Performance Enhancement of Air Conditioner Using Earth Air Tunnel Heat Exchanger

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Abstract - *Earth air tunnel heat exchanger is a passive cooling device with advantageous feature to reduce energy consumption in buildings. Electricity consumption of conventional vapor compression system based air-conditioner is a major concern especially in area with hot and dry weather conditions. The performance of conventional air conditioners can substantially be enhanced by coupling these active cooling systems with passive cooling systems. In the present research, the thermal performance and energy conservation potential of hybrid cooling system has been investigated experimentally. An attempt has been made to enhance the thermal performance of active cooling system by coupling it with earth air tunnel heat exchanger (EATHE) in two different hybrid modes. The air which comes out of EATHE is relatively cooler than the ambient air and therefore can be used either for cooling the condenser tubes of a conventional window type air conditioner or supplying it directly to the room being conditioned. The energy consumption of conventional 1TR air conditioner tutor is found to be reduced by 16 % when cold air from EATHE is completely used for condenser cooling.*

***Key Words*: Earth Air Tunnel Heat Exchanger ,Air Conditioner, Coefficient of Performance, Cooling Capacity**

1. INTRODUCTION

Due to the rapid economic development and urbanization in the past two decades world over, energy consumption in buildings, especially electricity use, has risen sharply. In many hot countries, and also in countries with a temperate climate having hot summers, there is growing interest in utilizing passive and low-energy systems for cooling buildings, both residential and commercial. Exploiting geothermal energy so as to achieve reduction on fuel consumption is becoming more and more popular. Air conditioning is widely employed not only for industrial productions but also for the comfort of occupants. The energy consumption of these units depends on the coefficient of performance (COP), which is improved by decreasing the condensing temperature. The COP of the refrigerating systems with air-cooled condenser drops down when the ambient air temperature increases, especially in hot regions in summer. It is a fact that the energy consumption of air-conditioning equipment to deliver a given rate of cooling increases with the entering temperature of the medium used for condenser cooling, therefore the use of air-cooled units in hot and dry climate of Sholapur (India) is particularly inefficient. The high outdoor air temperature, at around 40–45 0C in summer at Solapur, is one of the reasons. Because of high ambient temperature, condenser temperature, and pressure are increased considerably which consequently increase the power consumption of the air conditioner due to the increase in the pressure ratio. To reduce high grade energy consumption of these active cooling systems, numerous alternative techniques are being currently explored. One such proposition is the EATHE system.

1.1 PROBLEM IDENTIFICATION

Increasing the coefficient of performance of air-conditioner with air-cooled condenser is a challenging task especially in areas where weather conditions are quite hot. The performance of conventional vapour compression system based air-conditioners can substantially be improved by coupling these active cooling systems with less energy intense passive cooling systems. In the present project work, an attempt has been made to enhance the performance of active cooling system by coupling it with Earth Air Tunnel Heat Exchanger. Thermal performance of the developed hybrid cooling system has been investigated experimentally.

2. LITERATURE REVIEW

Many papers were published in the area of earth air tunnel heat exchanger are studied. Researchers from different fields had presented their thesis and papers related to earth air tunnel heat exchanger. Overviews of those papers are discussed below. Lot of information is gathered from this literature which will help the current research work.

- Bhansal V. investigate the Transient effect of soil thermal conductivity and duration of operation on performance of Earth Air Tunnel Heat Exchanger. they investigate Maximum air temperature drop of 15.6, 17.0 and 17.3 K was achieved for soil with thermal conductivity of 0.52, 2 and 4 Wm-1 K-1 respectively.

- Barakat S. investigate Enhancement of gas turbine power output using earth to air heat exchanger (EAHE) cooling system. Longer earth tube and deeply placed with smaller diameter and lower inlet air velocity lead to reducing the outlet air temperature. According to obtained results from the case study, using EAHE system increases the output power production as well as the thermal efficiency by 9% and 4.8%, respectively. For the selected case (New Gas Damietta power plant of 125MW rated power), inserting the EAHE increases the annual net electricity power production by 12991MWh with pay pack period of 1.2 year.

