EARTH TUBE HEAT EXCHANGER

Wilson[1], Dr. Shobhit Srivastava[2]

[1]*M.Tech, Production Engineering, Maharishi University of Information Technology, Lucknow, India*
[2]*Assistant Professor, Mechanical Engineering Department, Maharishi University of Information Technology, Lucknow, India*

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Abstract - *These days, everyone is worried about the gradually rising cost of power, which is something that we all experience. This is something that we all have in common. Everyone is making a concerted effort, as a direct consequence of this, to embrace a way of life that is friendlier to the environment. In the context of this hypothetical situation, the Earth Tube Heat Exchanger emerges as the option that offers the greatest number of benefits when compared to the other potential configurations for the installation of the HVAC system. A substantial quantity of electrical power is often required by residential constructions. This is so that the space can be heated and cooled appropriately. We have shifted to using a source of energy that is renewable to reduce the amount of stress that is placed on the active system. The Earth Tube Heat Exchanger is a system for transferring heat that is powered by geothermal energy and functions according to the fundamental principles of how heat should be transferred. Geothermal energy is used to power the system, and the system operates following these fundamental principles. The Earth Tube Heat Exchanger was analyzed using theoretical calculations and computer simulations, and this design displays the conclusions derived from those two methods. Because of the technology at our disposal, we can do complete as well as partial installations of HVAC in the living area. These options are both accessible to us. CFD analysis created in Ansys is used in the process of doing the system research so that it may be completed.*

Keywords: Geothermal Energy, Heat Exchanger, CFD, Fluent, Effectiveness of ETHE.

1. INTRODUCTION

It is predicted that residential and commercial structures, including places of business and retail establishments, would account for a significant share of the overall quantity of energy and electricity that is used around the globe. The cost of heating and cooling buildings that are utilized for residential, commercial, or industrial purposes accounts for a significant fraction of the total ultimate demand for energy. The implementation of the most effective combination of insensitive design techniques is the essential first step in the process of lightening the load that is imposed on the active systems that are responsible for transforming renewable energy into thermal or electrical energy. Solar design methods that do not rely on resistance are now at the forefront of this category of design strategies that do not rely on resistance. It is considered that geothermal energy is one of the sources of energy that may be replenished throughout time (no way- ending source of energy). Traditional heating and cooling systems included components such as compressors, condensers, and evaporators, all of which were essential to their operation. The Earth tube heat exchanger, on the other hand, is a type of subterranean heat exchanger that is capable of both drawing heats from the ground to warm a room and releasing heat into the ground to cool a room. It does this by absorbing heat from the ground and then releasing heat into the ground. An earth tube heat exchanger is an innovative way of making good use of geothermal energy within the living area, both for the goal of warming up the space as well as to cool it down. This may be done for either purpose. To promote the passage of air throughout the different components of the system, the earth tube heat exchanger needed the employment of a blower as a necessary component. It is possible to draw heat from the ground or send it back into it using a pipe that is buried in the ground and a fluid that is introduced into the system. This uncomplicated arrangement contributes to the system's total cost savings as well as a reduction in the amount of power that it draws from the wall outlet. This system can eliminate the need for expensive compressor, condenser, and evaporator components since it makes use of geothermal energy instead.

The concept of using renewable energy sources to power heating and cooling systems is beginning to pique the curiosity of an ever-increasing number of individuals. Earth-air heat exchangers are an efficient alternative to conventional heating and cooling systems that may reduce the amount of primary energy needed to keep a building at the temperature that is desired [1]. As a result of the fact that during the colder months the ground may be utilized as a source of heat, and during the warmer months it can be used as a source of cooling, the heat pump that is a part of the system can be used to both heat and cool the space. This suggests that during the cold months, the earth itself might be used as a source of heat. The temperature of the ground has a direct impact on the efficiency of the heat pump as an energy source, thus it is important to consider this. A heat exchanger is used in closed-loop systems to link the heat pump to the ground. This heat exchanger may be related to the ground in either a vertical or horizontal direction, depending on the design of the system.

