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Design and Development of Earth Tube Heat Exchangers

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Abstract - Now a days we all apprehensive of the increasing price of electricity. So, everyone is moving towards sustainable living. In this case, Earth Tube Heat Exchanger is the suitable choice for the HVAC installation. In domestic structures large quantum of the electricity needed for heating and cooling purpose. To reduce the burden on the active system we've moved e've moved towards a renewable source of e energy. Earth Tube Heat Exchanger works. on the basic sasic principles of a heat transfer and uses geothermal energy as a source of energy. This design presents the results of theoretical computation and computer simulations (analysis) of Earth Tube Heat Exchanger. By this system, we can achieve full and partial HVAC installations in the living area. Analysis of the system is done by using Ansys CFD analysis.

KeyWords: Geothermal energy, Heat Exchanger, CFD, Fluent, Effectiveness of ETHE

1. INTRODUCTION

Worldwide, it's estimated that the domestic structures, services, and stores consume large quantity of our energy and electricity. Heating and cooling for domestic, marketable, and artificial purposes regard for a large share of total final energy demand. To lessen the burden on the active systems substantiating renewable energy into the thermal or electrical energy, a necessary first step is to apply the optimal combination of unresistant design strategies, foremost among them unresistant solar design strategies. Geothermal energy is considered a wahle source of energy (no way- ending source of energy). Traditional heating and cooling system needed compressor, condenser, and evaporator setup. While Earth tube heat exchanger is an underground heat exchanger that can capture heat from the ground for heating purposes and dissipate heat to the ground for cooling purposes. Earth tube heat exchanger is a creative way to use the geothermal energy to our advantage, both for heating and cooling inside the living area. Earth tube heat exchanger needed blower to move the air throughout the setup of the earth tube heat exchanger. Heat is uprooted from or rejected. to the ground through a buried pipe, through fluid inflow. This simple setup helps in reducing cost, electricity consumption for the system. This system eliminates the compressor, condenser, and evaporator cost by simply using geothermal energy.

There's an increased interest in heating and cooling system grounded on renewable energy sources. The earth air heat exchangers are suitable method against conventional systems to reduce the primary energy consumption needed for heating and cooling of structure [1]. In the system the heat pump can be used for both space heating and cooling that means the ground can be used as a source of heat in winter and a source of cooling in summer. The energy effectiveness of the heat pump directly depends on the ground temperature. In closed circle systems, the heat pump is coupled with the grounds by means of heat exchanger that can be vertically or horizontally acquainted [2][3][4]. Kumar et al.

[5] estimated the conservation eventuality of an earth air pipe system coupled with a structure with no, Ghosal et al. [6] developed a thermal model to probe the performance of earth air heat exchanger integrated with greenhouse. Ajmi et al. (7) studied the e cooling capacity of earth hair heat exchangers for domestic structures in a desert climate. Badescu (8) developed a ground heat exchanger model grounded on numerical transitional bi-dimensional approach. Wu et al. [9] developed a flash and implicit model grounded on numerical heat transfer and computational fluid dynamics and also enforced it on the CFD platform, PHOENICS to estimate the effect of the operating parameters (Le the pipe length, compass, depth and air inflow rate) on the thermal performance and cooling capacity of earth pipe systems. Cucumo etal. [10] proposed one dimensional flash logical model to estimate the performance of earth to air heat ex-changers installed. at different depths used for erecting cooling/ heating. Cui etal. [11] developed a finite element numerical model for the simulation of the ground heat ex-changer in indispensable operation modes over a short time period for ground coupled. Heat pump operations.

In the present study, transient analysis of earth tube heat exchanger has been done using CFD. Earth tube heat exchanger is simulated to study the performance during winter for heating and during summer for cooling.

2. DESIGN PARAMETERS

The following parameters are truly important in designing of ETHE.

1. Tube Material while concluding the tube material for ETHE we have to consider given parcels like strength, corrosion resistance, durability, and cost of the material.

2. Tube Length Heat transfer depends on the face area.

3. The face area of a pipe depends on: (a) Fringe

(b) Length

So, the increased length would mean raised heat transfer rate and hence advanced effectiveness. After, a certain length no significant heat transfer occurs. Hence, optimizing the length is necessary. Adding length also results in a pressure drop. Hence increase addict energy.

4. Tube Fringe

Lower fringe gives better thermal performance but results in larger pressure drops increased fringe results in a reduction in air speed and heat transfer.

5. Tube Depth Ground temperature affected by the

a) External climate.

b) Soil Composition.

c) Water Content,

d) Soil Contact Factor

6. The ground temperature fluctuates in time, but the breadth of change lowered with depth. Burying pipe/ tubes as deep as possible would be constant and become ideal. Generally, 4-5m below the earth's face dampens the oscillation significantly.

1-Length of tube = 21m

2-External diameter of the pipe = 1.8m

3-Internal diameter of the pipe = 1.5 m

4-Velocity of the air = (1.5,2,3,4) m/s

5-Inlet Temperature = 40 "Celsius

6-Thermal Conductivity of the air = 0.0266 W/mK

7- Thermal conductivity of the Pipe = 205 W/m K

8-Viscosity = 1.84×10 Ns/m²

Description of Numerical Method

Numerical method basically includes the basic equations to solve the heat exchange or flow.