- Tiwari G. N. have proposed Design of an Earth Air Heat Exchanger (EAHE) for Climatic Condition of Chennai, India. the power required to operate the fan for desired number of air changes is 0.09 kW and the thermal energy gains in summer and winter are 0.38 kW and 0.45 kW. Design I gives the net thermal energy gains of 0.29 kW and 0.36 kW in summer and winter respectively. For Design II, the power required for fan is 0.14 kW and the thermal energy gains in summer and winter are 0.40 kW and 0.48 kW respectively;

- Khabbaz M. have proposed Experimental And Numerical Study of An Earth-To-Air Heat Exchanger For Air Cooling In A Residential Building In Hot Semi-Arid Climate. They concluded that dynamic simulation of the EAHX, with continuous operation of one or three pipes, shows that this system provides air temperature reductions up to 19.5 °C and 18.3 °C respectively for an EAHX with one and three pipes, with an outlet air temperature of 25.1 °C and 26.3 °C.

3. THEORY OF EARTH AIR TUNNEL HEAT EXCHANGER

The working principle of cooling air with ventilated underground spaces has been known since ancient times (Bahadori 1978); however, in the past, applications were very rare due to uncertainties in airflow driving forces. Since mechanical ventilation systems became widespread, a large number of ETAHE systems have been built in residential and commercial buildings, as well as in greenhouses and livestock houses. ETAHEs can also be applied to a wide range of climates with large temperature differences between summer and winter as well as between day and night. In literature, names such as Earth Cooling Tube, Ground Coupled Air System, Cool-Tube in-Earth Heat Exchanger, Earth Air Tunnel, Earth Contact Cooling Tube, Earth Tube Heat Exchanger, Buried Pipe Cooling System, Underground Solar Air heater, Earth Air-Pipes System,

4 DESIGN OF EARTH AIR TUNNEL HEAT EXCHANGER

Preliminary design of EATHE use basic heat transfer and fluid flow equations. The design parameters of EATHE are selected according to space conditioning. The mass flow rate and outlet temperature of ventilating air, which are the sizing parameters are the fixed for a specified requirement.

The geometric parameters of an EATHE include the tube diameter (D), Tube length (L) and number of tubes in parallel (n) in the heat exchanger. First we select arbitrary size (D=0.05m) of tube and then with the help of known velocity 4 m/s the following parameters are calculated. Velocity is measured by Anemometer. Mass flow rate is 0.0023 Kg/ sec. Seven

Table 1: Different Design Parameters

Parameter	Re	Pr	F	Nu	Hc	NTU	€	L	ΔP
At V=4 m/s	20731	0.71	0.02	52.63	13.3	2.16	0.884	20	2.65

4. DESCRIPTION OF EXPERIMENTAL HYBRID EATHE SYSTEM

The below figure is the actual setup of our project. The ground was dug 5 feet deep and thermocouple apparatus was inserted. After inserting the apparatus, the hole was filled with soil again in order to get correct readings. It is galvanized iron pipe buried in a digging pit by taking the standard dimensions of the pit which will give cooling effect to the heat exchanger. The dig is 2 m below the surface of the earth. The dig has the dimensions 5 ft×5 ft× 5ft.The outlet G.I. pipe has been covered with the insulation of polyurethane foam. The site selected for excavation is in shady place such that the soil remains cool. The site selected is one of room of NKOCET, Sholapur.

Fig. 1 Actual Set up Of EATHE system

The schematic diagram of hybrid EATHE is shown in below figure. It comprises of 20 m long horizontal Galvanized Iron pipe of 0.05 m inner diameter, buried at a depth of 2 m in a flat land with dry black soil. Inlet of EATHE is connected to a 0.75 kW (1 H.P.) single phase, variable speed motorized blower having maximum speed of 19000 rpm and maximum flow rate of 0.0945 m3/s through a vertical pipe. The air from the ambient was forced to move through the earth air pipe system with the help of blower. Velocity of air through the pipe can be varied by changing the speed (rpm) of the blower with the help of an auto transformer (0–270 V, 2 A maximum current, single phase with a least count of 1 V). The energy consumed by the blower for blowing air at 5 m/s through EATHE was measured to be 0.2 kW.

