CFD Analysis of GATHE system using different geometries

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Abstract

Ground Air Tube Heat Exchanger are simple system have valuable feature to diminish energy consumption in uptown building which are operational with an active ventilation system. This system conditioning and distributing of the air in the building the fresh air is passed through pipes buried in the ground. In this method the fresh air is pre-cooled for the era of summer. Solar energy accumulated in soil may be utilised Earth Air Heat Exchanger, which have single tube or multiple tubes buried in ground. When the ventilation air drawn through tube(s), the air is heated in winter and cooled in summer due to the temperature difference between air and ground. By taking advantage of this free energy, we can reduce the energy consumption required for space cooling. The present paper investigates the different types of geometries used for the EAHE system. The obtained results shows the serpentine model used for analysis has better cooling capacity.

Key words: *Ground Air Heat Exchanger, Parametric Analysis, Earth's Undisturbed Temperature*

1. INTRODUCTION

Conservation of energy is one of the most significant global challenges in now a day. The energy crisis of the mid 1970s dealt a harsh blow to developing countries including India. The most energy beneficial outcomes of crisis are that it stimulated interested in the diversification of energy sources and renewable energy. Meanwhile, environmental concerns push this trend much further. Earth as a heat supply and warmth sink may be a well-studied topic. Victimization the world as an element of the energy system or earth tempering will be accomplished through 3 primary methods: direct, indirect and isolated. This paper is targeted on indirect system. This system i.e Earth Air Heat Exchanger System, sometimes called earth tubes, or ground coupled air heat exchanger are an interesting and promising technology. Tubes are positioned in the ground, through which air is passes because of the high thermal inertia of the exterior climate are damped deeper in the ground. Further a delay arises between the temperature fluctuations within the ground and at the surface. Thus at a sufficient depth the soil temperature is lower than the outside air temperature in summer and higher in winter. When the fresh air is drawn through the earth tube heat exchanger the air is thus cooled in summer and heated in winter. In combination with other passive system and good thermal design of the building, the earth air heat exchanger can be used to preheat air in winter and avoid air conditioning units in building in summer, which result in a major reduction in electricity consumption of a building.

II. LITERATURE REVIEW

In recent years, there is a global consensus for exploration and utilization of different renewable energy sources to meet the energy demand [1] of a rapidly growing world population and limited energy resources of conventional or fossil fuels. The new options should be ecofriendly as well as abundant in nature. The various options may be nuclear, wind, bio mass, solar etc. Solar energy is a renewable, ecofriendly and freely available energy resource on earth. Bisoniya et al. [6] have been worked on three dimensional model for simulation of Earth Air Heat Exchanger. The simulation model was developed in CFD platform CFX12.0. The simulated results were validated against the experimental setup installed at Bhopal. The statistical analysis carried out for validation of simulation results against experimental results gave the values of coefficient of correlation and root mean square of percent deviation in the range of 0.989- 0.997 and 8.09- 8.18% respectively for air flow velocities 2- 5m/s. Vikas Bansal et al. [4] work on transient and implicit model based on CFD (FLUENT) was developed to predict the thermal performance and cooling capacity of earth–air–pipe heat exchanger systems. Results show that modeling of

EPAHE system with maximum deviation of 11.4%. The 23.42 m long and 0.15 m diameter EPAHE system gives cooling in the range of 8.0–12.7 8C for the flow velocities 2–5 m/s. Cooling is found to be in the range of 1.2–3.1MWh. Velocity of air affects the thermal performance of EPAHE system. The COP of the EPAHE system is from 1.9 to 2.9 for increase in velocity from 2.0 to 5.0 m/s. Vikas Bansal et al [5] analysis of the integrated system based on (CFD) modeling with FLUENT software. Results show that a simple EATHE system provides 4500 MJ of cooling effect during summer months, whereas 3109 MJ of additional cooling effect can be achieved by integrating evaporative cooler with the EATHE. Performance analysis shows that while ambient air itself is comfortable for 25.6% of the hours, use of integrated EATHE evaporative cooling system provides comfortable air for 34.16% hours in one year, whereas simple EATHE system is able to provide comfortable air for only 23.33% additional hours. Girja Sharan [15] has developed some applications of earth tube heat exchangers in gujarat, India. It is seen that the ETHE could warm-up the cold air by as much as 12 -130C.

