INTERNATIONAL JOURNAL OF INNOVATIVE TRENDS IN ENGINEERING (IJITE) ISSN: 2395-2946
VOLUME-13, NUMBER-01, 2016

Experimental Evaluation of Earth Tube Heat Exchanger Cooling of Air With Different Velocities

Avinash Kumar[1], Prof. Shishir Selukar[2]
[1]M.Tech Scholar ME Deptt. SIRT, [2]Asst. Prof. ME Deptt. SIRT

Abstract - Earth tube heat exchanger systems can be used to cool the building in summer climate and heat the buildings in winter climate. In a developing country like India, there is a huge gap in demand and supply of electricity and rising electricity prices have forced us to look for cheaper and cleaner alternative. Our objective can be met by the use of earth tube heat exchangers and the system is very simple which works by moving the heat from the house into the earth during hot weather and cold weather. Measurements show that the ground temperature below a certain depth remains relatively constant throughout the year. Effects of the operating parameters i.e. air velocity and temperatures on the thermal performance of horizontal ground heat exchanger are studied. For the pipe of 9m length and 0.05m diameter, temperature falling of 3.93^0C-12.6^0C in hot weather and temperature rising of 6^oC-10^oC in cold weather have been observed for the inlet flow velocity 11 m/s,13m/s,&15m/s. At higher outlet velocity and maximum temperature difference, the system is most efficient to be used .after that this experimental data validate with the help of CFD.

Keywords – Earth tube heat exchanger, blower.

1. INTRODUCTION

Saving energy is one of the most important global challenges. A large portion of the global energy supply is used for electricity generation and space heating, having the major portion derived from fossil fuels. Fossil fuels are non renewable resources and their combustion is harmful to the environment, through the production of greenhouse gases, which effects the climate change and other pollutants. Fossil fuel depletion along with pollutant emissions and global warming are important factors for sustainable and environmentally benign energy systems. These concerns have motivated efforts to reduce society's dependence on non renewable resources, by reducing demand and substituting alternative energy sources. First of all efforts are focused on producing electricity with higher efficiency. Old power plants are more rapidly phased out and replaced by new, more efficient plants. More efficient use of energy not only reduces the consumption of electricity, but also lowers the consumption of non renewable resources. Renewable energy resources are sought that are more environmentally benign and economic than conventional fossil fuels. Beyond fossil fuels, the earth's crust stores an abundant amount of thermal energy [1]. Geothermal systems are relatively benign environmentally, with the emissions much lower than for conventional fossil fueled systems. Geothermal energy is the heat from within the earth. Geothermal energy is generated in the earth's core and core is made up of very hot magma (melted rock) surrounding a solid iron center. High temperatures are continuously produced inside the earth by the slow decay of radioactive materials and this process is natural in all rocks. The outer core is surrounded by the mantle, which is made of magma and rock. The outer layer of the earth, the land that forms the continents and ocean floors is called the crust. The crust is not a solid piece, like the shell of an egg, but it is broken into pieces called plates. Magma comes close to the earth surface near the edges of these plates. We can dig wells and pump the hot underground water to the surface. People use geothermal energy to heat their homes and to produce electricity.

Ground heat transfer mechanism

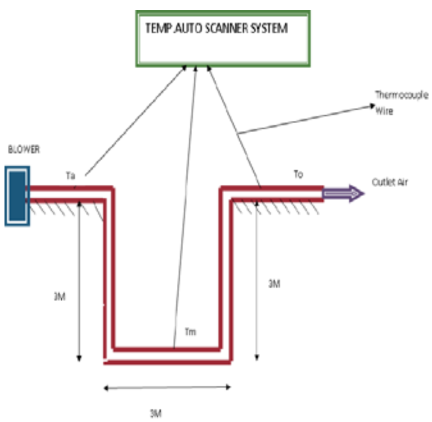
The temperature field in the ground is influenced by different quantities Absorption of the solar radiation depends on the ground cover and color, while the long wave radiant loss depends on soil surface temperature.

