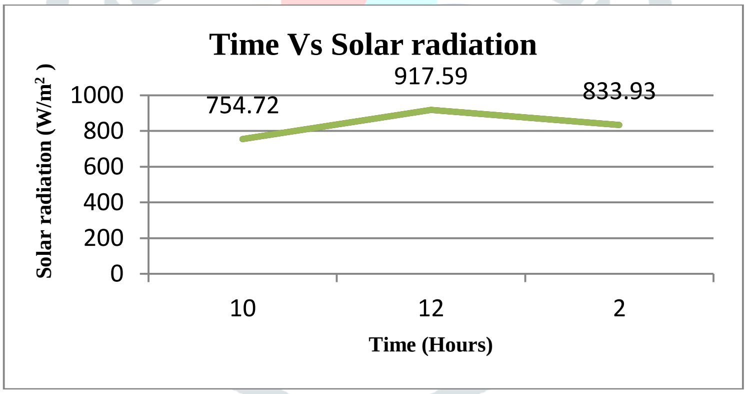
Table 2. Experimental reading for stainless steel

Time (Hour)	Solar Radiation (W/m^2)	Inlet Temperature (◦C)	Outlet Temperature (◦C)	Efficiency (%)
10.00	754.72	27	29	8.40
12.00	917.59	30	41	37.9
02.00	833.93	30	34	15.2

Table 3. Experimental reading for copper

Time (Hour)	Solar Radiation (W/m^2)	Inlet Temperature (◦C)	Outlet Temperature (◦C)	Efficiency (%)
10.00	754.72	27	36	37.72
12.00	917.59	30	48	62.05
02.00	833.93	30	44	53.10

Tables 2 and 3 consist the details of solar radiation values with respect to time and the inlet, outlet temperatures of the receiver tubes were obtained at relevant time intervals. The instantaneous efficiency of the absorber tubes were also predicted based on the readings obtained. Graph 1 shows the range of solar radiation with respect to time.



Graph 1. Time Vs Solar Radiation

SIMULATION ANALYSIS

From an experimental results the simulation analysis was made by CFD. For an analysis the following numerical calculations were done using standard formulas. The simulations were also analysed for March 27, 2018 at 10h00, 12h00, 14h00. The hour angle of 10h00, 12h00, 14h00 are -30°, 0°, +30° respectively.

$\delta = 23.45 \sin [(360/365) (284+d_n)]$-------(1)

$\theta = \cos^{-1} (1- \cos^2 (\delta) \sin^2 (\omega))^{1/2}$ -------(2)

$r_b = \cos\theta / (\sin (\phi) \sin(\delta)+ \cos (\phi) \cos(\delta) \cos(\omega))$ -------(3)

$S = I_b r_b[0.90\times0.85+(0.90\times0.85\times D_o)/(W-D_o)]$ -------(4)

$V= m /(\pi/4)(D_i^2\rho)$ -------(5)

Where,
d_n= Day of the year.
δ= Declination angle of sun.
θ= Angle of incidence.
ω= Hour angle.
ϕ= Latitude of location.
$I_b r_b$= Solar radiation.
S= Solar flux.
D_o= Outer diameter of receiver tube.

D_i= Inner diameter of receiver tube.
V= Average velocity of fluid.
m= Mass flow rate of fluid.
ρ= Density of fluid.
W= Aperture of collector.

Solar flux was calculated from the above mentioned relation(4) [7]. The values of solar flux for simulation analysis was derived from measured solar radiations of 754.72W/m^2, 917.59W/m^2, 833.93W/m^2 were 609.09W/m^2, 740.53W/m^2, 673.02W/m^2 respectively. The model was meshed by CFD Fluent, in which the tube surface meshes are built of triangular cell and volume meshes are built of tetrahedral cell. The boundary condions have given to the numerical model to get results. Figures 4,5,6,7,8,9 shows the outlet temperature of fluid at 10h00, 12h00, 14h00 for stainless steel and copper receiver tubes.

