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A Review Paper on Computational Study of Earth Tube Heat Exchanger System

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Abstract: Earth Tube heat exchanger can be proved as a better substitution to the space heating and HVAC problems that we face in our day to day lives. Earth tube heat exchangers can work in two phases, i.e. as a heater during winter seasons and as a cooler during summer season. ETHE can work more efficiently than traditional HVAC. This project concentrates on computational study of earth tube heat exchanger. The designing calculations were done for appropriate length and area of an earth tube heat exchanger. A model of ETHE was produced on basis of this calculations and dimensions obtained. The model was generated using Solidworks R2021 software. The ETHE model generated was then analysed for thermal stresses, distribution and other parameters. A CFD simulation of model for velocity and flow was carried on. The conclusions obtained show that ETHE works efficiently and can be used as a substitution for traditional HVAC.
Keywords: Heating ventilation and air conditioning(HVAC), Earth tube heat exchanger(ETHE), Computational fluid Dynamics (CFD), Efficiently, Thermal stresses.

I. INTRODUCTION

An Earth tube heat exchanger is a device which uses the geothermal energy of earth for space heating and air conditioning purposes. Earth tube heat exchanger comprises of a tube at a depth of 3m below the ground surface. The temperature of ground 3m below the earth is different from the ground surface. The air passed through tube exchanges heat from the ground surface and conditions the air accordingly. There are various factors that affect the performance of the earth tube heat exchanger. Some of the important parameters are characteristics of soil, Tube material, velocity of air, Temperature of air, mass flow rate, and speed of the blower used and location of the earth tube heat exchanger. An earth tube heat exchanger model that was installed previously shows a temperature drop of about 15-20 degree Celsius during the summer phase and temperature rise of about 20-25 degree Celsius in winter phase. An earth tube heat exchanger can be operated as open cycle and closed cycle both ways.

1) Open cycle earth tube heat exchanger: An earth tube heat exchanger that uses atmospheric air and conditions the same for cooling/heating by using the earth's temperature. An open loop system has no feedback device or sensors.

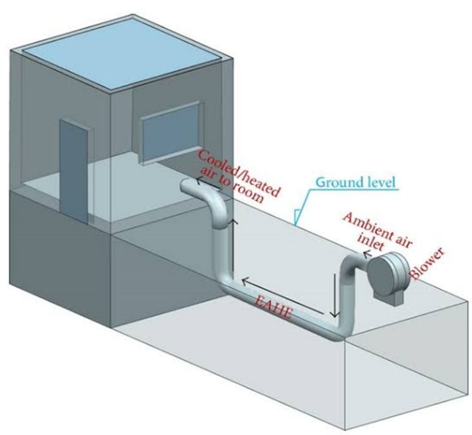

Fig 1. Open loop earth tube heat exchanger[1]

2) Closed cycle earth tube heat exchanger: An earth tube heat exchanger that utilizes the air conditioned in previous cycle again for the next cycle is called closed loop earth tube heat exchanger. An closed loop system has a feedback device or sensor for sensing the condition of the air.

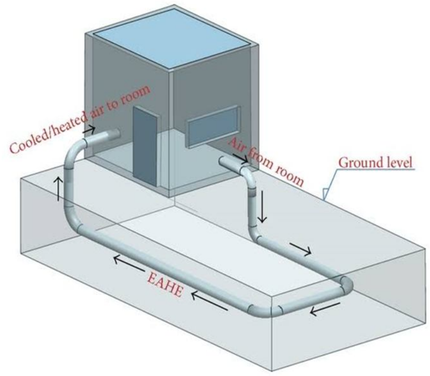

Fig 2. Closed loop earth tube heat exchanger[1]

The computational study of ETHE was carried with using aluminium as material.