The net radiant balance between solar gain and long wave loss is usually positive in summer and negative in winter. This causes heat to flow down from the surface into the ground in the summer and upward to the surface during the winter. The net radiant balance also determines the relationships between the averages of the earth surface and the ambient air temperatures. By shading the soil in summer while partially exposing it to the sky in winter, for example, with trees, it is possible to lower the ground temperature in summer to a greater extent while possibly increase the ground temperature in winter somehow. The performance of ground coupled air heat exchanger is directly related to the thermal properties of the ground. The ground has thermal properties that give it a high thermal inertia. The heat transfer mechanisms in soils are, in order of importance: conduction, convection and radiation. The temperature field in the ground depends on the soil type and the moisture contained respectively.

2. SYSTEM MODEL

Description Of The Set-Up

For the experimental work we used MS pipe of 5 cm diameter and was buried at a depth of 3meters. A blower was used to drive the air through the pipe which was circulated throughout the pipe. A vane type anemometer and thermocouple was used to measure the velocity and temperature of the air respectively. The thermocouple was attached with the Temperature sensor The experimental set-up in the figure 5.1 consists of the 5 cm diameter MS pipe buried below the ground level at a depth of 3 m. At a depth of 3 m, the pipe is spread horizontally for a length of 3m. The total length of the experimental set-up is 9 m.



Cooling Model Test:

The air velocity was 11 m/s,13m/s & 15m/s Velocity was measured by a portable, digital vane type anemometer .The vane size is 66 x 132 x29.2 mm and velocity range 0.3 to 45 m/s. The anemometer measures mean air velocity. The volume flow rate of air was 0.0863 m3/s and mass flow rate 0.0269 kg/s. The ETHE system was operated for seven hours a 3days (28,29&30may-2015) for May month. The tube air temperature at the inlet, middle and outlet, were noted at the interval of one hour. System was turned on at 10.00 AM and shut down at 5 PM. Tests in May were carried out on 28th, 29th, and 30th 2015). The ambient temperature on these three days was very similar. The results of the three days were therefore averaged. Table-1(a) shows the data, which is reading of three days and Table-1(b) mean of the reading of three days. The ambient temperature started with 30.73oC at 10.00 AM and rose to a maximum of 40.13oC at 2 PM. The temperature of air at outlet was 26.8oC at when system started in 10am.. The outlet temperature was just above the basic soil temperature (26.6oC). The table also shows the COP values. The maximum COP Achieved at 2pm i.e2.702

Average Inlet Temp, Middle And Outlet Temp. Of ETHE(MAY-2015)					
Time	Velocity	Ta=Ti	Tm	To	COP
10:00	11m/s	30.4	28.2	26.72	0.5702
	13m/s	30.4	28.4	27.61	0.567
	15m/s	30.4	29.41	28.67	0.501
11:00	11m/s	33.65	29.42	25.9	1.648
	13m/s	33.65	30.3	27.16	1.6319
	15m/s	33.65	31.86	30.14	1.018
12:00	11m/s	36.57	30.47	27.26	1.978
	13m/s	36.57	32.2	28.56	1.878
	15m/s	36.57	32.47	32.76	1.1025
13:00	11m/s	37.63	32.37	27.0	2.2404
	13m/s	37.63	33.87	31.34	1.58
	15m/s	37.63	34.17	33.3	1.256
14:00	11m/s	40.14	34.56	29.19	0.232
	13m/s	40.14	35.87	33.4	1.69
	15m/s	40.14	31.17	35.54	1.33
15:00	11m/s	40.00	33.27	30.17	2.09
	13m/s	40.00	36.77	30.16	2.08
	15m/s	40.00	37.17	35.87	1.19
16:00	11m/s	39.97	34.51	33.23	1.43
	13m/s	39.97	35.87	35.5	1.12
	15m/s	39.97	36.47	35.54	1.08
17:00	11m/s	39.6	34.47	30.89	1.64
	13m/s	39.6	35.4	32.67	1.54
	15m/s	39.6	38.03	37.47	0.61

Table 5.1(b): Average Inlet Temp, And Outlet Temp. Of ETHE(MAY-2015)

HEATING MODEL TEST:

Heating mode test tests were carried out for three Day of Jan.2015 (06' 7&8th)The system was turned on at 10am and operated for 8 hours continuously, till 5 pm that day.