When it came to conventional heating and cooling systems, it was essential to position the compressor, condenser, and evaporator in the appropriate areas of the building. The Earth tube heat exchanger, on the other hand, is a type of subterranean heat exchanger that is capable of both drawing heat from the ground to warm a room as well as releasing heat into the ground to cool a room. This allows the Earth tube heat exchanger to be used for both heating and cooling a room. This is accomplished by the plant drawing heat from the ground, storing it in its cells, and then releasing it back into the earth. An earth tube heat exchanger is an innovative technique for making excellent use of geothermal energy inside the living area. This can be done both to warm up the space as well as to cool it down. Both of these goals may be accomplished with the help of geothermal energy. Either goal might be served by carrying out this action. During the process of installing the ground loop heat exchanger, it is vital to make use of a blower so that air can be moved throughout the whole system. This ensures that the air is heated and cooled evenly. This is necessary for the earth tube heat exchanger to function properly. Via the use of fluid movement, heat may either be taken from the ground or reintroduced into it through a pipe that is buried under the surface. Both of these processes are accomplished by placing the pipe in the ground. The technique in question is referred to as geo-exchange. This easy design helps contribute to the overall cost savings of the system and also adds to a decrease in the amount of power that is used from the wall outlet by the system. Because it operates off of geothermal energy rather than traditional forms of power, this system can dispense with the pricey compressor, condenser, and evaporator components that are normally required.

2. METHODOLOGY

In this section of the methodology, we will discuss the method used for the analysis, the software used for the analysis, etc, these details are given below:

2.1. Geometrical Parameter of the Tube Pipe

The tube pipes which are used for the heat exchanger, the geometrical parameter are given below in the form of the table:

Table-01: Tube Pipe Parameter

Serial Number	Parameter	Name
1	Length of tube Pipe	21 meter
2	External Diameter of tube pipe	1.80 meter
3	Internal Diameter of tube pipe	1.50 meters
4	Velocity of Air	1.5, 2.0, 3.0,4.0 meters/second
5	Inlet Temperature	40-degree Celcius
6	Thermal Conductivity of Tube Pipe	205.0 W/mK
7	Thermal Conductivity of Air	0.0266 W/mK
8	Viscosity	$1.840*10^{-5}$ Ns/m^2

2.2. Description of Numerical Models

The numerical method essentially consists of the fundamental equations that are used to solve the heat flow or exchange. These equations are used to model the heat flow or exchange.

$$Q = m. Cp. (T2 - T1)$$

This is the basic equation used for the heat energy equation, where,

Q represents Heat flow.

C_p represents the specific heat of substance, the unit of this is "J/Kg degree Celsius"

M represents the mass of the substance (Kg)

T_2-T_1 represents the temperature change.

We need to LMTD (Logarithmic mean temperature difference)

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

Where the COP of the system is calculated by using the following equation:

$$COP = Q/W.$$

Where the W term represents the electricity consumption of the system.

It has been shown that modifying a few elements, such as increasing the diameter of the pipe and the airspeed, has the most significant influence on the coefficient of performance (COP) of the system. This was one of the discoveries made by scientists.

2.3. Description of CFD Model

The computational fluid dynamics (CFD) software offered by Fluent is mostly made up of numerical techniques. To analyze the results, the CFD codes offered by Fluent contain three components:

1. A pre-processor
2. A solver
3. A post-processor

You will first need to create a grid (or mesh) of elements (or volumes), then you will need to describe the characteristics of the fluid, and then you will need to add boundary conditions. To begin, you will need to create a grid (or mesh). During the pre-processing stage, every one of these components is regarded as an input. The solver then applies a method known as the finite control volume method to solve the governing equations of heat and fluid flow. After that, the results of those simulations will be presented to the user in a graphical format by a post-processor, which may include graphs, charts, and animations.

During this inquiry, it will be presumed that the air itself (the fluid that is moving) is incapable of being compressed and that the temperature of the ground will not change.

