Performance Evaluation for Thermal comfort on Earth Air Heat Exchanger with Different Material with and without Fin for heating using CFD

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***Abstract*- Earth-air heat exchangers, also called ground tube heat exchangers, are an interesting technique to reduce energy consumption in a building. They can cool or heat the ventilation air, using cold or heat accumulated in the soil. The temperature of earth at a certain depth about 2 to 3m the temperature of ground remains nearly constant i.e. 25.4 ^{0}C throughout the year. This constant temperature is called the undisturbed temperature of earth which remains higher than the outside temperature in winter and lower than the outside temperature in summer. When ambient air is drawn through buried pipes, the air is cooled in summer and heated in winter, before it is used for ventilation. The earth air heat exchanger can fulfill in both purpose heating in winter and cooling in summer. In use of complex dimensioning process required such a system, which involves optimization of numerous parameters such as the diameter, air flow rate depth, tube length and condensation in the meantime have to be considered. In this work Thermal comfort on earth tube heat exchanger with different material with and without for heating using CFD is evaluated. The pipe material taken for the analysis are Aluminium and PVC.For the analysis Ansys 17.0 fluent software used. For the CFD simulation analysis the pipe of 12m length, 0.003m thickness and 0.15m diameter with and without fin considered .Using the CFD analysis it is observed at air velocity of 3 m/s, Aluminium pipe material with fin gives maximum outlet temperature of 298.4 K.**

Index Terms- Earth air Heat Exchanger (EAHE), Computational Fluid Dynamics (CFD), Heating, Different Materials, Fins, Ansys 17.0.

I. INTRODUCTION

1.1 Earth air heat exchanger

Earth air heat exchanger system are long metallic, plastic or concrete pipes that are laid underground and are connected to the air intake of the buildings,particulary houses .There purpose is to provide some pre-conditioning of air either pre-heating in the winter or pre-cooling in the summer.

Earth-air heat exchangers, also called ground tube heat exchangers, are an interesting technique to reduce energy consumption in a building. They can cool or heat the ventilation air, using cold or heat accumulated in the soil.

1.1.1 Working Principal of Earth Air Heat Exchanger

The temperature distribution in the ground is distinguished in three zones. The Surface zone, which reaches a depth of about 1m, the Shallow zone extending at a maximum depth of 20 m, and the Deep zone, where the ground temperature remains nearly constant throughout the year. To effectively exploit the heat capacity of the soil a heat-exchanger system has to be constructed. Usually an array of buried pipes running along the length of the building, a nearby field or buried vertically into the ground is utilized. A circulating fluid (water or air) is used in summer to extract heat from the hot environment of the building and dump it into the ground and vice versa in winter. The temperature of earth at a depth of 1.5 to 2 m remains fairly constant throughout the year (Bisoniya et al. 2013). This constant temperature is called earth's undisturbed temperature (EUT). The EUT remains higher than ambient air temperature in winter and lower than ambient air temperature in summer. The concept of earth–air heat exchanger (EAHE) is very simple. The ambient air is drawn through the pipes of the EAHE buried at a particular depth, moderated to EUT, and gets heated in winter and vice versa in summer. In this way, the heating and cooling load of building can be reduced passively.

1.1.2 Types of earth air heat exchanger

There are two general types of ground heat exchangers:

1. Open loop EAHE system
2. Closed loop EAHE system
3. Combination EAHE system

1.1.3 Design parameters of earth air heat exchanger

The effectiveness of earth air heat exchanger systems is mainly related to the following parameters:

- Ground temp. at depth of the installed exchanger
- Thermal diffusivity of soil
- Pipe length, width
- Inlet air temp.
- Thermal conductivity of pipes
- Air velocity

II. LITERATURE REVIEW

The heat transfer to and from Earth tube heat exchanger system has been the subject of many theoretical and experimental investigations. By having a review on previous research papers published by many authors we can have an idea on how it works. In the last two decades, a lot of research has been done to develop analytical and numerical models for analysis of the EAHE systems

2.1 Previous work

Sodha et al. [1981], found variance in ground temperature using Fourier coefficient calculations and predicted that the variance decreases rapidly with depth and temperature approaches to a constant value after 0.4 m depth.