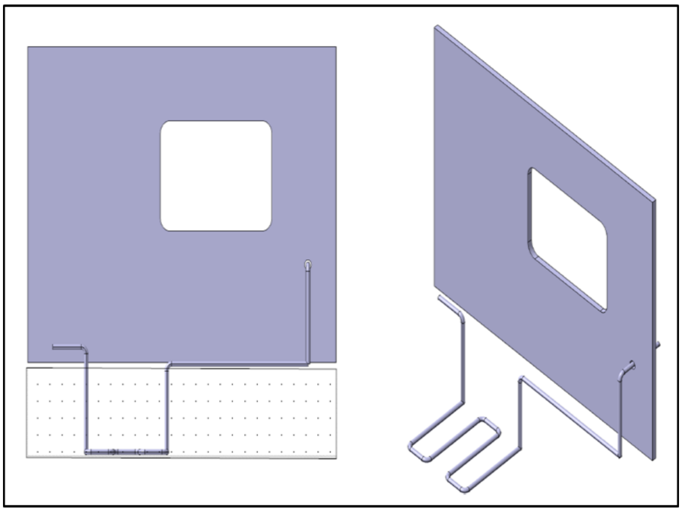


Fig. 2 CATIA Model of Earth Air Tunnel Heat Exchanger

4.1 DIFFERNET LAYERS IN EATHE SYSTEM

There are four different layers are taken in Earth Air Tunnel Heat exchanger System. first layer is of the black soil up to 2 feet, Thermal conductivity of black soil is high as compare to sand that's why we choose black soil for first layer. Second layer is of sand. Third layer is soft stone. Fourth layer is of bricks.

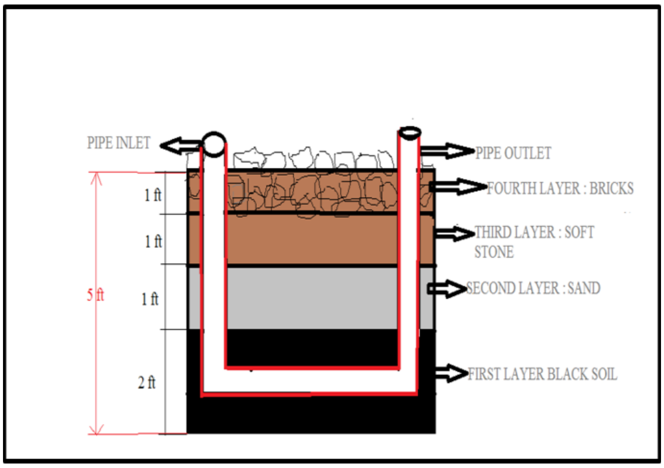


Fig. 3 Different Layers of EATHE system

5. MODES OF HYBRID EATHE AND TEST PROCEDURE

Two different arrangements of EATHE and air conditioner have been investigated experimentally as follows:

(1) Mode-I: Air conditioner alone supplies the conditioned air to the room and EATHE is not functional. This mode has been treated as base case.

(2) Mode-II: Air conditioner supplies the conditioned air to room and 100% conditioned air from EATHE is used for cooling the condenser tubes of air conditioner.

Experimentation was performed March 2018 & April 2018 covering the entire summer season, usually the monsoon season in Sholapur starts from the first week of June observing the frequent and continuous rains.

Seven Thermocouples temperature sensors T1 to T7 were inserted at the Centre of the pipe along the length at a horizontal distance of T_1=0.2 m,T_2=3.2 m ,T_3= 6m,T_4=7.5 m,T_5=10m, T_6=14 m,T_7=18m respectively from the upstream end to measure temperature of the air. Three K Type Thermocouples temperature sensors T8 toT10 were mounted at a depth of 0 m, 1.5 m, 2 m respectively from the ground surface in vertical direction to measure temperature of the soil layers at different depths.

6.OBSERVATION FOR COOLING AND DEHUMIDIFICATION

6.1 Observation Table of Air Conditioner Trainer without Using Earth Air Tunnel Heat Exchanger

Sr.No.	Description	Unit	Reading
1	Condenser Pressure	Psi	114
2	Evaporator Pressure	Psi	30
3	Rotameter Flow Rate	LPH	45
4	Condenser Inlet Temp.	^{0}C	58
5	Condenser outlet Temp.	^{0}C	35
6	Evaporator Inlet Temp.	^{0}C	10
7	Evaporator Inlet Temp.	^{0}C	25
8	Compressor Energy	Sec	10.67
9	Compressor Current	Amp	1.5
10	Compressor Voltage	Volt	240
11	Air inlet temp.(DBT)	^{0}C	30
12	Air outlet temp.(WBT)	^{0}C	20
13	Air inlet temp.(DBT)	^{0}C	18
14	Air outlet temp.(WBT)	^{0}C	13
15	Ambient Temp.	^{0}C	39

