Performance Evaluation of Air Conditioner Using Earth Air Tunnel Heat Exchanger

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Abstract:- Energy is essential for the existence of human life and it plays a vital role in programmer of nation. Countries energy demand is growing 3.67% yearly, so nowadays, refrigeration systems have become one of the most important systems for people's daily lives. In India, it can be seen that several houses have a room air conditioner installed in it. The use of air conditioner consumes about 40 % of the total of electricity used in a house. So it is essential to develop energy efficient refrigeration and air conditioning systems to conserve the energy. In this paper, performance evaluation of air conditioner with and without using earth air tunnel heat exchanger is being investigated by using the experimental results. The results are improved when the EATHE is coupled with air conditioning system, which increases the COP of the system by nearly 11%. The power consumption of the compressor reduces by nearly 15% when the Earth Air Tunnel Heat Exchanger system is used instead of condenser fan.

***Keywords**:- Earth Air Tunnel Heat Exchanger (EATHE), Coefficient of Performance (COP), Air Conditioning system.*

I. INTRODUCTION

Thermal comfort is required to provide good quality of air at desired place but environment is a great concern. So everyone is looking towards green energy. Passive heating or passive cooling systems are known for their advantages of consuming no or very less active energy. Earth to air heat exchanger is one of the most important passive system it provides both heating effect in winter and cooling effect in summer Temperature of air-cooled condenser is directly dependent on the ambient air temperature, therefore, in the area with very hot weather temperature in summer like Sholapur (India) the condenser temperature and pressure are increased considerably which consequently increases the power consumption of the air conditioner due to the increase in the pressure ratio. Increasing condenser temperature also decreases cooling capacity of the cycle due to the reduction of liquid content in the evaporator. These two effects decrease performance of air conditioner considerably. In order to increase the performance of air conditioner in this situation, one of the best solutions is decreasing the condenser temperature. Reducing the condenser temperature reduces the pressure ratio across the compressor which results into reduction in power consumption. The temperature of the condenser tubes can be reduced by cooling them down with the help of cold air form the Earth Air Tunnel Heat Exchanger.

A. Project Objectives

Observing the problems of electricity consumption by air conditioner system objectives of project was decided. The basic primary objective of this system is to increase the coefficient of performance of air conditioner system using EATHE. In the present paper, an attempt has been made to enhance the performance of active cooling system by coupling it with EATHE.

B. Literature Review

➢ *Sodha M. et al.*

This paper presents Evaluation of an Earth-Air Tunnel System for Cooling/Heating of a Hospital Complex. The humidity of the air at the outlet was observed to remain high, about 75-89% in summer and 59- 76% in winter.

➢ *Singh A. et al.*

In this work they investigate Performance Analysis of Rectangular Earth-Air Tunnel System used for Air-Conditioning of the College Classroom. The C.O.P and cooling effect of the prototype is best in the months of May and June, when the summer is on its peak. Though the C.O.P. is reduced drastically in winters in the months of November, December, February, and March, it can be increased by employing a small heating coil at the duct outlet.

➢ *Saini D. et al.*

In this work they investigate a critical analysis of design of earth air tunnel heat exchanger. . The effectiveness is calculated which 88.4 %, 93.2 % and 95.7 % is for flow velocities 3 m/s, 4 m/s and 5 m/s respectively.

II. MODELING OF DESIGN PARAMETER

Now input parameter and variables are required to identify which affect the effectiveness of EATHE system. The inlet air temperature and ground temperature vary with climate condition. The soil temperature at a depth of 2-3 meter is estimated as mean annual average temperature at particular location. Once the design -output is fixed then we directly relate our governing equations to estimate length of tube, pressure drop across one particular tube and effectiveness.

A. Heat Exchanger Design Sheet (Mathematical Analysis)

In the Heat Exchanger design sheet the effectiveness of EATHE is fixed according to set of input parameter and fixed output parameter. With the help of input of tube size (D), inlet temperature, volume flow rate (V), number of parallel tube (n), mean annual average air temperature and fixed output temperature the value of NTU is estimated. For the determining of length of tube for a desired NTU parameter we used design calculations. The mean temperature input in Celsius and selected Galvanized Iron material of tube having thermal conductivity (k_t) =79 W/mK. We select surface roughness for different tube material using ASHRAE STANDARD 2009. The main output of design sheet is length of tube (m), pressure drop across the tube, NTU, Ut, hc and effectiveness. First we select diameter of pipe (D) which is 0.05 m and velocity (V) which is 4 m/s is taken.

B. Description of Experimental EATHE System

The diagram of EATHE system is shown in figure 2.2 .It comprises of 20 m long horizontal cylindrical 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 m^3/s through a vertical pipe. The air from the atmosphere was forced to move through the EATHE system with the help of blower.