Temperature readings were noted at hourly interval. Here also the conditions on the three consecutive days were similar and therefore the results combined. Table 5.2(a) shows the measured data, and Table 5.2(b) which is the mean of three test runs. The ambient temperature started at 21oC (10 AM), increasing the highest value 30.30oC at 5 pM. Basic soil temperature at 3 m depth was constant at 24.2oC. Temperature of the air at the outlet varying from 27.53oC to 40.36oC. ETHE was able to raise the ambient air temperature at 5 PM from 21.00oC to 30.30oC.The table also shows the COP values. The maximum COP Achived at 5pm i.e2.25

Average Inlet Temp, Middle And Outlet Temp. Of ETHE(JAN2015)					
Time	Velocity	Ta=Ti	Tm	To	COP
10:00	11m/s	21.00	23.23	27.5	1.388
	13m/s	21.00	22.8	24.26	0.189
	15m/s	21.00	22.33	23.13	0.167
11:00	11m/s	22.13	24.5	28.4	1.334
	13m/s	22.13	23.1	25.10	0.746
	15m/s	22.13	23.07	24.6	0.716
12:00	11m/s	24.30	28.56	31.2	1.468
	13m/s	24.30	26.21	28.70	1.106
	15m/s	24.30	25.32	27.30	0.870
13:00	11m/s	26.52	30.8	34.2	1.680
	13m/s	26.52	29.52	30.72	1.052
	15m/s	26.52	28.17	29.32	1.043
14:00	11m/s	27.30	32.56	36.30	2.340
	13m/s	27.30	29.11	32.70	1.357
	15m/s	27.30	28.8	30.4	1.28
15:00	11m/s	27.27	33.57	36.5	1.96
	13m/s	27.27	29.81	32.1	1.292
	15m/s	27.27	28.4	30.92	1.058
16:00	11m/s	28.1	34.77	37.3	1.957
	13m/s	28.1	33.37	35.67	1.903
	15m/s	28.1	33.8	36.97	1.887
17:00	11m/s	27.1	29.23	32.3	1.106
	13m/s	27.1	28.37	30.67	0.897
	15m/s	27.1	28.4	29.93	0.821

Table-5.2(b)Inlet Temp, And Outlet Temp. Of ETHE(JAN-2015)

CALCULATIONS:

FOR SUMMER SEASON (MAY-2015)

Area = π x $d^2/4$= π x 0.05x0.05/4=0.00196 m^2

Density of air = 1.225 kg/m3

Specific heat capacity of air,

Cp= 1007 J/kg K

Total cooling, Qc = mCp(Tinlet – Toutlet)

Coefficient of Performance, COP = = mCp(Tinlet – Toutlet)/Power Input

Mass flow rate, m = density x area x velocity=0.0269

Power Input = 125

FOR SUMMER SEASON (MAY-2015)

Area = π x $d^2/4$= π x 0.05x0.05/4=0.00196 m^2

Density of air = 1.225 kg/m3

Specific heat capacity of air,

Cp= 1007 J/kg K

Total cooling, Qc = mCp(Tinlet – Toutlet)

Coefficient of Performance, COP = = mCp(Tinlet – Toutlet)/Power Input

Mass flow rate, m = density x area x velocity=0.0269

Power Input = 125.

CFD VALIDATION

INTRODUCTION:

Computational fluid dynamics (CFD) is the use of applied mathematics, physics and computational software to visualize how a gas or liquid flows -- as well as how the gas or liquid affects objects as it flows past. Computational fluid dynamics is based on the Navier-Stokes equations. These equations describe how the velocity, pressure, temperature, and density of a moving fluid are related.

HOW TO WORK:

You've probably heard the word "CFD" (Computational Fluid Dynamics) plenty of times when going through some technicalities inside the automotive world. In the article below, we'll try to explain how exactly CFD works, in an as humanly-understandable manner as possible, without getting stuck too much in the equations that come with it.

Computational Fluid Dynamics is a method by which one uses certain algorithms or other numerical formulas to analyze the fluids' flow. Needless to say, the millions of calculations required to simulate how certain fluids flow after the interaction with a clearly-shaped body are made by a supercomputer, via well-designed software. Ergo,the more powerful the supercomputer, the more accurate the results of the CFD process.