Thomas Woodson et al. [16] have measured ground temperature at a depth of 0.5 m and 1.5 m the average temperature 32.1°C and 30.4°C was found. The measured values were, on average, 1.2°C, 2.0°C and 1.7°C higher than the theoretical values for the temperature gradient at depths of 0.5 m, 1.0 m and 1.5 m, respectively. The air was cooled by an average of 2.07°C, 1.90°C, 1.82°C and 2.53°C after the air had travelled 5 m, 10 m, 15 m and 20 m, respectively.

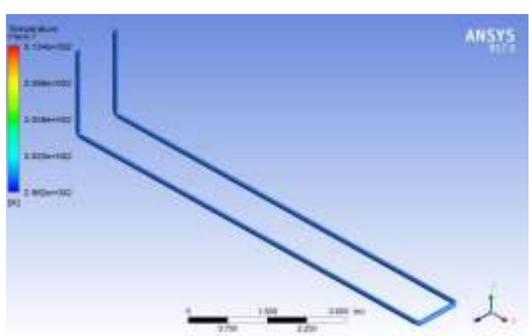
Against this background, present research work includes the preparation of three dimensional model of Ground Air Tube Heat Exchanger with all the dimensions to be analyzed, in solidworks and parametric analysis of different types of model of Earth Air Heat Exchanger in ANSYS Fluent 17.0 to obtain the temperature difference in inlet and outlet air for different air flow velocity and different ambient temperature. Validation of results obtained from numerical simulation with the previously reported experimental investigations.

III.GATHE Modelling

The experimental model of GATHE is made in solid works as mentioned earlier. The different dimensions of EAHE is mentioned below:

1. Length= 19.28 m
2. Diameter= 0.1016m
3. Inlet Air Velocity= 2 m/s
4. Inlet Air Temperature = 40.4 ^{o}C
5. Wall Temperature = 25.2 ^{o}C
6. Element type is Hexahedron.
7. The method of meshing used is Sweep.
8. The orthogonal quality for all models on an average is 0.9
9. The skewness for all models on an average is 0.25

Fig 1. CFD model of parallel pipe Arrangement



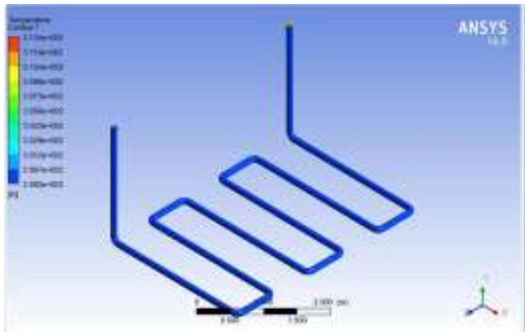


Fig 2. CFD model of Serpentine Arrangement

At Inlet of GATHE the subsonic flow regime with medium turbulence is taken. The values of velocity of air flow is 2m/s, 4m/s and 5m/s is taken with the static inlet temperature of the air as 40.4^{O}C respectively is defined at inlet. The density, specific heat capacity, dynamic viscosity and thermal conductivity of air is defined at static temperature at the inlet. At outlet the relative pressure of GATHE pipe was taken as zero atm in subsonic flow regime.

IV. Results and Discussion

In this section comparison of both types of GATHE systems were compared and it was observed that maximum temperature drop was obtained for the serpentine design of GATHE system. This was due to the fact that in serpentine system the flow speed is reduced during the air flow and this may lead to maximum contact area during the flow.