3. DEVELOPMENT OF AN EARTH-TUBE HEAT EXCHANGER USING COMPUTATIONAL FLUID DYNAMICS

Creating the model on the CFD platform by making use of the parameters that have been provided.

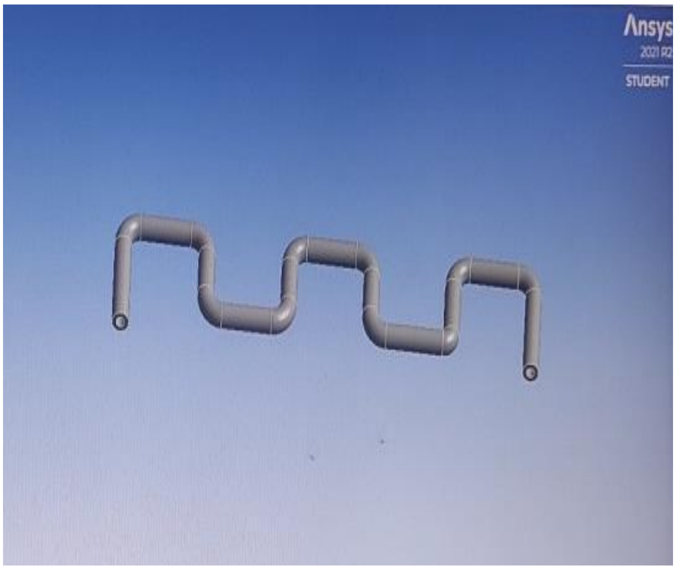

Figure-1: Sketching

First, the appropriate material (i.e.) needs to be selected, and then the model or geometry needs to be sketched out with the appropriate dimensions. (As Depicted in Figure 1)

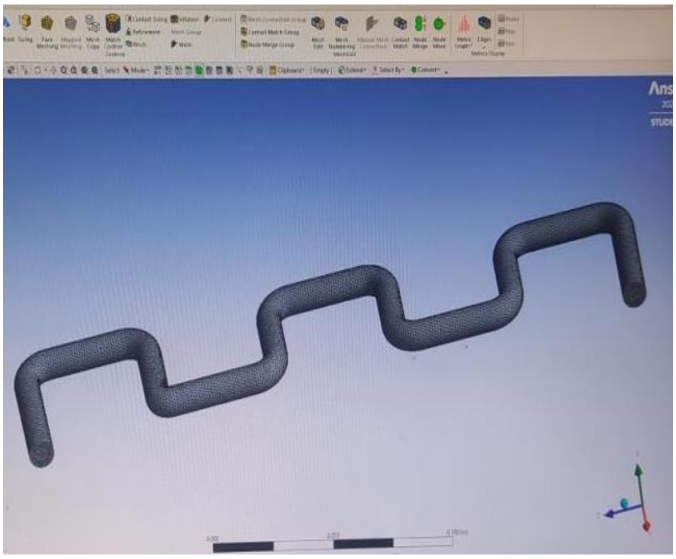

Figure-2: Meshing

After that, tetrahedral volumes are used so that the model may mesh. We use something that is termed grid-independent solutions as a method for figuring out the density of the mesh. (This can be seen in Figure 2) We are always trying to enhance the grid ratio so that the greater accuracy of the meshing will result in improvements to the situation as a whole.

The next phase, which is to choose the Faces, follows after that (i.e. Inlet of the Pipe, the wall, the Outlet of the Pipe, and the Fluid domain). (As shown in Figure 3.)