6.2 Observation table of Earth Air Tunnel Heat Exchanger System 4 m/s velocity using EATHE

At Velocity 4 m/s Ambient Temperature = 40 ^{0}C

Temp. / Time	T1	T2	T3	T4	T5	T6	T7	T8	T9
11:00	36	36	35	34	34	33	33	32	33
12:00	38	37	36	35	35	34	33	32	33
1:00	40	38	37	37	35	34	33	32	34
2:00	42	39	37	36	35	34	33	33	35
3:00	43	40	37	36	35	34	33	33	35
4:00	43	41	38	37	36	35	34	34	35

Table6.3 Observation of Air conditioner trainer with using EATHE system on Day 1 at velocity 4m/s at 1:00 PM

Sr.No.	Description	Unit	Reading
1	Condenser Pressure	Psi	118
2	Evaporator Pressure	Psi	45
3	Rota meter Flow Rate	LPH	36
4	Condenser Inlet Temp.	^{0}C	59
5	Condenser outlet Temp.	^{0}C	32
6	Evaporator Inlet Temp.	^{0}C	4
7	Evaporator Inlet Temp.	^{0}C	20
8	Compressor Energy	Sec	7.8
9	Compressor Current	Amp	1.5
10	Compressor Voltage	Volt	240
11	Air inlet temp.(DBT)	^{0}C	38
12	Air outlet temp.(WBT)	^{0}C	25
13	Air inlet temp.(DBT)	^{0}C	18
14	Air outlet temp.(WBT)	^{0}C	12
15	Ambient Temp.	^{0}C	40

Table 6.4 Observation Table of Earth Air Tunnel Heat Exchanger system on day 2 at Velocity 4 m/s

At Velocity 4 m/s Ambient Temperature = 40 ^{0}C

Temp. / Time	T1	T2	T3	T4	T5	T6	T7	T8	T9
11:00	37	37	36	36	35	34	33	32	33
12:00	38	37	36	35	34	34	34	32	33
1:00	40	38	37	36	34	34	33	32	34
2:00	42	39	38	36	34	34	33	33	35
3:00	43	40	38	37	35	34	33	33	35
4:00	43	41	39	37	36	35	34	34	35

Table 6.5 Observation of Air Conditioner trainer Using EATHE system on Day 2 at velocity 4m/s at 1:00 PM

Sr.No.	Description	Unit	Reading
1	Condenser Pressure	Psi	120
2	Evaporator Pressure	Psi	42.5
3	Rota meter Flow Rate	LPH	32
4	Condenser Inlet Temp.	^0C	55
5	Condenser outlet Temp.	^0C	31
6	Evaporator Inlet Temp.	^0C	7
7	Evaporator Inlet Temp.	^0C	15
8	Compressor Energy	Sec	8.43
9	Compressor Current	Amp	2.2
10	Compressor Voltage	Volt	240
11	Air inlet temp.(DBT)	^0C	37
12	Air outlet temp.(WBT)	^0C	24
13	Air inlet temp.(DBT)	^0C	16
14	Air outlet temp.(WBT)	^0C	12
15	Ambient Temp.	^0C	39

7. RESULTS

In this chapter the calculations of cooling and dehumidification is done. Also discuss the results of air conditioning system without using EATHE System and With using EATHE At Velocity 4 m/s.

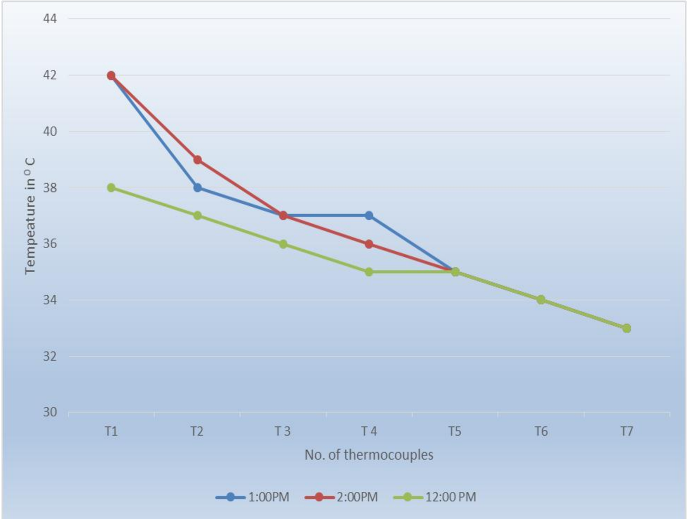
7.1 Results of air conditioner system without using EATHE system