II. LITERATURE REVIEW

Nilesh.S.Shelar[1] in his research work stated about the open loop and closed loop ETHE system operations. Giouli Mihalakakou et al [2] presented a review on methodologies and technologies that would help earth tube heat exchanger achieve energy conversation and comfort in the built environment. The review covered factors affecting performance, experimental studies and implications, recent advancement and trends in earth tube systems. Dastan Zrar Ghafoor and Younis Khalid Khdir [3] Aimed on utilization of geothermal energy to control the ventilation of standard zones. They conducted experiments on Earth tube heat exchanger considering temperature of ground as the basic data and found that temperature varies inversely with the length of tube. Arpit Thakur and Aashish Sharma [4] carried a computational study on finned and finless model and compared the results to find effect of fins on thermal performance of earth tubes. It was found that addition of fins can help in improving performance independent of geometrical parameters. Kunj M. Chauhan et al [5] carried simulation on earth tube heat exchanger with material properties of PVC and found that higher temperature drop can be achieved by reducing the diameter and increasing the length of tube. Abdullahi Ahmed et al [6] evaluated thermal performance of earth tube heat exchangers in different configurations and operating conditions of United Kingdom. The results obtained showed that earth tube heat exchanger works significantly in both summer and winter phase. The performance of ETHE depends on dimension and climatic condition of area under study. Abdelkrim.Sehli et al [7] presented a report on effects of different factors affecting thermal performance of ETHE. In above paper reynold's number and form factor was used to find thermal performance of earth tube heat exchanger. Girja Sharan and Ratan Jadhav [8] carried experimental tests on performance of ETHE and found that temperature was reduced in range of 14-15 degree Celsius during month of may in summer phase and rose by the same amount during the month of march in winter phase. Trilok Singh Bisoniya et al [9] reviewed the calculation models of ETHE systems. Shivam Jaiswal et al [10] carried experimental investigations on earth tube heat exchanger in Lakshmi Narayan College of Technology, Bhopal. Effects of velocity and air temperature at inlet on the performance of earth tube heat exchanger was studied experimentally. S.F. Ahmed et al [11] Two different piping systems, i.e. vertically laid and horizontally laid were compared on the basis of performance. Effect of air velocity and temperature on cooling is also assessed. Both the systems showed temperature drop but vertical system performs better than horizontal ones. D Darius et al [12] studied variation in performance due to different parameters also the methods to assess performance was discussed with recent advancement in computational Technologies. Kamal Kumar Agrawal et al [13] carried an experimental study, where the moisture content of soil was raised in the region of ETHE pipes and its effect on thermal performance and adequate pipe length for certain degree rise in winter season was determined. It was found that soil achieved its undisturbed temperature within 12 non-working hours. Indrakant Singh [14] performed a series of experiments to estimate thermal performance and cooling ability of earth tube system. The author also reviewed different parameters affecting performance of earth tube heat exchangers. Rohit Misra et al [15] carried an experiment humidity content of soil is increased to improve thermal performance of ETHE and tube length required was experimentally determined for summer cooling in hot and arid climate. Two identical experimental set ups with water impregnation system to maintain the moisture content of soil were used. the author has developed a one-dimensional model of the EAHE system.

III. METHODOLOGY

1) *Material Selection:* There are various materials that can be used for Earth tube heat exchanger. Copper has highest thermal conductivity and corrosion resistance. Copper is expensive but durable. PVC has good thermal conductivity and corrosion resistance. PVC is cost effective but gets ruptured due to loads. Concrete pipes have good thermal conductivity and is cost effective but faces the same problem as PVC pipes. Iron and brass have optimum thermal conductivity desired and good corrosion resistance but are expensive. Aluminium has good thermal conductivity and corrosion resistance. Aluminium is cost effective and its properties can be modified by alloying. Hence, we choose aluminium as material for earth tube heat exchanger
2) *Designing Calculations:* The calculations for optimum dimensions and area of earth tube heat exchanger is necessary as heat transfer rate is directly proportional to the area of surface in contact. An optimum length and depth for earth tube heat exchanger is important as earth's geothermal temperature varies from 2m below the ground surface. Hence, by calculations we choose the depth of earth tube heat exchanger to be 3m. An optimum length for earth tube heat exchanger was found out to be 20.58m which was rounded to 21m. Calculations for Reynold's number, efficiency and effectiveness of earth tube heat exchanger was also done.
3) *Modelling:* The dimensions obtained by designing calculations was then used for modelling. A 2D design of the model was made. This 2D design was then used to generate a 3D model of the earth tube heat exchanger. The model was generated using Solidworks R2021 software. The model was then given properties and appearance characteristics of aluminium.