Q = m. Cp. (T2-T1)

This the basic heat energy equation where,

Q = Heat flow

C_p = specific heat of Substance (1/kg °C)

m = mass of substance (Kg)

(T_2-T_1)=Change in temperature

We need to LMTD (Logarithmic mean temperature difference)

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\log_e\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

COP of the system is calculated as:

COP= Q/W

Where W is the system electricity consumption.

It is found that by changing different parameters is increasing the diameter of the pipe and air speed has the more significant impact on the system COP.

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Description of CFD Model

CFD software, Fluent mainly includes Numerical algorithms and to examine the results there are mainly three elements in CFD codes of Fluent.

Those elements

a) A pre-processor

b) A solver

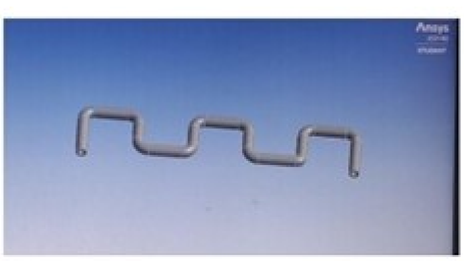
c) A post-processor

A grid (or mesh) of elements (or Volumes) is need to be developed, fluid properties needs to be defined, boundary conditions needs to be added. These all are the inputs of pre-processing. Then the solver uses finite control volume method and solve governing equations of heat and fluid flow. Then the results of those simulations are shown in the form of graphs, charts and animations by post-processor.

In this study it is assumed that the air (Flowing fluid) is in-compressible and soil temperature remains constant.

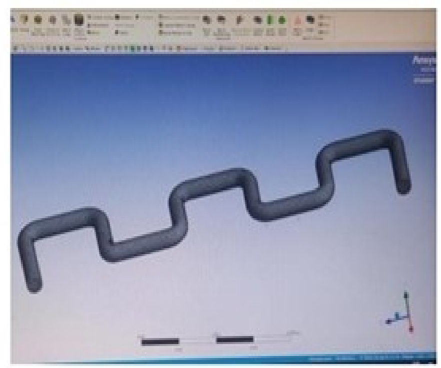
3. CFD Designing of Earth Tube Heat Exchanger

1. Designing the model on the CFD platform by using the given parameters.



(Fig 1. Sketching)

2. Firstly, selecting the appropriate material (Le) and then sketching the model or Geometry with appropriate dimensions. (Shown in Fig1.)



(Fig 2. Meshing)

3. Then meshing of the model is done using tetrahedral volumes. By the method of grid independent solutions we decide the density of mesh. (Shown in Fig 2.)

4. To increase the meshing accuracy for better results we keep on enhancing the grid ratio and refining it.

5. Then selection of Faces is to be done (Le. Inlet of Pipe, the wall, Outlet of Pipe and Fluid domain). (Shown in Fig 3.)

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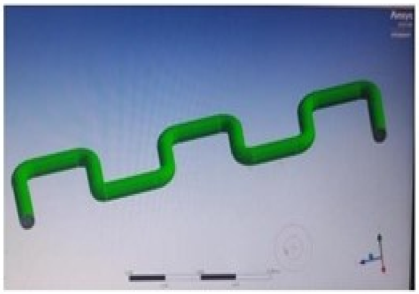
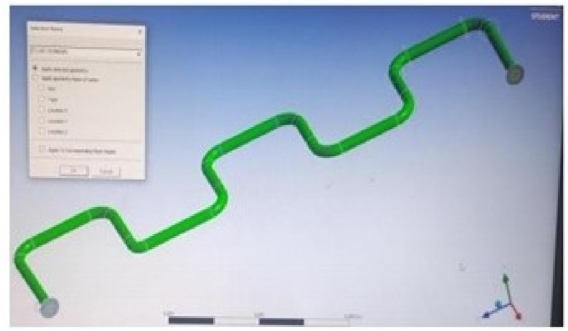


(Fig 3. {a}Selection Wall of the Pipe)

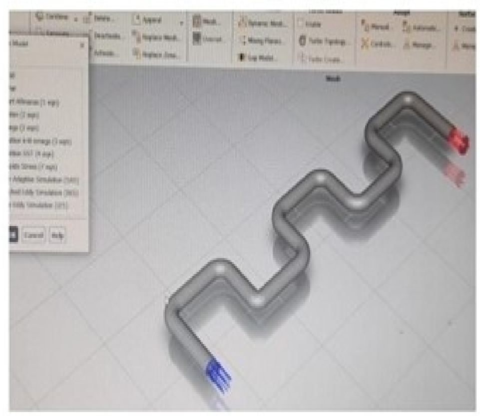
(fig 3. {b} Selection-Inlet of the Pipe)

(fig 3. {c} Selection-Outlet of the Pipe)



