 P-ISSN: 2659-1561
E-ISSN: 2635-3040

Research Article

Heat Transfer Analysis on Parabolic Trough Absorber for Various Materials by Numerical Study

[1]Mon Mon Aye and [2]Ei Ei Wai

Mon Mon Aye (Lecturer); Ei Ei Wai (Professor)
Faculty of Precision Engineering, University of Technology (Yatanarpon Cyber City), Myanmar
Email: monmonaye.mech@gmail.com; eieiwai.mech@gmail.com

Received: Jul 28, 2019 **Accepted:** Aug 4, 2019 **Published:** Aug 8, 2019

Abstract: The purpose of this study was produced the water heating with relatively higher temperature. A heat transfer fluid circulates through an absorber tube. The heat transfer and optical analysis of the absorber is essential to optimize and its performance under different absorber's materials conditions. It was constructed three-dimensional numerical model for heat transfer analysis of absorber tube by COMSOL. Absorber tube material is made by copper. Model with absorber tube length was 0.6096 m, the inner diameter of absorber tube was 17 mm and the outer diameter was 19 mm. The fluid was water.
Keywords: Heat transfer, absorber tube, COMSOL.

1. Introduction

Parabolic trough absorber tube is in fact composed of two concentric pipes. It included an inner pipe containing the working fluid and an outer glass tube surrounding the inner pipe. The glass tube was used the high transmittance material for solar radiation. The outer surface of the pipe has an optically selective surface with a high solar absorptance and low remittance for thermally generated infra-red radiation [1].

The absorber of a parabolic trough is linear. The size of the tube was determined by the size of the reflected sun image and the concentration ratio of the trough. A glass cover tube is usually placed around the absorber tube to reduce the convective heat loss from the receiver and it was reduced the heat loss coefficient. The glass envelope usually has an antireflective coating to improve transmissivity [3]. Therefore, the purpose of this study is to construct the three dimensional model of parabolic trough reflector.

2. Energy Balance Model of the Parabolic Trough Absorber

Figure 1 shows the heat transfer analysis of absorber tube. The absorber tube was surrounded by the environment. In this stage, it had the radiation and convection medium at the outer surface of the glass cover.

The conduction heat transfer had between the outer surface and inner surface of the glass. The inner surface of the glass to the outer surface of the absorber tube had radiation and convection heat transfer. The outer surface of the absorber tube to the inner surface of the absorber tube occurred conduction.

The convection heat transferred between the inner surface of the absorber tube and the working fluid. Finally, the working fluid got the required heat.

P-ISSN: 2659-1561
E-ISSN: 2635-3040

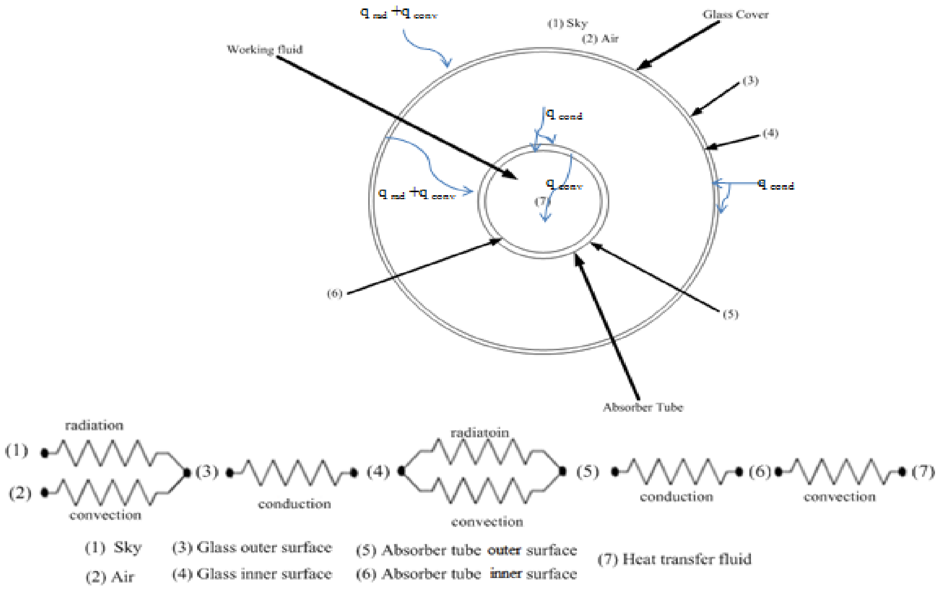

Figure 1. Heat Transfer Analysis of Absorber Tube

3. Comsol Multiphysics

COMSOL Multiphysics is a powerful interactive environment for modeling and solving all kinds of scientific and engineering problems based on partial differential equations (PDEs). This software can easily extend conventional models for one type of physics into multiphysics models that solve coupled physics phenomena and do so simultaneously. It is the mathematics or numerical analysis. To build the physics models, it must define the relevant physical quantities such as material properties, loads, constraints, sources, and fluxes rather than by defining the underlying equations. It can always apply these variables, expressions, or numbers directly to solid domains, boundaries, edges, and points independently of the computational mesh. COMSOL Multiphysics compiles a set of PDEs representing the entire model. The power of COMSOL Multiphysics is a standalone product through a flexible graphical user interface, or by script programming in the COMSOL Script language or in the MATLAB language. Using these application modes, it can perform various types of analysis. They are stationary and time dependent analysis, linear and non-linear analysis and Eigen frequency and modal analysis.