Sr. No.	(COP)th	(COP)car	(COP)act	Power Consumption (Kw)
1	5.79	6.65	1.47	25.86

7.2 Results for 4 m/s velocity With Using Earth air Tunnel Heat exchanger

Sr. No.	(COP)th	(COP)car	(COP)act	Power Consumption (Kw)
1	7.4	9.06	1.9	18.12

7.3 Graph of Temperature Vs No. of thermocouples placed on Earth Air Tunnel Heat Exchanger at Velocity 4 m/s



Graph of Temperature vs No. of thermocouples placed on EATHE system at Velocity 4 m/s

In the graph on X axis 7 thermocouples taken (T1-T7) & on Y axis temperatures taken. The results from above graph shows that at time 12p.m.,1p.m.,2p.m. as the air passes through thermocouples at 4 m/s velocity the temperature decreases. At 1 p.m. ambient temperature is 39^0C & outlet temperature of earth air tunnel heat exchanger system is 32^0C so the temperature difference is 7^0C.

8. CONCLUSIONS

1] EATHE coupled to the air cooled condenser is an efficient, reliable and cost-effective method to increase the performance of any vapor compression refrigeration system such as window type air-conditioners which have wide spread application.

2] Experimental tests showed that power consumption and performance of EATHE assisted air-conditioner improved significantly as compared to the air-conditioner having its condenser tubes cooled by ambient air.

3] The power consumption of system is increases as the ambient temperature increases because for higher temperature cooling load on system increases.

4] Therefore without using earth air tunnel heat exchanger the actual COP of system decreases and power consumption increases.

5] The results are improved when the earth air tunnel heat exchanger is coupled with air conditioner which increases the coefficient of performance of the system by nearly 11%.

6] The energy consumption of conventional 1TR air conditioner tutor is found to be reduced by 16 % when cold air from EATHE is completely used for condenser cooling.

REFERENCES

[1] Ahmed S.F., Khan M.M ,"Performance assessment of earth pipe cooling system for low energy buildings in a subtropical climate", Energy Convers Manage 2015;106: 815–25.

[2] Bansal V, Misra R, Agrawal GD,Mathur J,"Transient effect of soil thermal conductivity and duration of operation on performance of Earth Air Tunnel Heat Exchanger.Energy",Build,2012;47:525–32.

[3] S. Barakat, Ahmed Ramzy,"Enhancement of gas turbine power output using earth to air heat exchanger (EAHE) cooling system", Energy Conversion and Management 111 (2016) 137– 146

[4] M.K.Ghosal,G.N.Tiwari,"Modeling and comparative thermal performance of ground air collector and earth air heat exchanger for heating of greenhouse", Energy and Buildings 37 (2005) 613–621.

[5] Mohamed Khabbaz , Brahim Benhamou,"Experimental And Numerical Study Of An Earth-To-Air Heat Exchanger For Air Cooling In A Residential Building In Hot Semi-Arid Climate", Sol. Energy 53 (1994) 301– 305.

[6] Pierre Hollmuller , Bernard Lachal, "Air–soil heat exchangers for heating and cooling of buildings: Design guidelines, potentials and constraints, system integration and global energy balance" Applied Energy 119 (2014) 476–487

[7] S. K. Khandelwal,A. Mathu,"The Design of Earth Air Tunnel Heat Exchanger System for an Institute Library",Volume No.4 Issue No.3,pp : 141-145,2015

[8] Sanjeev Jakhar,Rohit Misra,"Parametric simulation and experimental analysis of earth air heat exchanger with solar air heating duct earth–air heat exchangers for domestic buildings in a desert climate", Build. Environ. 41 (2006) 235–244

[9] Rakesh Kumar,."Performance evaluation and energy conservation potential of earth-air-tunnel system coupled with non-air-conditioned building",Building and Environment 38,807-813,2003

[10] Sodha M., "Evaluation of an Earth-Air Tunnel System for Cooling/Heating of a Hospital Complex" Volume No.4 Issue No.3, pp : 141-145,2015

[11] Sameer Nadaf, Dipak Bhoge, "A Review On Performance Enhancement Of Air Conditioner Using Earth Air Tunnel Heat Exchanger",Volume No. 6 issue 4, pp:113-116, March 2016.