(fig 3. {d} Selection-Fluid Domain of the Pipe)

6-Then we set up the Geometry to observe the flow of air (fluid) in the pipe. (Shown in Fig. 4)



(fig 4. Set of the Model)

4. Result and Discussion

Comparison of Numerical Method Output and CFD Analysis Output

A- Outlet Temperature of Heat Exchanger –

Table 1

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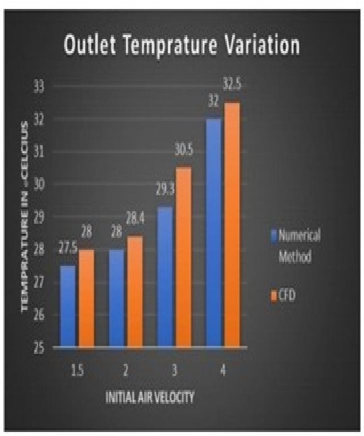
S. No.	Inlet Velocity	Numerical Method Output	CFD Analysis Output
	(m/s)	Degree ◦Celsius	Degree ◦Celsius
1.	1.5	7.5	28
2.	2	28	28.4
3.	3	29.3	30.5
4.	4	32	32.5

The variation is clearly given in the Figure 5 below in the form of bar graph.



In the table 1, it is clearly seen there is no such variation of difference between the outlet temperature of either the Numerical Method or the CFD analysis. Both are nearly same.

B. Heat Flow and COP of the Earth Air Heat Exchanger

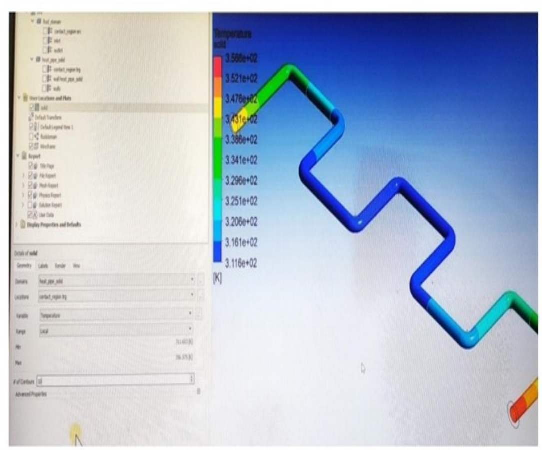
Table 2

S. No.	Inlet Velocity	Heat Flow (Numerical Method Output)	Coefficient of Performance
	(m/s)	(watt)	
1.	1.5	384.795	1.5
2.	2	488.916	1.9
3.	3	642.23	2.5
4.	4	733.34	2.9

Here we can clearly observe that with the increase in initial velocity the value of coefficient of performance and heat output increasing rapidly.

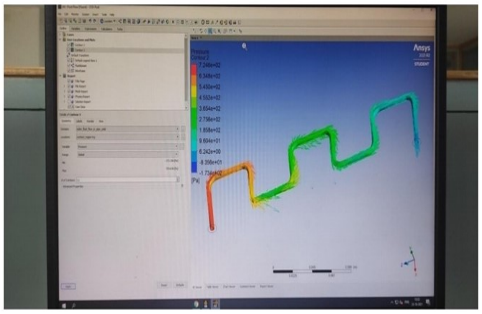
Simulation Curves –

1 – Temperature Contour or Temperature Variation in the tube .



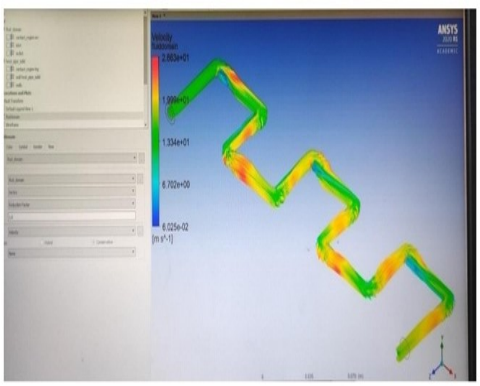
(fig. 6)

2. Pressure Contour or Pressure variation in the tube.



(Fig. 7)

3- Fluid Domain Velocity Contour



(Fig. 8)

In the above three figures (6, 7, 8) you have observed the temperature, pressure and Fluid domain Contour that how with time their variation is happening. From Fig. 7, it is clearly seen in at the outlet the pressure is quite less as compared to initial condition. The fluid flow or fluid domain is nearly same whole time. No such variation is there expect at corner points of the pipe due to sudden change. The looks of these three is different and it can be same it totally depends on the phase you are selecting in 'Solution' part, how much you want to clearly show the Variation.

Conclusion:

It has been found that with minimum velocity of air, maximum temperature fall down is there. EAHE system is more effective when buried in more depth inside the soil and after about 4-5 meters of depth the conditions become constant and ideal. The increase in air velocity increase the heat convective heat transfer coefficient and reduce the ground contact factor. And in these EAHE system convective heat transfer play more important role in compared to conductive heat transfer. The pipe material does not create any such change except the setup cost.

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