Analysis of Earth Tube Heat Exchanger

Modeling andanlysis of ETHA

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Abstract

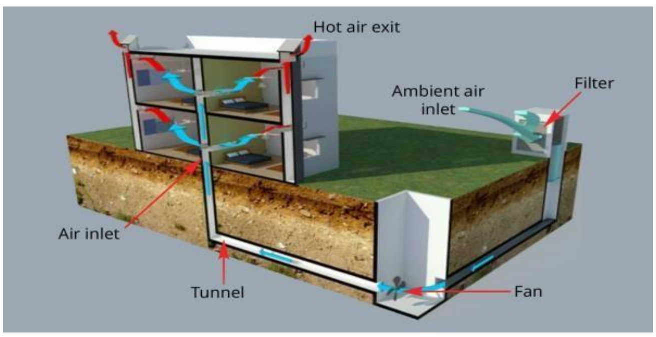
These days, everyone is aware of the rising cost of electricity. Thus, everyone is pursuing sustainable living. The optimum option for the HVAC facility in this situation is an earth tube heat exchanger. More than 40% of the electricity needed for heating and cooling in residential buildings. We have switched to a renewable source of energy to lessen the strain on the active system. The Earth Tube Heat Exchanger uses geothermal energy as a source of energy and operates according to the fundamentals of heat transmission. The examination of an earth tube heat exchanger's theoretical calculations and computer simulations is presented in this project. We can achieve full and partial HVAC capabilities in the living area with the help of this system. Ansys is utilised to analyse the system. The length of the ETHE and the impact of velocity on the ETHE's efficacy are calculated using the NTU approach. The experimental setup included a 0.15 m-diameter, 25 m-long <u>aluminium tube</u> that was burider at a depth of 2 m. In an open-loop system, the air is transported by a 250 W blower.

***KeyWords**:Geothermalenergy,NTU, Effectivenessof ETHE.*

1. Introduction

According to estimates, 40% of the energy and 70% of the power used worldwide is consumed by homes, workplaces, and retail establishments. A significant portion of the overall end energy demand is made up ofcoolingand heating needs for residential, commercial, and industrial buildings. Using the best combination of passive design techniques, prominent among them passive solar design methods, is a critical initial step in order to decrease the burden on the active systems that convert renewable energy into thermal or electrical energy.Geothermal energy is regarded as a renewable energy source (never-ending source of energy).

Compressor, condenser, and evaporator configuration were necessary for conventional heating and cooling systems. An earth tube heat exchanger is a type of underground heat exchanger that can both heat and cool the ground by transferring heat to it. The earth tube heat exchanger is a cutting-edge way to use geothermal energy to heat and cool interior living spaces. A blower is needed to move the air in the ground loop heat exchanger setup for the earth tube heat exchanger. A underground pipe allows fluid flow to reject or remove heat from the ground. This simple configuration helps to reduce system costs and electricity usage.



The cost of the compressor, condenser, and evaporator is eliminated by using this technique. merely utilizing geothermal power.

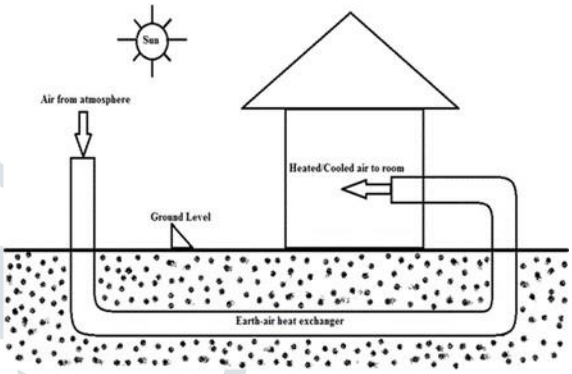


Fig.1:Earthtubeheatexchanger

2.DESIGN

2.1 Design Considerations

Make sure your template is the appropriate size for your paper first. This template has been designed to print on A4-sized paper. If you utilize the following factors are crucial for designing ETHE.