Mihalakakou et al. [1997], present a complete model for the prediction of the daily and annual variation of ground surface temperature. The model uses a transient heat conduction differential equation and an energy balance equation at the ground surface to predict the ground surface temperature. The energy balance equation involves the convective energy exchange between air and soil, the solar radiation absorbed by the ground surface, the latent heat flux due to evaporation at the ground surface as well as the long-wave radiation.

De Paepe and Janssens [2003], used a one-dimensional analytical method to examine the influence of the design parameters of the heat exchanger on the thermo-hydraulic performance and devise an easy graphical design method which determines the characteristic dimensions of the earth-air heat exchanger in such a way that optimal thermal effectiveness is reached with acceptable pressure loss. The choice of the characteristic dimensions becomes thus independent of the soil and climatological conditions. This allows designers to choose the earth-air heat exchanger configuration with the best performance.

Ghosal et al. [2005] developed a simplified analytical model to study year around effectiveness of an EAHE coupled greenhouse located in New Delhi, India. They found the temperature of greenhouse air on average 6–7 °C more in winter and 3–4 °C less in summer than the same greenhouse when operating without EAHE.

Bansal et al. [2010] investigated the performance analysis of EAHE for summer cooling in Jaipur, India. They discussed 23.42 m long EAHE at cooling mode in the range of 8.0–12.7 ˚C and 2–5 m/s flow rate for steel and PVC pipes. They showed performance of system is not significantly affected by the material of buried pipe instead it is greatly affected by the velocity of air fluid. They observed COP variation 1.9–2.9 for increasing the velocity 2–5 m/s.

Santamouris et al. [2011] investigated the impact of different ground surface boundary conditions on the efficiency of a single and a multiple parallel earth-to-air heat exchanger system.

Mishra et al. [2014] experimentally investigated the performance of the hybrid EAHE and concluded that energy consumption was reduced by 18% when the conditioned air from EAHE was utilized for condenser cooling compared to the energy consumption when ambient air was used for condenser cooling.

Thiers and Bruno Peuportier [2015] analyzed the performance of a passive building coupled with EAHE in France. They have concluded that the passive concept efficiently enhances the environmental performance of the dwellings in the French context.

Chlela et al. [2016] concluded that a balanced ventilation system coupled with EAHE significantly reduces a building's heat demand and hence its CO_2 emissions.

Bisnoyia et al. [2017] gave an extensive literature review covering design, characteristics of EAHE, modelling adopted by several researchers etc. When the earth air heat exchanger was integrated by solar chimney which utilizes the geothermal energy as well as the solar energy, the energy savings were greater compared to uncoupled system.

Shreekant Kumar et al. [2017] investigated the CFD Evaluation on Earth Tube Heat Exchanger with Different Velocity in Parallel Design for Heating. ETHE is made by parameter of 50 m long MS pipe,10 cm nominal diameter and 3 mm wall thickness. Buried 3 m deep underground surface. They have concluded Heat transfer rate increases with slip boundary condition at low velocity.

2.2 Summary of Literature Review

The above-mentioned researches had studies on topics, which are based on various methods implemented to enhance the performance of earth air heat exchanger system. In some research papers, the study is focused on an increase in the effectiveness, (Mishra et al. [2014]). However, in some different technique is utilized (Bisnoyia et al. [2017], Shreekant Kumar et al. [2017]) .There was no work found which considered cumulative effect of fins on earth air heat exchanger system.