Fig 3. Earth Tube heat Exchanger Solid model

4) *Analysis:* The generated 3D model of earth tube exchanger was then imported to Ansys workbench R2021. The model was then meshed. The meshed model generated has Analysis element size of 50mm, 53,716 nodes and 1,59,875 elements. This model was then used for thermal analysis and CFD analysis. The energy equations that we used for analsyis were k-epsilon equation, turbulence and energy equation and continuity equation. Inlet temperature was used as the fixed boundary condition. The inlet temperature was assumed to be 40 degree Celsius and properties of aluminium was inserted as material properties.
5) *CFD Simulation:* The model generated was then used to study computational fluid dynamics properties. The model was then checked various velocities of air. The performance of air was then analysed for various wind velocities. The pressure of air and temperature distribution was also carried on using Ansys workbench R2021.

IV. RESULTS

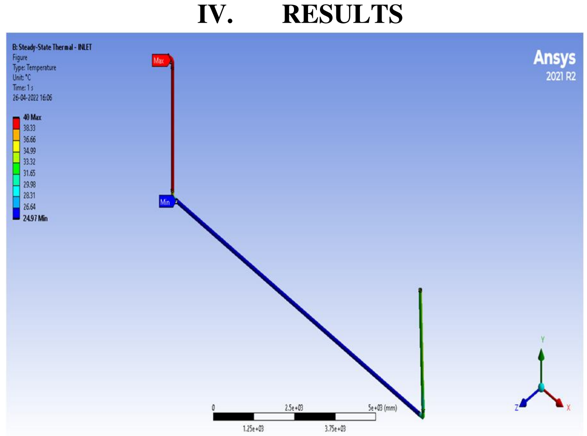

Fig 4. Steady State Thermal Analysis

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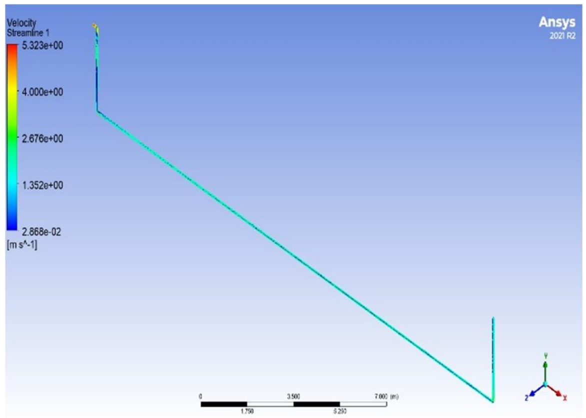

Fig 5. Velocity Analysis(CFD)

The earth tube heat exchanger model analysed shows a temperature drop of 15 degree Celsius on an normal summer day. The performance of earth tube heat exchanger can be more effective by altering or improving some of the affecting parameters. The COP of earth tube heat exchanger can be improved by using a blower at the inlet to increase the velocity. The velocity of air affects the mass flow rate and pressure of air. As velocity increases gradually, there might be fall in pressure at some points. The characteristics of soil also plays an important role on the performance of ETHE. Earth tube heat exchanger has high seasonal energy efficiency ratio than traditional HVAC systems. Temperature of the air decreases as it moves forward in the earth tube heat exchanger. The pressure is maximum at inlet and decreases as it expands in the earth tube heat exchanger and then decreases negligibly at the outlet. The mass flow rate of earth tube heat exchanger decreases as air moves towards the outlet. The results obtained were then validated against the previously done research works and practical works. The results were found to fairly agree with the references used and the practical results.

V. CONCLUSION

There are number of applications where Earth tube heat exchanger can be used as a substitution to the traditional HVAC. Aluminium as a material gives higher life at lower cost. The seasonal energy efficiency ratio of earth tube heat exchanger is higher than traditional HVAC system. Initial cost and maintenance cost of HVAC system is higher than earth tube heat exchangers. Efficiency and effectiveness of earth tube heat exchanger is higher than HVAC system.

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