2.2Tube Composition

We must take into account features like a material's cost, strength, corrosion resistance, and durabilitywhile choosing the tube material for ETHE.

2.3Tube Length

Surface area affects heat transfer. A pipe's surface area is determined by its diameter.

a) Diameter.

b) Length

c) Dimension

Hence, the longer length would result in a faster rate of heat transmission and more effectiveness. No observable heat transmission remains after a particular amount of time.takes place. hence, make it longer. Furthermore, lengthening causes pressure to decrease.
boost fan energy as a result.

2.4.Tube Diameter

Although smaller tubes have greater thermal performance, they have higher pressure drops. Air speed and heat transfer are reduced as diameter increases.

2.5Tube Depth

The external climate has an impact on ground temperature.
c) The makeup of the soil.

2.6Thermal Characteristics

The ground temperature varies throughout time, but as you go deeper, the size of the variation decreases. It would be best to bury pipes and tubes as deeply as feasible. Typically, the oscillation is greatly dampened at a depth of 4-5 meter’s below the earth's surface.

2.7 Purpose

Using an earth tube heat exchanger to efficiently heat and cool interior spaces is a clever method to take advantage of geothermal energy. The following list includes this project's primary goal:

1. To identify a substitute for an active heating and cooling system, such as an air conditioner or heater.
2. Making use of the surroundings and ground temperature nearby.
3. Making the transition to renewable energy sources.
4. Focusing on environmentally friendly technology.
5. Lowering the heating and cooling system's energy usage.

You can design a heating and cooling system that uses geothermal energy with the aid of this project. In this project, we discussed crucial factors to consider when designing ETHE.

3. Tube Material Choice

The tube is ETHE's primary component. While choosing the tube material, there are a few characteristics we need to take into account. Strength, durability, resistance to corrosion, thermal conductivity, and cost of the tube materialmust all be good.

1. The thermal conductivity of copper is 385 W/mk.
2. The heat conductivity of aluminum is 205 W/mk.
3. The heat conductivity of brass is 109 W/mk.
4. Iron has a 79.5 W/mk thermal conductivity.
5. The heat conductivity of steel is 50.2 W/mk.
6. Thermal conductivity for PVC is 0.19 W/mk. As a material for tubes, let's use aluminum. It is less expensive, better at resisting corrosion, and has superior thermal conductivity.

A. Simulation and Modeling

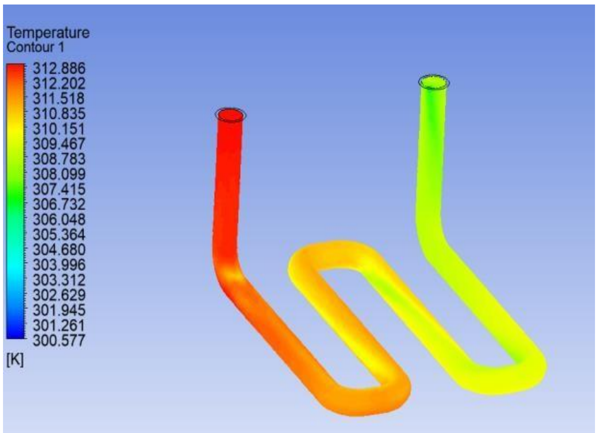


Fig.2 Simulation of ETHE

3.1Equation

1. Mass flow rate = m = (v x ρ x π x Di2)/4
2. Reynolds number = Re= $pvDi/\mu$
3. Prandtl number =Pr = $\mu Cp/Ka$
4. Convective heat transfers Co-efficient per unit length=h= NuKair/Do
5.Overall heat transfer coefficient $=\frac{Tairout-Tairin}{Twall-Tairin}$

6. Effectiveness = Output ÷ Input
7. Amount of heat transfer = Q = m Cp (Tout - Tin)
8. Coefficient of performance COP = m Cp (Tout- Tin) / Power input

The Autodesk Fusion 360c 3D Modeling software, version 2, was used to create the 3D model. Following creation 3D design. Using the Ansys workbench programme, the earth tube heat exchanger is analyzed. It displays the fluid flow and heat transfer rate in ETHE (heat transfer betweenfluidand soil). The fluid goes through the wizard's basic setup, adding inlet and exit caps, giving goals for the cooling off while looking at some results. The mathematical model mentioned above illustrates the observed heat transfer between the soil, earth tubes, and fluid. This simulation showed a 7–10°C decline in temperature.
The length of the aluminum tube can affect the temperature differential.