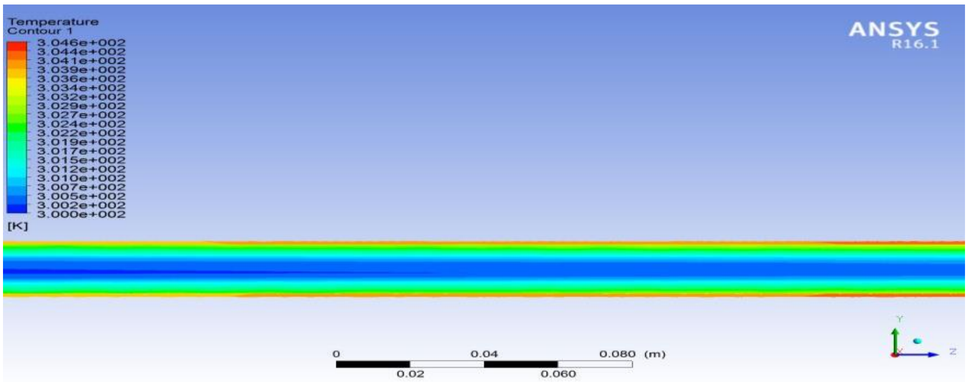


Fig: 4 Outlet temperature contour of fluid at 10h00 for stainless steel tube

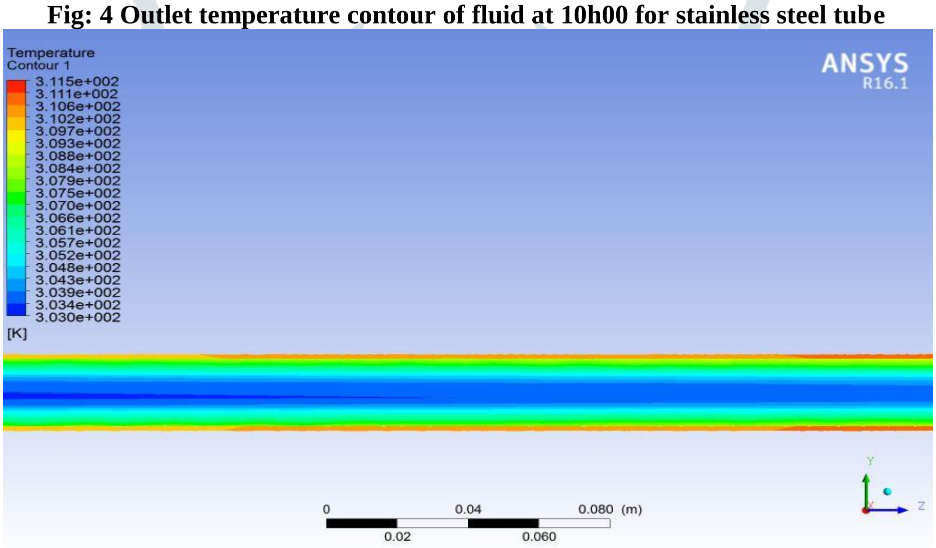


Fig: 5 Outlet temperature contour of fluid at 12h00 for stainless steel tube

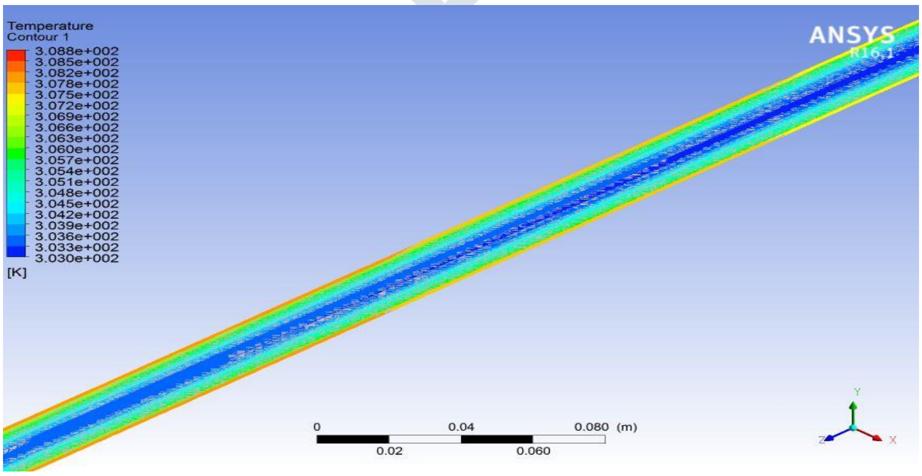


Fig: 6 Outlet temperature contour of fluid at 14h00 for stainless steel tube

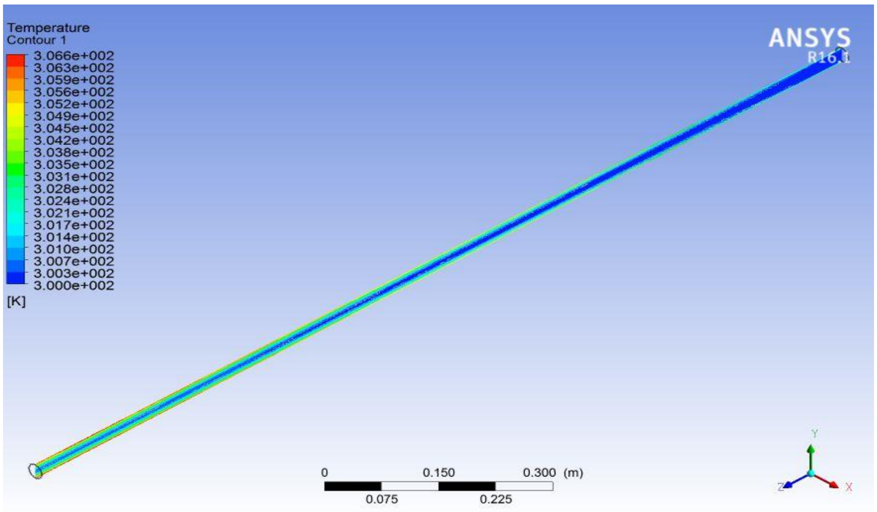


Fig: 7 Outlet temperature contour of fluid at 10h00 for copper tube

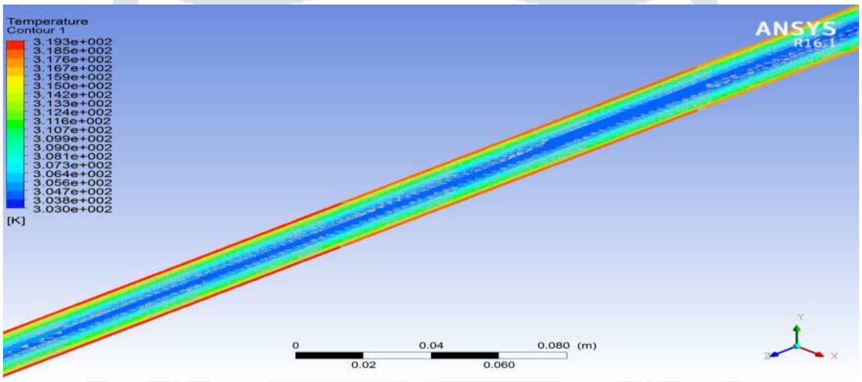


Fig: 8 Outlet temperature contour of fluid at 12h00 for copper tube

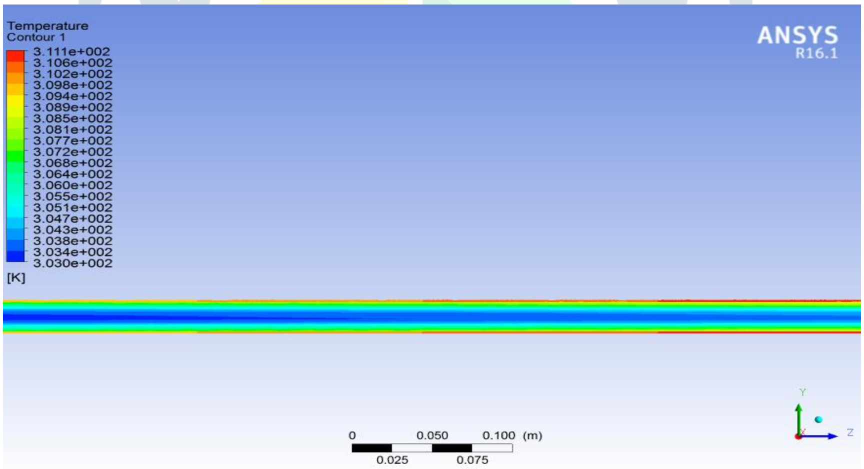


Fig: 9 Outlet temperature contour of fluid at 14h00 for copper tube

RESULTS AND DISCUSSION

From the above simulation analysis resuts were tabulated for Stainless steel and copper receiver tube. And also an increased temperature was calculated for both tubes. Tables 4,5 shows the simularion analysis of stainless steel and copper tubes.

Table 4. Simulation analysis for stainless steel tube

S.No	Heat Flux (W/m^2)	Stainless steel receiver tube		Increased Temperature (k)
		Inlet Temperature (k)	Outlet Temperature (k)	
1.	609.09	300	304	4
2.	740.53	303	311	8
3.	673.02	303	308	5

Table 5. Simulation analysis for copper tube

Outlet

S.No	Heat Flux (W/m^2)	Copper receiver tube		Increased Temperature (k)
		Inlet Temperature (k)	Outlet Temperature(k)	
1.	609.09	300	306	6
2.	740.53	303	319	16
3.	673.02	303	311	8

temperature of fluid is increased in copper absorber tube with increase in heat flux value. Based on the simulation and an experimental investigation the performance of the collector increased when it has a copper receiver tube. Table 6 shows the deviation between experimental and simulation results. The maximum deviation was found about 8.98% under the solar radiation of 833.93 W/m^2at 2 P.M.

Table 6. Deviation of experimental and simulation analysis

Material	Increased Temperature (k)		Deviation (%)
	Experimental	Simulation	
Stainless steel	2	4	2.44
	11	8	6.98
	4	5	1.96
Copper	9	6	6.98
	18	16	2.44
	14	8	8.98

CONCLUSION

Based on the significance of the solar energy and its prospective a 1.5 m length parabolic trough solar collector was designed and fabricated. And the performance of parabolic trough collector was investigated by an experimental. From the experimental results, the simulation analysis was done by CFD Fluent 16.1.It was found that the highest efficiency of about 62.05% obtained at a water inlet temperature of 30°C under the solar radiation of 917.59 W/m^2 in copper receiver tube. The simulation result showed better agreement with an experimental values, reported a 2.44% of deviation.

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