The heat transfer module is an optional package that extends the CMSOL multiphysics modeling environment with customized user interfaces and functionality optimized for the analysis of heat transfer. Heat transfer is involved in almost every kind of physical process. COMSOL Multiphysics using the two application modes that are the incompressible Navier-Stokes application mode for fluid flow and the convection and conduction application mode for heat transfer. This mode is coupled with heat and flow at Navier-stokes incompressible module as volume force. This simulation has seven steps. They are creating geometry, modeling physics and equation, defining subdomain such as it must define solid or fluid, defining boundary conditions such as it define input properties, meshing to geometry, solving the model and post processing and visualization means that it show the results.

4. Numerical Solution

Heat transfer analysis of parabolic trough absorber tube was transient state conditions. It used the two application modes that are the incompressible Navier-Stokes application mode for fluid flow and the convection and conduction application mode for heat transfer. This

P-ISSN: 2659-1561
E-ISSN: 2635-3040

analysis had two assumptions. They were radically heat transfer analysis and no heat losses between one medium to another medium.

The partial differential equations (PDE) were discretized for transient state conditions by using the finite element method and taking into account the dependence of the thermal properties with the temperature.

$$\rho\frac{\partial u}{\partial t}+\rho u.\nabla u=-\nabla p+\eta\nabla^2 u+F \quad (1)$$

$$\nabla.u=0 \quad (2)$$

$$\rho C_p\left(\frac{\partial T}{\partial t}+u.\nabla T\right)+\nabla.(-k\nabla T)=Q \quad (3)$$

where, u - velocity
p- pressure
F- volume force
η - dynamic viscosity
∇ - vector differential operator
Q- heat source

$$F_z=\alpha g\rho(T-T_{in}) \quad (4)$$

where, α= thermal expansion coefficient
g=acceleration due to gravity
ρ=fluid density
T= initial temperature
T_{in}=inlet temperature

5. Model Validation

In order to validate the heat transfer model, it was defined the boundary conditions in figure 2 and the each medium of the numerical equations were showed in table 1.

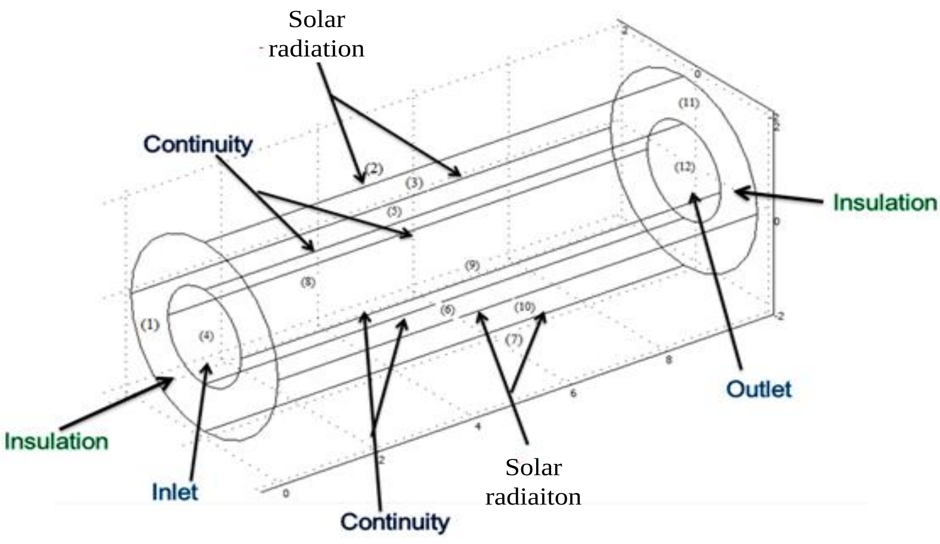

Figure 2. Absorber tube by numerical model

P-ISSN: 2659-1561
E-ISSN: 2635-3040

In figure, number 1 to 11 were defined the heat transfer boundary layer excepted the number 4 and 12. The number 4 was inlet of fluid and the number 12 was the fluid outlet.