CAD Drawing

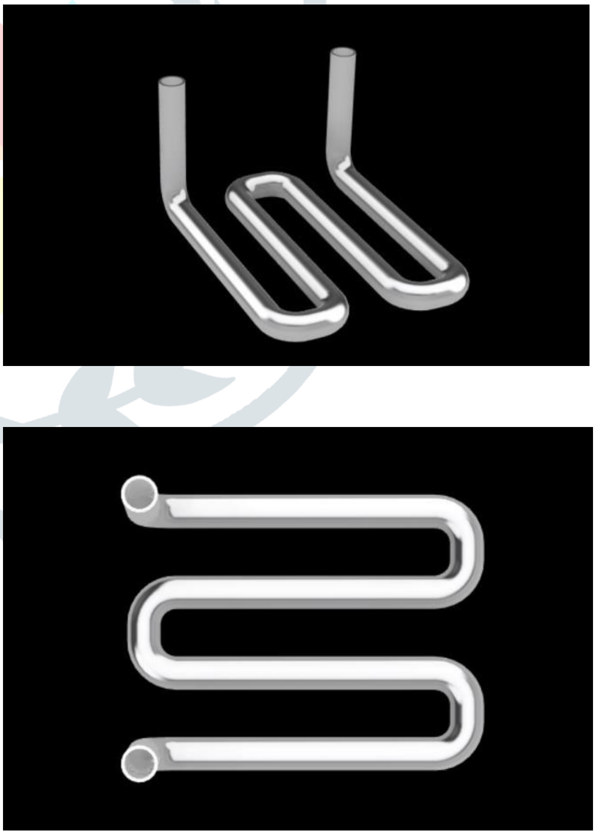


Fig.3 CAD Model

3.1Humidification and dehumidification:

One of the primary issues with underground dwelling is the possibility of mould growth due to condensation of humid air on

cool walls. Directly drawn hot, humid outside air will condense on the cool inside surfaces of an earth shelter.
Condensation could, however, occur in chilly earth tunnels when the air is being sucked in. Of course, you don't want mould in the earth tubes too, so you need to make sure they are made of fine, smooth HDPE tubing and slanted to drain the water.
With air travelling through a 60°F tube at 95°F with 100% relative humidity outside, the cooler air cannot carry as much moisture even though the relative humidity remains the same. It warms to 70°F after it is blended with other air within the house.
The RH is now just 70% due to the rise in temperature, which is still a bit high for comfort but considerably better than outside. The RH would only be 50% if the air was allowed to warm back up to 70°F from the underground tube temperature of just 51°F. This notion of lowering the air's temperature as far as possible in order to eject water from it, precisely why air conditioning (AC) devices are so effective at lowering the temperature, then boosting it again. dehumidification. In order to remove the moisture before it enters the residence and mixes with the "return air" to warm up again, they often lower the entering air temperature much below the comfort level. Notably, only the air entering the unit is chilled; it is then mixed with the warmer air that we are seeking to cool. These devices do not attempt to cool and reheat all the air. The evaporator and condenser are both positioned in the flow when humidification is desired without cooling. The condenser uses the heat that was just extracted from upstream to immediately rewarm the air once the evaporator has lowered its temperature, condensation has been removed, and so on. Dehumidifying the air before combining it with the return air that you are recirculating through your home will make everything much simpler because there is less volume to deal about.