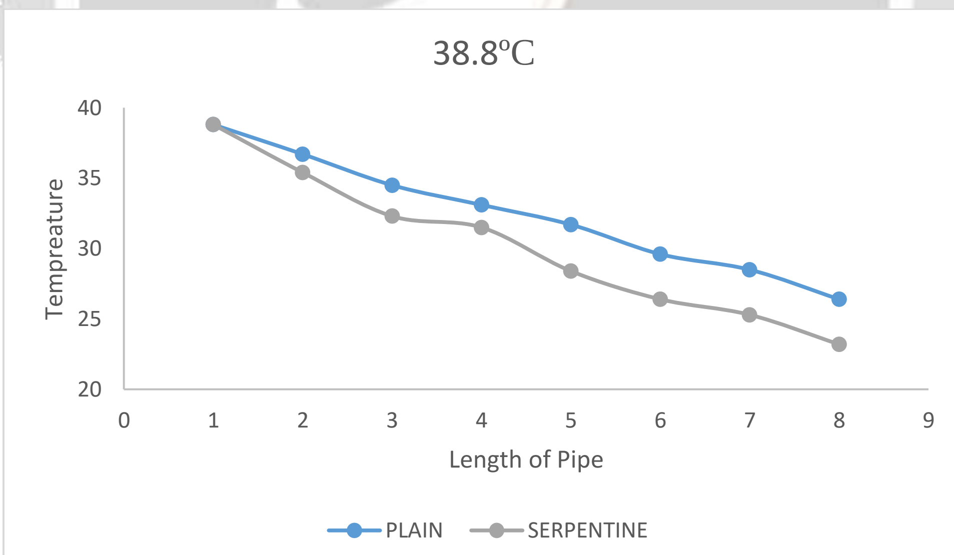


Fig.3 Comparison of EATHE system at 38.8ºC

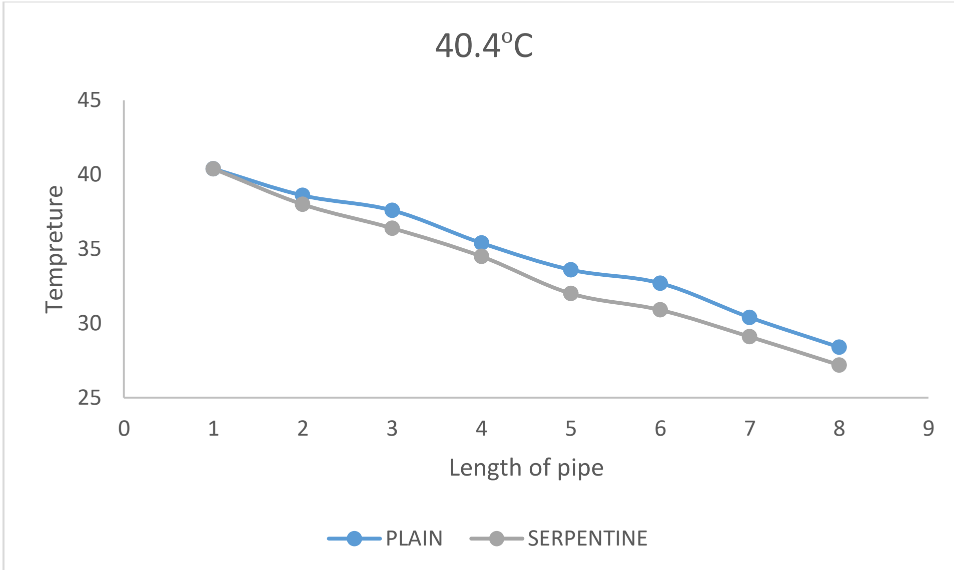


Fig 4. Comparison of EATHE system at 40.4ºC

Same pattern for temperature drop is seen for the inlet temperature of 40.4C.The maximum drop is seen for flow velocity of 2m/s and goes on increasing as the flow velocity of inlet air increases. The maximum temperature drop was of 15.6 ºC. at inlet temperature of 38.8ºC.

5. Conclusion

This present investigation on Ground Air Tube Heat Exchanger has led to the following conclusions.

- GATHE is a type of horizontal open loop system consists of a 19.228 m long and 0.1016 m inner diameter and the pipe is made up of PVC. GATHE is buried 2 m deep below surface. The air velocity was taken between 2, 3.5 and 5 m/s.
- The three dimensioned model of GATHE is made in solidworks with actual dimensions and proper material properties is provided at time of simulation which generate the actual working conditions for the GATHE.
- CFD simulation shows good working of the system with the maximum temperature drop of 15.6°C in case of serpentine model at a flow velocity of 2m/s. As the air flow velocity increases, the temperature drop goes on increasing.

Refrences

[1] Bisoniya Trilok, Kumar Anil, Baredar Prashant. "Parametric Analysis of Earth-Air Heat Exchanger System Based on CFD Modelling." International Journal of Power and Renewable Energy Systems, vol. 1, 2014, 36-45.

[2] Darkwa J, Kokogiannakis G, Magadzire C.L and Yuan K, "Theoretical and practical evaluation of an earth-tube (E-tube) ventilation system", Energy and Buildings, vol. 43, 2011, pp. 728–736.