Table 1. Boundaries Setting of the absorber tube

Boundary	Condition	Governing equation
1,11	insulation	$nq=0, q=-k\nabla T+\rho C_p Tu$
2,3,7,10	Heat flux	$-nq=0, q=-k\nabla T+\rho C_p Tu$
5,6,8,9	Continuity	$n(q_1-q_2)=0, q_i=-k_i\nabla T_i+\rho_i C_{pi} T_i u_i$ $u=0$
4	Inlet temperature, inlet velocity	$T=T_0$ $u=-U_0 n$
12	Convective flux, outlet pressure	$n(-k\nabla T)=0$ $P=P_0$

6. Results and Discussion

Figure 3 showed the slide plot and direction of the heat transfer flow with time. The different colors defined the value of water outlet temperature. The next figure 4 described the value of water outlet temperature by line plot. This plot described that the water outlet temperature with time at the end of the absorber tube position(x= 0.6096 m).

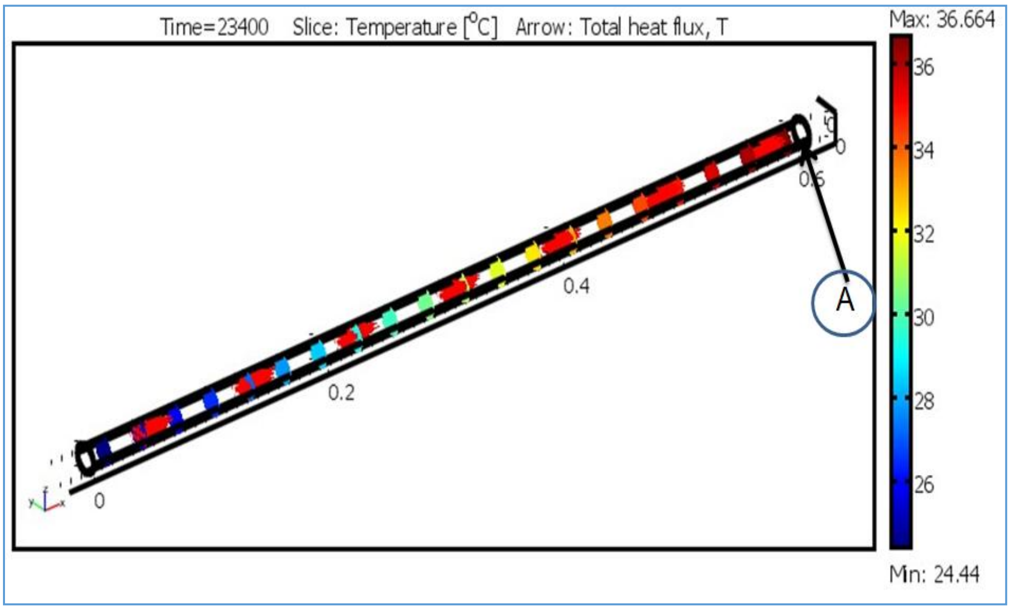

Figure 3. Water outlet temperature along with the absorber tube length

Figure 4 can be see that the value of water inlet temperature is increased with time until 12 noon. And then, it will be slightly decreased until 4pm. This simulation can be showed definitely value of water outlet temperature for any length of the tube with time.

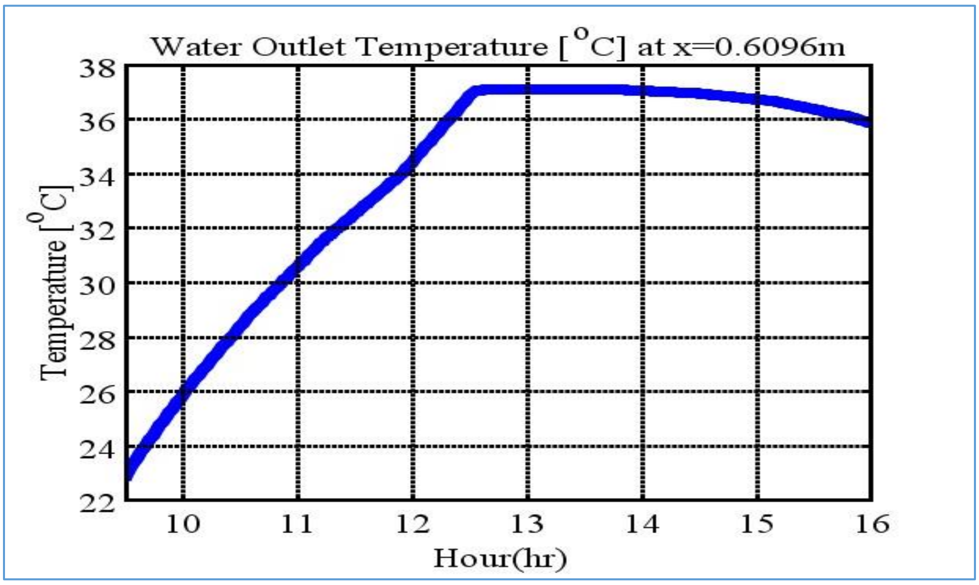

Figure 4. Point plot of the absorber tube at A

In figure 5 showed the comparison between steel, copper and aluminium tube using the heat transfer fluid is water. The water outlet temperature of steel is higher than copper because the heat capacity of steel is higher than copper. The lowest water outlet temperature is the aluminium and its heat capacity value is smaller than above two materials.