RESULT VALIDATION:

Result validation with the help of CFD is on the basis of following points

1. Advantage

2. Economy

3. Cost

4. Operation

5. Labour requirement

6. Drawing graph

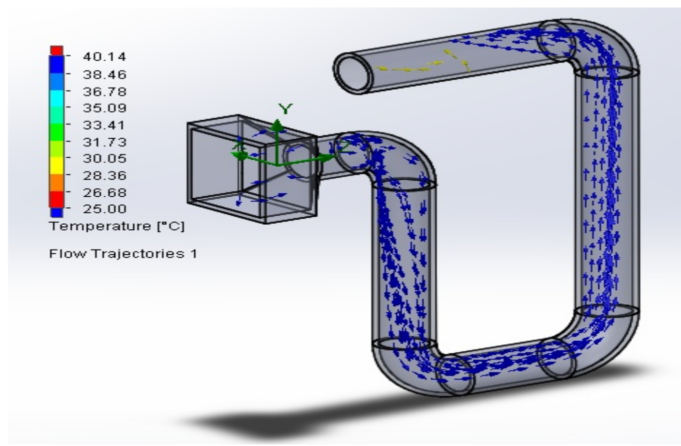
7. Experimental result & cfd result compression

CFD RESULT FOR SUMMER

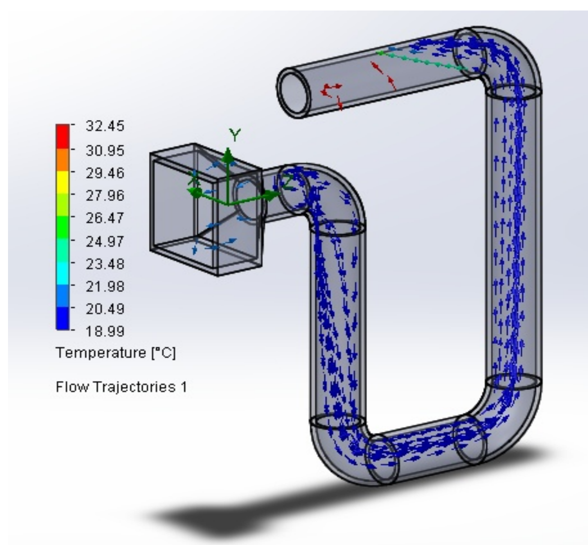
TIME	11m/s			13m/s			15m/s		
	Tin	Tout	COP	Tin	Tout	COP	Tin	Tout	COP
10:00	30.4	26.78	0.839	30.4	27.78	0.738	30.4	28.28	0.707
11:00	33.65	26.72	1.615	33.65	27.42	1.730	33.65	27.50	1.681
12:00	36.57	27.10	2.009	36.57	28.08	2.205	36.57	28.09	2.450
13:00	37.63	27.08	2.240	37.63	27.74	2.481	37.63	28.67	2.591
14:00	40.14	27.10	2.770	40.14	27.72	3.115	40.14	28.10	3.483
15:00	40.00	27.08	2.743	40.00	27.09	3.159	40.00	28.09	3.447
16.00	39.97	27.17	2.683	39.97	27.65	3.052	39.97	28.16	3.368
17.00	39.64	27.10	2.656	39.64	27.87	2.947	39.64	28.10	3.330

CFD RESULT FOR WINTER

TIME	11m/s			13m/s			15m/s		
	Tin	Tout	COP	Tin	Tout	COP	Tin	Tout	COP
10:00	21.00	27.47	1.393	21.00	26.50	1.386	21.00	25.88	1.436
11:00	22.13	28.60	1.343	22.13	27.60	1.336	22.13	25.90	1.048
12:00	24.30	31.40	1.515	24.30	30.40	1.536	24.30	29.80	1.599
13:00	26.52	34.52	1.712	26.52	33.52	1.770	26.52	32.82	1.839
14:00	27.30	36.48	1.961	27.30	35.47	2.066	27.30	34.76	2.181
15:00	27.27	36.62	2.001	27.27	35.63	2.112	27.27	34.62	2.148
16.00	28.10	39.47	2.219	28.10	38.48	2.368	28.10	37.80	2.538
17.00	27.10	40.30	2.189	17.10	39.30	2.332	27.10	38.30	2.401