[3] Bansal Vikas, Misra Rohit, Agrawal Ghanshyam Das and Mathur Jyotirmay, "Performance analysis of earth–pipe–air heat exchanger for summer cooling", Energy and Buildings, vol. 42, 2010, pp.645–648.

[4] Bansal Vikas, Misra Rohit, Agrawal Ghanshyam Das and Mathur Jyotirmay, "Performance analysis of integrated earth–air-tunnel-evaporative cooling system in hot and dry climate", Energy and Buildings, vol. 47, 2012, pp. 525–532.

[5] Sharan Girja, "Development and Some Applications of Earth Tube Heat Exchanger in Gujarat", Agricultural Engineering [Farm Machinery & Power] http://www.aiim.ac.in/smallimg/girjasharan.htm

[6] Ascione Fabrizio, Bellia Laura and Minichiello Francesco, "Earth-to-air heat exchangers for Italian climates", Renewable Energy, vol. 36, 2011, pp. 2177-2188.

[7] Zhang Jian and Haghighat Fariborz, [2009] "Convective heat transfer prediction in large rectangular cross-sectional area Earth-to-Air Heat Exchangers", Building and Environment, 44, 1892–1898.

[8] Lee Kwang Ho and Strand Richard K, "The cooling and heating potential of an earth tube system in buildings", Energy and Buildings, vol. 40, 2008, pp. 486–494.

[9] Muehleisen Ralph T, "Simple design tools for earth-air heat exchangers", Fifth National Conference of IBPSA-USA, Madison, Wisconsin, 2012.
[10] Amara S, Nordell B and Benyoucef B, "Using Fouggara for Heating and Cooling Buildings in Sahara", Energy Procedia, vol. 6, 2011, pp. 55–64.
[11] Misra Rohit, Bansal Vikas, Agrawala Ghanshyam Das, Mathura Jyotirmay and Aseric Tarun, "Transient analysis based determination of derating factor for earth air tunnel heat exchanger in summer", Energy and Buildings, vol. 58, 2013, pp. 103–110.
[12] Ozgener Leyla and Ozgener Onder, "An experimental study of the exergetic performance of an underground air tunnel system for greenhouse cooling", Renewable Energy, vol. 35, 2010, pp. 2804-2811.
[13] Woodson Thomas, Coulibaly Yézouma and Traoré Eric Seydou, "Earth-Air Heat Exchangers for Passive Air Conditioning: Case Study Burkina Faso", Journal of Construction in Developing Countries, vol. 17, 2012, pp. 21–32.
[14] Paepe M. De and Janssens, "Thermo-hydraulic design of earth-air heat exchangers", Energy and Building, vol. 35, 2003, pp. 389-397.
[15] Misra Rohit, Bansal Vikas, Agrawal Ghanshyam Das, Mathur Jyotirmay and Aseri Tarun K, "CFD analysis based parametric study of derating factor for Earth Air Tunnel Heat Exchanger", Applied Energy, vol. 103, 2013, pp. 266–277.
[16] Yildiz Ahmet, Ozgenerb Onder and Ozgenerc Leyla, "Exergetic performance assessment of solar photovoltaic cell (PV) assisted earth to air heat exchanger (EAHE) system for solar greenhouse cooling", Energy and Buildings, vol. 43, 2011, pp. 3154–3160.
[17] Ghosal M.K, Tiwari1 G.N, Das D.K. and Pandey K.P, "Modeling and comparative thermal performance of ground air collector and earth air heat exchanger for heating of greenhouse", Energy and Buildings, vol. 37, 2005, pp. 613–621.
[18] Lee Kwang Ho and Strand Richard K, "Implementation of an earth tube system into energyplus program, 2012. http://www.coursehero.com/file/7108937/17
[19] Freire, A.D.J., Alexander, J.L.C., Silva, V.B., Couto, N.D., and Rouboa, A., "Compact buried pipes system analysis for indoor air conditioning", Applied thermal Engineering, Vol 51, Sept. 2012, pp 1124-1134. Doi: 10.1016/j.applthermaleng.2012.09.045
[20] Ozgener Onder, Ozgener Leyla and Tester Jefferson W, "A practical approach to predict soil temperature variations for geothermal (ground) heat exchangers applications", International Journal of Heat and Mass Transfer, vol. 62, 2013, pp. 473–480.