III.METHODOLOGY

To perform analysis is done on the investigation measurements through Computational Fluid Dynamics (CFD) software employed, the uncertainties in the measurement of air outlet temperature are estimated as 3 m/s in winter season for heating using Aluminium and PVC as pipe material with and without fin's we know that in Bhopal the average winter temperature lies between 16-18^{0}C and due to availability of land problems we can't bear a system that was proposed in previous model in which earth air heat exchanger system was developed in parallel system with a mild steel tube length of 30m which occupies space much more. So we replace the model by providing a tube length of 12m as compared to of 30m.As we know that the soil temperature below 3m of ground surface maintained at 25.4 ^{0}C throughout the year and average winter temperature lies between 16-18^{0}C so the tube length doesn't play much more vital role in terms of heat transfer rate .Therefore concept of fins help us to increase the heat transfer rate. Therefore, depending on the nature of the design problem the mass flow rate of air, $\dot{m}$; inlet air temperature, T_{in}; desired outlet air temperature from EAHE, T_{out}; and EUT are considered as parameters of the sizing problem.

Assumptions

The following assumptions were made in order to simplify the development of the one-dimensional model of the EAHE system:

- The surface temperature of the ground is defined as equal to the ambient air temperature, which equals the inlet air temperature.
- EUT can be approximated to the annual average temperature of the location (Bhopal, India).
- The Aluminium and polyvinyl chloride (PVC) pipe used in the EAHE is of uniform cross-section.
- The thickness of the pipe used in the EAHE is very small; hence, thermal resistance of pipe material is negligible.
- The temperature on the surface of the pipe is uniform in the axial direction.

3.1 Geometry Modeling

3.1.1 without fin

The geometry modelling of earth air heat exchanger system without fin for Aluminium and PVC remains same. EAHE system is made by parameter of 12 m long Aluminium and PVC pipe, 0.15 m tube diameter and 3 mm pipe thickness. Buried 3 m deep underground surface.

Firstly, ANSYS workbench 17.0 software was installed on the system. CFD fluent package is required to operate. Select design modular and run then select the dimension in which the model is to be creating and the type of model i.e. either 2D or 3D.

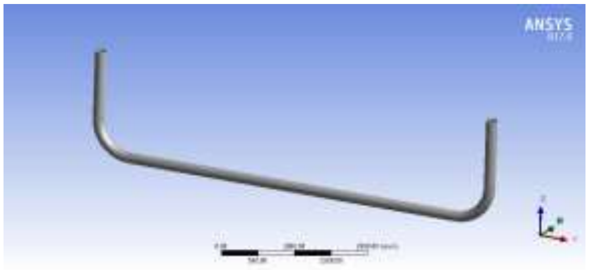

Figure 1 Geometry of earth air heat exchanger without fin for PVC and Aluminium.

3.1.2 with fin

The geometry modelling of earth air heat exchanger system with fin for Aluminium and PVC remains same. EAHE system is made by parameter of 12 m long Aluminium and PVC pipe, 0.15 m tube diameter and 3 mm pipe thickness. Fin is provided at the horizontal part of the pipe which is of length of 6m. Circular fins of square cross-section are provided of side 3mm. Buried 3 m deep underground surface.

Again model is created in design modular.

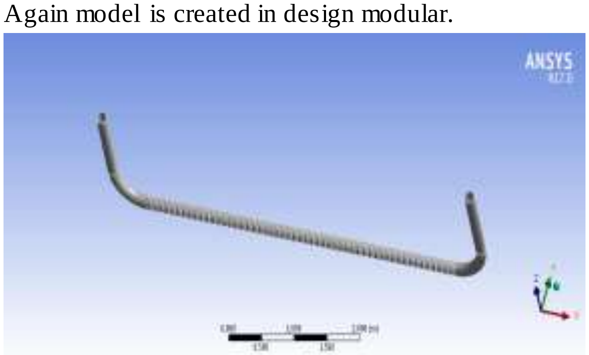

Figure 2 Geometry of earth air heat exchanger with fin for PVC and Aluminium.

3.2 Meshing

Meshing is defined as the process of dividing the whole component into number of elements so that whenever the boundary conditions are applied on the component it distributes the inputs uniformly called as meshing.

3.2.1 Meshing of EAHE without fin

Meshing detail –ICEM CFD meshing

Method: Automatic

Meshing type: Tetrahedral and Quardcore.

No of node -56223

No of element- 115354

Figure 3 Meshing of earth air heat exchanger without fin for PVC and Aluminium.