Cfd Analysis For Summer



Cfd Analysis For Winter

CONCLUSION

Explanation of the results:

After done the calculation in the previous chapter, we can see that the results are quite encouraging. The results are summarized under the following points:

- For the pipe of 9 m length and 0.05 m diameter, temperature rise of 3.230C-6.10C has been observed for the outlet flow velocity 11m/s
- The maximum COP obtained in summer season is 2.817 at time 14:00 and the maximum COP obtained in winter season is 2.25 at time 17:00
- The COP of the system varies from 0.85 – 2.70 in summer season and 1.41-2.25 in winter season in outlet velocity 11m/s.
- The results also show that conduction plays very important role in the cooling of air, it is evident from the fact that temperature remains constant where the insulation is done.
- If the length of pipe is less then 50-70m the system is useless because the cooling rate or heating rate is so small.
- If the blower speed is high and the length of pipe is less than the temperature difference inlet and outlet is very small.

This work can be used as a design tool for the design of such systems depending upon the requirements and environmental variables. The work can aid in designing of such systems with flexibility to choose different types of pipes, different dimensions of pipes, different materials and for different ambient conditions. So this provides option of analyzing wide range of combinations before finally deciding upon the best alternative in terms of the dimension of the pipe, material of the pipe, type of fluid to be used.

7. FUTURE SCOPES

Futures Scope:

- The blower with variable running speed should be used.
- Theoretical model should be developed to predict the temperature of soil per meter depth of soil and affect of moisture content in the soil.
- This system will be tested for different length and different diameter pipe.
- For further study humidity control mechanism should be incorporated for Winter and Summer season.
- The fluid dynamics studies should be conducted to minimize the flow losses in the pipe and effect of moisture to be studied.

REFERENCES

[1] Stuart J. Self, Bale V. Reddy, Marc A. Rosen, Geothermal heat pump systems: Status review and comparison with other heating options, Applied Energy 101(2013) 341-348.

[2] Fuxin Niu, Yuebin Yu, Daihong Yu, Haorong Li ,Heat and mass transfer performance analysis and cooling capacity prediction of earth to air heat exchanger, Applied Energy 137(2015) 211-221

[3] Wagner R, Bisel S, Speiler A, Measurement, modeling and simulation of an earth to air heat exchanger, Applied thermal engineering24(2000) 241-249.

[4] 4.Vikas Bansal., Rohit Misra, Ghanshyam Das Agrawal, Jyotirmay Mathur,Performance evaluation and economic analysis of integrated earth–air–tunnel heat exchanger–evaporative cooling system, Energy and Buildings 55 (2012) 102–108

[5] 5.Georgios Florides, Sctris Kalogrirou, Ground heat exchanger-A review of system model and applications , Renewable energy 32(2007) 2461-2478

[6] 6.Haorong Li ,Yuebin Yu,Fuxin Niu,Michel Sha.k ,Bing Chen, Performance of a coupled cooling system with earth-to-air heat exchanger and solar chimney,Renewable Energy 62(2015)468-477

[7] 7.Girja saran and rattan jadhav, Performance of Single Pass earth-Tube Heat Exchanger: An Experimental Study agricultral jurnals 6(2000) , 32-40

[8] 8.Fabrizio Ascione, Laura Bellia, Francesco Minichiello-Earth-to-air heat exchangers for Italian climates, Renewable Energy 36 (2011) 2177-2188

[9] 9.Vikas Bansal, Rohit Misra, Ghanshyam Das Agrawal, Jyotirmay Mathur- Performance analysis of earth-pipe-air heat exchanger for winter heating, Energy and Buildings 41 (2009) 1151–1154

[10] 10.W.H. Leong, V.R. Tarnawski and A. Aittomaki- Effect of soil type and moisture content on ground heat pump performance, Int J. Refrig. Vol. 21, No. 8, pp. 595–606, 1998

[11] 11.Weibo Yang, Mingheng shi, Guangyuan Liu, Zhengian Chen- A two-region simulation model of vertical U-tube ground heat exchanger and its experimental verification, Applied Energy 86 (2009) 2005–2012