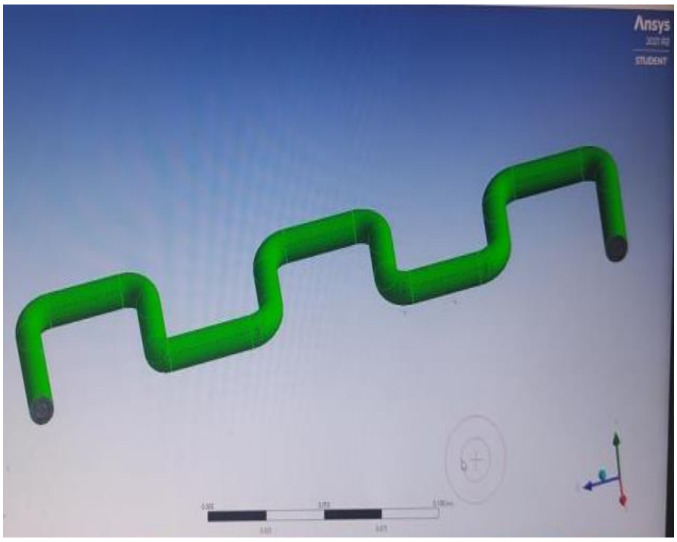

Figure- 3. a: Selection- Wall of the Pipe

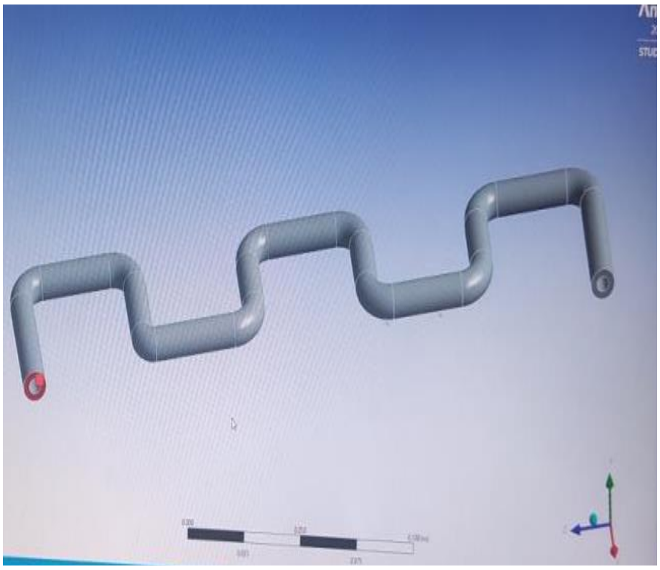

Figure-3 b: Selection- Inlet of the Pipe

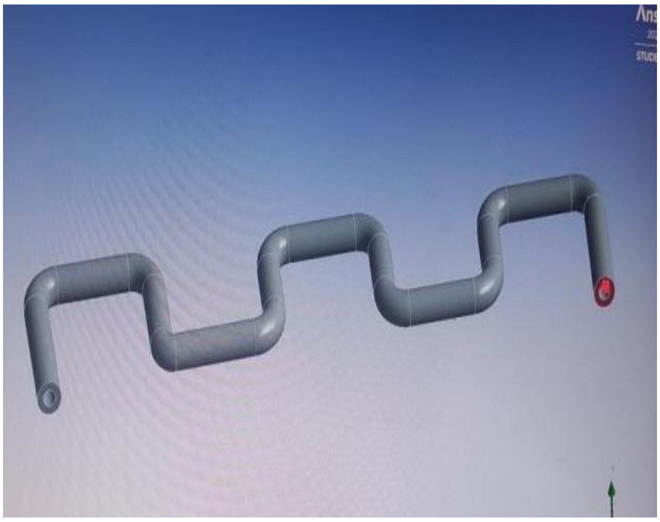

Figure- 3. c: Selection- Outlet of the Pipe

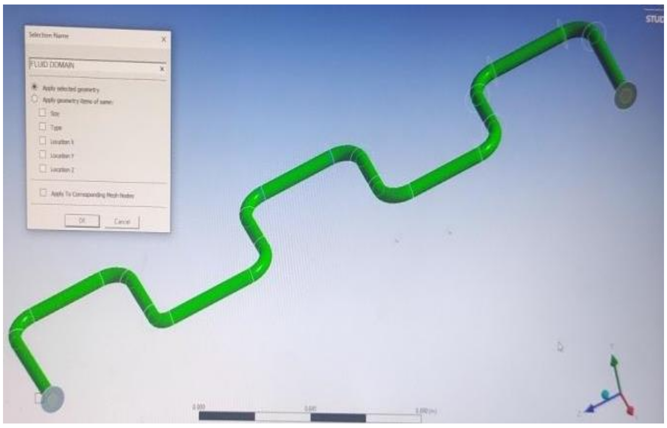

Figure-3.d: Selection- Fluid Domain of the Pipe

After that, we arranged the geometry such that we could see the movement of air (fluid) through the pipe. (As seen in Figure 4).