3.2.2 Meshing of EAHE with fin

Meshing detail –ICEM CFD meshing

Method: Automatic

Meshing type: Tetrahedral and Quardcore.

No of node -57504

No of element- 116354

Figure 4 Meshing of earth air heat exchanger with fin for PVC and Aluminium.

3.3 Name Selection

A different part of the earth air heat exchanger system and fluid flowing inside the heat exchanger is selected and the names are given to them so that boundary conditions can be applied on different boundary.

3.4 Type of Solver

After mesh generation defined the following setup in the ANSYS fluent. For with fin and without fin solver type remains same.

Problem Type- 3D, Transient State

Type of Solver- Pressure-based solver

3.5 Model selection

The special input required is pressure based solver, Viscous, K, e two equation turbulence model and solution techniques. Energy is on.

3.6 Material Selection

Physical Properties for the working fluid i.e. Air considered for this study are as below:

Table 1 Properties of Air.

Thermal conductivity(W /m-K)	Density (Kg/ m^3)	Specific Heat(J/K g-K)	Dynamic viscosity(Kg /m-s)
0.0253	1.2185	1006	1.804 e-5

The material property which is use in analysis is shown in Table 2 and 3.

Table 2 Properties of pipe material i.e. Aluminium

Thermal conductivity(W /m-K)	Density (Kg/ m^3)	Specific Heat(J/K g-K)	Dynamic viscosity(Kg /m-s)
202.4	2719	871	----------

Table 3 Properties of pipe material i.e. PVC

Thermal conductivity(W /m-K)	Density (Kg/ m^3)	Specific Heat(J/K g-K)	Dynamic viscosity(Kg /m-s)
0.16	1380	900	---------

Table 4 Properties of Soil

Thermal conductivity(W /m-K)	Density (Kg/ m^3)	Specific Heat(J/K g-K)	Dynamic viscosity(Kg /m-s)
0.54	2058	1843	---------

3.7 Boundary condition

Here in the analysis the boundary condition is same for both the materials for with fin and without fin as considered by Shreekant Kumar et al. [2017] during the work. Some of the conditions are shown in the Table 5.

Table 5. Boundary condition of different parameters

Name	Velocity(m/s)	Temperature(K)
Fluid inlet i.e. Air	3	293

The temperature on the surface of pipe (wall) was uniform in axial direction and was defined as equal to earth's undisturbed temperature at Bhopal city (25.4°C). No slip condition with smooth wall was assumed at the inner surface of the pipe. Since the analysis is transient so the time taken for the analysis is 60 minute. Number of iteration =60

3.8 Solution and results

After putting the boundary conditions, the solution is initialized and then iteration is applied so that the values of all parameters can be seen in a curve line graph. After the iteration gets completed final result could be seen.

IV. RESULTS AND DISCUSSIONS

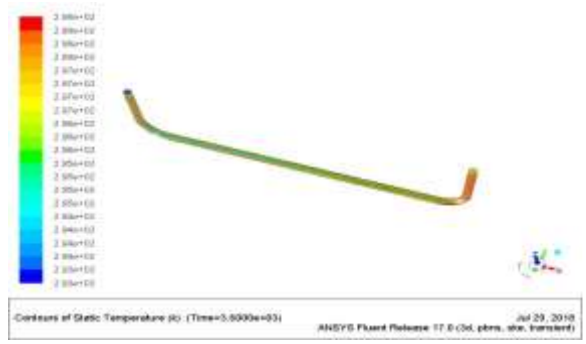

Figure 5 Temperature contour of earth air heat exchanger system without fin for pipe material Aluminium.

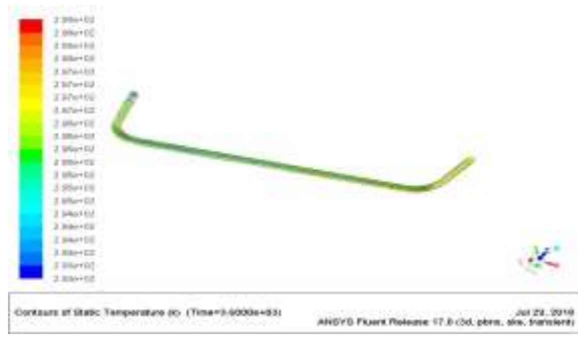

Figure 6 Temperature contour of earth air heat exchanger system without fin for pipe material PVC.