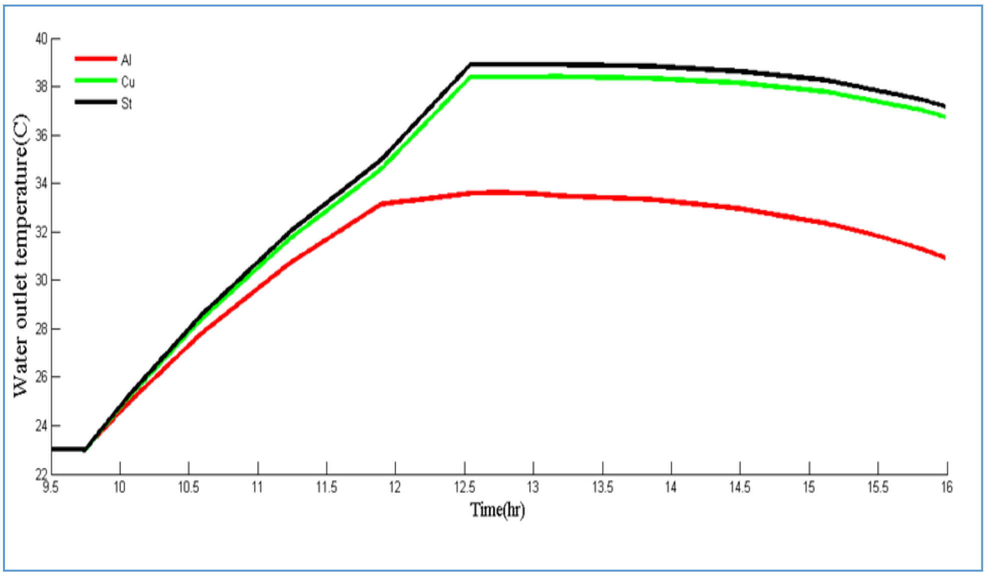

Figure 5. Comparison between Steel, Copper and Aluminium Tube using the Heat Transfer Fluid is Water

7. Conclusion

In conclusion, figure 3 to 5 showed the value of water outlet temperature on December 6, 2014 and the optimum fluid flow velocity is 0.002 m/s. The artificial diffusion is very important parameter in heat transfer analysis because the thermal conductivity of the material is varying with time. As a result, the best pair for water heating application is stainless steel for the absorber tube with water as a working fluid.

Conflicts of interest: There is no conflict of interest of any kind.

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

References

1. Lovegrove, K. and Stein, W. (Eds.). 2012. Concentrating solar power technology: principles, developments and applications. Elsevier.
2. Bhargva, M. and Agrawal, V.P. 2012. Modeling Analysis, Evaluation, Selection and Experimental Investigation of Parabolic Trough Solar Collector System. Doctoral Dissertation .
3. Padilla, R.V. 2011. Simplified methodology for designing parabolic trough solar power plants. University of South Florida.
4. Bastos, J.P.A. and Sadowski, N. 2007. Comsol multiphysics modeling guide version 3.4.
5. Kalogirou, S.A. 2004. Solar thermal collectors and applications. Progress in Energy and Combustion Science, 30(3): 231-295.
6. Forristall, R. 2003. Heat transfer analysis and modeling of a parabolic trough solar receiver implemented in engineering equation solver (No. NREL/TP-550-34169). National Renewable Energy Lab., Golden, CO.(US).
7. Brown, H., Hewett, R., Walker, A., Gee, R. and May, K. 1997. Performance contracting for parabolic trough solar thermal systems. Energy Engineering, 94(6): 33-44.
8. Duffie, J.A. and Beckman, W.A. 1991. Solar engineering of thermal processes. New York: Wiley, 770-772 pp.
9. Kothari, D.P., Singal, K.C. and Rakesh Ranjan. 2008. Renewable energy sources and emerging Technologies, Prentice Hall of India pvt. Ltd., New Delhi, 2nd Edition, 2008
10. Rabl, A. 1985. Active solar collectors and their applications. Center of energy and environmental studies, Princeton University.

Citation: Mon Mon Aye and Ei Ei Wai. 2019. Heat Transfer Analysis on Parabolic Trough Absorber for Various Materials by Numerical Study. International Journal of Recent Innovations in Academic Research, 3(8): 29-34.