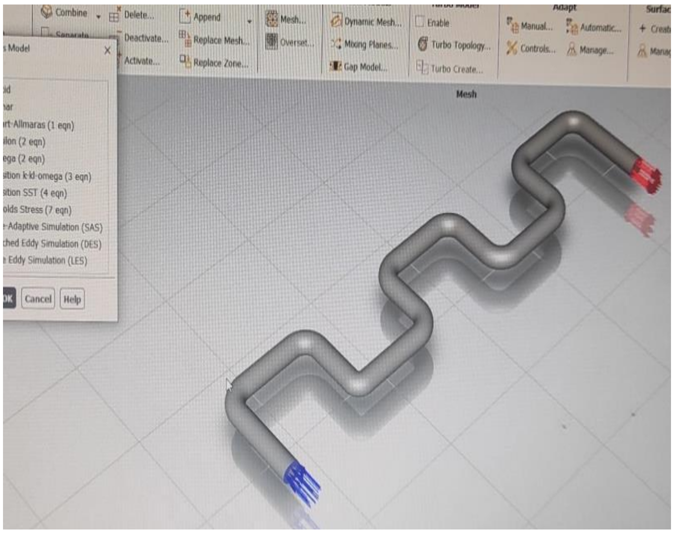

Figure 4: Set of the Model

4. RESULT AND ANALYSIS

A Comparison of the Results Obtained from the Numerical Method and Those Obtained From CFD Analysis

4.1. Outlet Temperature of Heat Exchanger

The variance is shown rather well in the form of a bar graph in the next figure, which is numbered 5.

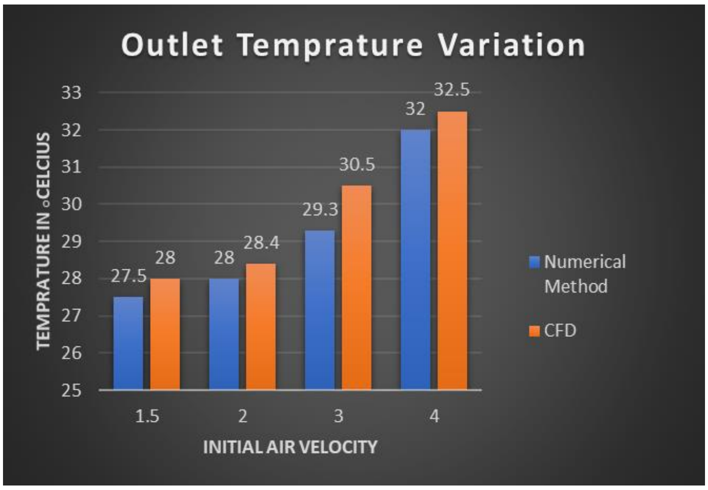

Figure-5: Outlet Temperature of Heat Exchanger

It can be seen quite plainly that the output temperature of either the numerical method or the CFD analysis does not alter or change in any visible manner. This is something that can be viewed pretty easily. Both are quite similar to one another in many ways.