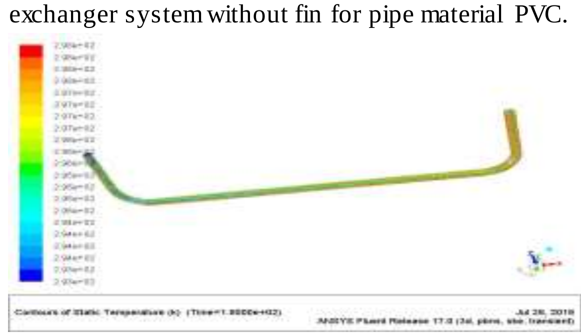

Figure 7 Temperature contour of earth air heat exchanger system with fin for pipe material Aluminium.

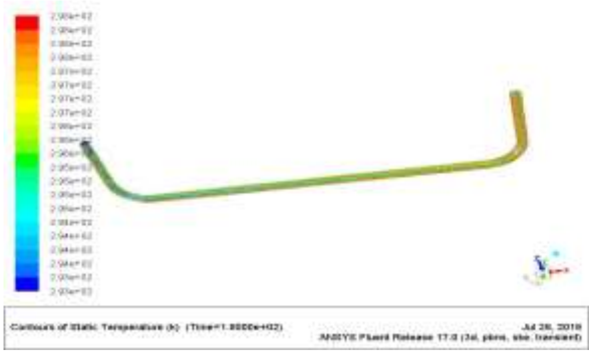

Figure 8 Temperature contour of earth air heat exchanger system with fin for pipe material PVC.

Table 6 Comparison of maximum outlet temperature for different material with and without fin.

	Pipe Material			
	Aluminium (without fin)	PVC (without fin)	Aluminium (with fin)	PVC (with fin)
Inlet Temperature (K)	293	293	293	293
Velocity(m/s)	3	3	3	3
Soil Temperature (K)	298.4	298.4	298.4	298.4
Mid Temperature (K)	296.237	295.375	297.024	295.932
Outlet Temperature (K)	298.3241	297.84	298.4	298.024

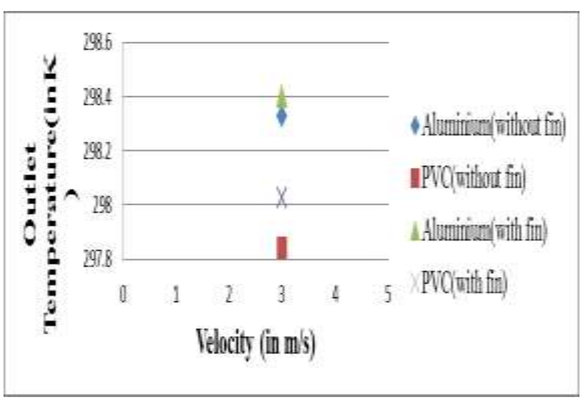

Figure 9 Outlet temperatures for an inlet velocity of 3m/s for different material with and without fin.

V. CONCLUSIONS

After going CFD analysis through the comparison charts shown in the above, we can see that the results are quite encouraging. From the CFD analysis by using properties and boundary conditions the following conclusions are made:

- For the pipe of 12 m length and 0.15 m diameter, temperature value considered for inlet is 293K; pipe material Aluminium with fin is effective as comparable to other ones.
- The outlet temperature of Aluminium pipe with fin is 298.4K.
- Performance is effective with fin.
- Outlet maximum temperature is 298.4K for Aluminium with fin and the minimum temperature is 297.84 K for PVC without fin.
- Thermal point of view Aluminium pipe material is more effective than compared to PVC and Mild steels.
- Cost point of view PVC is more acceptable because of low cost and performance in moisture present because the difference in outlet temperature compared to other on is quite less.

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