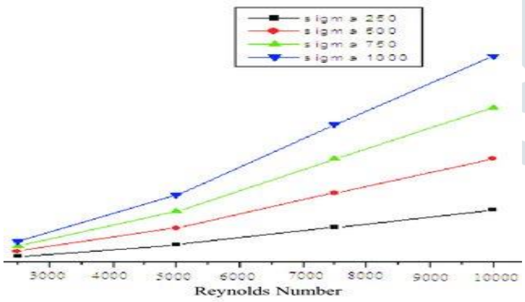


Fig 4.Tempreture/Pressure change

3.2 Outcomes

The following bullet points provide a summary of the findings:
The experiment setup included a 21 m long, 0.15 m in diameter aluminum tube that was buried depth of 3.5 m. In an open-loop system, the air is transported by a 250 W blower.
The ideal length for ETHE is determined by taking a temperature drop of 10°C into account.
• Calculations based on theory were made for fluid velocities of 0.15 m/sec, 2 m/sec, 3 m/sec, and 4 m/sec, respectively.
• It has been found that when fluid velocity rises, the rate of heat transfer through the heat exchanger falls. In comparison to a low fluid velocity, the temperature loss is likewise reduced with the minimal heat transfer rate.

- Yet, as air velocity drops, so does pressure inside the heat exchanger. Consequently, the range of air velocity should be between 2 and 4 m/sec.
- One of the most crucial factors while designing ETHE is the tube material. We are aware that lengthening would speed up the rate of heat transfer. Yet, at a given length, no appreciable heat transfer takes place. Hence, the tube's substance will aid in accelerating the rate of heat transfer.
- Aluminum has excellent corrosion resistance and strong thermal conductivity, which allows for more efficient heat transmission through heat exchangers. As a result, we utilizedaluminum for the tubes.

4.Result

- The following bullet points provide a summary of the findings:
- The experiment setup included a 21 m long, 0.15 m in diameter aluminum tube that was buried depth of 3.5 m. In an open-loop system, the air is transported by a 250 W blower.
- The ideal length for ETHE was calculated theoretically for fluid velocities of 0.15 m/sec, 2 m/sec, 3 m/sec, and 4 m/sec, respectively, with a temperature drop of 10 °C.
- It has been noted that when fluid velocity rises, the heat exchanger's capacity to transmit heat declines. In comparison to a low fluid velocity, the temperature loss is likewise lessened with the lowest heat transfer rate. Yet, as air velocity drops, so does pressure inside the heat exchanger. Therefore, the range of air velocity should be between 2 and 4 m/sec.
- One of the most crucial factors when designing ETHE is the tube material. We are aware that lengthening would speed up the rate of heat transfer. Yet, at a given length, no appreciable heat transfer takes place. Hence, the tube's substance will aid in accelerating the rate of heat transfer.
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5. Advantage

1. The ground heat exchangers are particularly user- and maintenance-friendly.
2. The minimal maintenance costs and the electricity cost savings more than offset the original investment in the long run.
3. Ground heat exchangers do not harm the environment because they only utilize the energy that is already present in the earth.

6. Disadvantages

1. Expensive initial investment.
2. The use of ground heat exchangers is advised in newly constructed homes with exceptional airtightness and

insulation.

3. The need for space is the main obstacle to the widespread use of ground heat exchangers.
4. To receive the benefits of a well-intended system, one desires to ask an experienced installer, which raises the cost of the system. The design and installation of an effective ground heat exchange depend on the local geology and the heating or cooling requirements of thestructure.

7. Conclusion

In this study, an analytical model and the design of an Earth Tube Heat Exchanger (ETHE) are produced. A 21-meter-long, 0.15-meter-diameter aluminum tube served as the experimental setup. Theoretical calculations are made using the NTU approach.

According to the current research, air velocity and heat transfer rate are inversely related. Temperature drop reduces as velocity rises. The ideal length for ETHE is determined to be 21 meter's. Better cooling and heating results from lower air velocity, but optimum air velocity—between 2 and 4 m/s—is needed.

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