4.2. Tube Temperature Profile or Temperature Gradient.

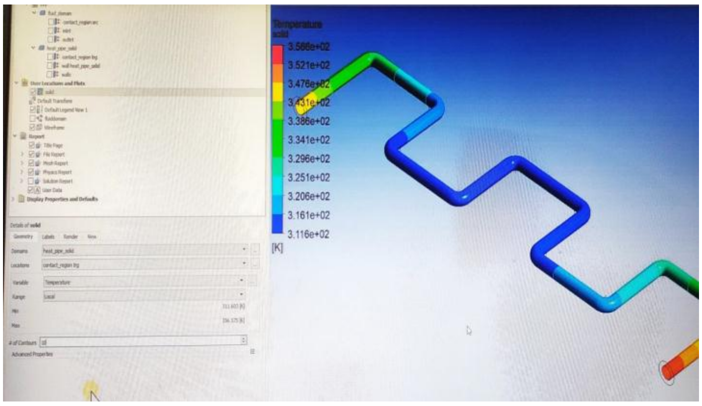

Figure-6: Tube temperature profile or temperature gradient.

4.3. Pressure Contour or Pressure Variation.

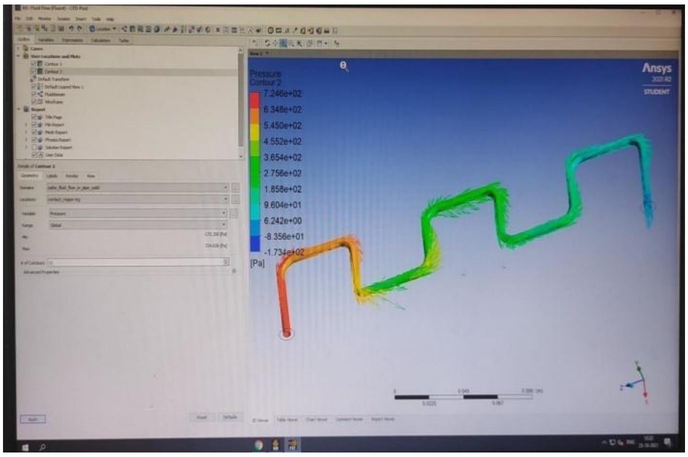

Figure-7: Pressure Contour or Pressure Variation.

4.4. Fluid Domain Velocity Contour

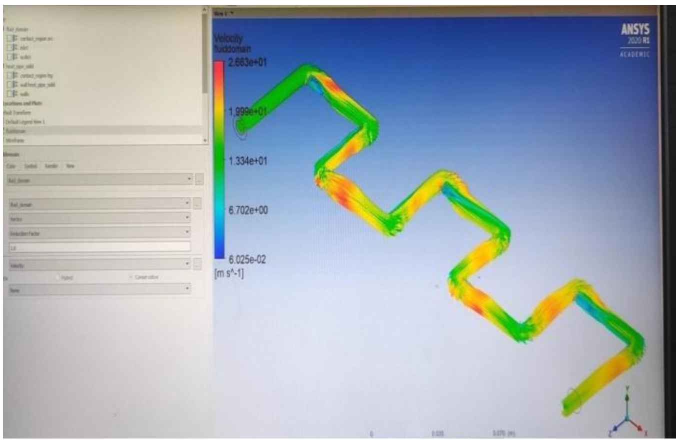

Figure-8: Fluid Domain Velocity Contour

In the three images that have been shown so far (6, 7, 8), you have seen how the temperature, pressure, and fluid domain contours vary with time. You have also seen how this fluctuation occurs. When compared to the original situation, it can be seen fairly clearly in Figure 7 that the pressure is much lower where the exit is located. The flow of the fluid or the fluid domain is almost the same the entire time. There is no such fluctuation, except for the abrupt change that occurs at the corner points of the pipe. It wholly relies on the phase you pick in the 'Solution' portion, how much you want to demonstrate the Variation, and whether or not these three appearances are distinct from one another or whether or not they may be the same.

5. CONCLUSION

It has been discovered that the biggest temperature drop occurs when the velocity of the air is at its lowest point. When buried at a greater depth inside the earth, the EAHE system operates at a higher level of efficiency. At a depth of around 4-5 meters, the circumstances become stable and optimal. Due to an increase in air velocity, the heat convective heat transfer coefficient has increased, but the ground contact factor has decreased. When compared to conductive heat transfer, the contribution that convective heat transfer plays in these EAHE systems is far more significant. The material of the pipe does not generate any of these changes, except for the initial cost.

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