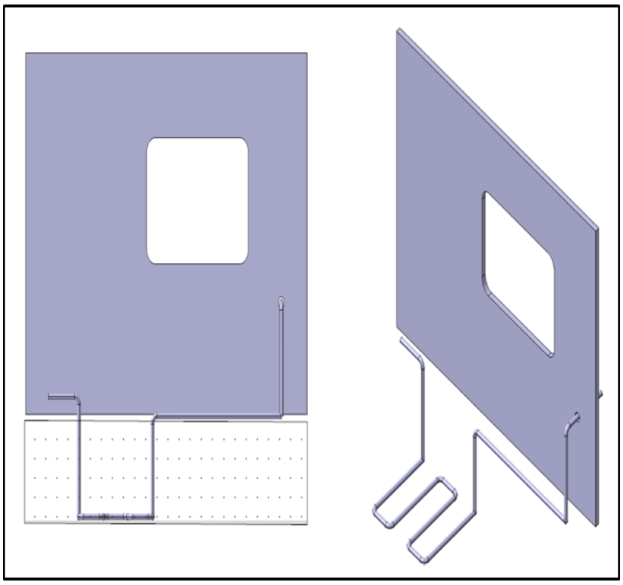

Fig 1:- CATIA model of EATHE (Front View and 3 D View)

Fig 2:- Installation Pipe structure on Project Site

Fig 3:- EATHE Cold air supplied to Experimental setup

Seven k type Thermocouples are mounted on pipe. Thermocouples T_1 to T_7 were inserted at the center of the pipe along the length at a horizontal distance of T_1=0.2 m,T_2=3.2 m ,T_3= 6 m, T_4=7.5 m,T_5= 10 m, T_6=14 m,T_7= 18 m respectively from the upstream end to measure temperature of the air. Three K Type Thermocouples temperature sensors T_8 toT_{10} 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. 1 TR air conditioner tutor has been used as an active cooling system. Research room is having dimensions of 4.3 m × 3.8 m × 3.05 m, with three windows (1.52 m × 1.22 m walls respectively) and a door (1.82 m × 0.91 m).Interstices around the door were also taken care of by providing packing's and minimizing the leakage of conditioned air from the room.

C. Test Procedure

Experimentation was performed April 2018 & May 2018 covering the entire summer season. Measurements and recording of hourly data include the ambient air temperature and relative humidity, temperature and relative humidity of air at the inlet and outlet of EATHE, temperature of air in the buried pipe at nine different locations, depth-wise temperature of soil at seven points, temperature ,electrical energy consumed by air conditioner and air blower. Readings were taken for 6 hrs. of continuous operation for each mode of hybrid EATHE system on alternate days from morning 11:00 A.M. to 4:00 P.M. Flow velocity of air through the EATHE was maintained at 4 m/s,5 m/s ,6 m/s with the help of Blower.

III. OBSERVATIONS FOR COOLING AND DEHUMIDIFICATION WITH & WITHOUT USING EATHE

In this the observation of air conditioning system is made without using EATHE and with using EATHE at different velocity is discussed.

Sr. No	Description	Units	Day 1	Day 2	Day 3	Day 4	Day 5
1	Condenser Pressure	Psi	114	120	121	115	130
2	Evaporator Pressure	Psi	30	40	35	32	31
3	Rotameter Flow Rate	LPH	45	43	42	50	52
4	Condenser Inlet Temperature	^{0}C	58	55	59	61	59
5	Condenser Outlet Temp.	^{0}C	35	33	37	38	35
6	Evaporator Inlet Temp.	^{0}C	10	9	12	8	10
7	Evaporator Outlet Temp.`	^{0}C	25	24	22	27	25
8	Compressor Energy	Sec	9	11	10	13	12
9	Compressor Current	Amp	1.5	1.5	1.5	1.5	1.5
10	Compressor Voltage	Volt	240	240	240	240	240
11	Air Inlet Temperature	^{0}C	30	36	34	33	34
12	Air Inlet Temp.	^{0}C	20	20	17	19	19
13	Air outlet temp.	^{0}C	18	23	22	20	23
14	Air outlet temp.	^{0}C	13	15	10	10	11
15	Ambient Temp.	^{0}C	39	38	36	36	38

Table 1. Observation of Base Case without Using Earth Air Tunnel Heat Exchanger

Time / Temp.	11:00 A.M.	12:00 P.M.	01:00 P.M.	02:00 P.M.	03:00 P.M.	04:00 P.M.
T_1 °C (inlet temp.)	38	39	40	40	39	39
T_7 °C (outlet temp.)	36	35	34	34	35	36

Table 2 Observation Table of EATHE at Inlet Velocity 6 m/s on 06-05-18.

From the above table we can conclude that at 1:00 P.M. and 2:00 P.M. Inlet temperature (T_1) is 40^{0}C and outlet Temperature (T_7) of Earth Air Tunnel Heat Exchanger system is 34^{0}C.the Difference between inlet temperature & EATHE outlet temperature is 6 ^{0}C.

Sr. No	Description	Readings
1	Condenser Pressure	114
2	Evaporator Pressure	31
3	Rotameter Flow Rate	44
4	Condenser Inlet Temperature	59
5	Condenser Outlet Temperature	34
6	Evaporator Inlet Temperature	9
7	Evaporator Outlet Temperature`	20
8	Time for 10 impulses for compressor energy consumption	13
9	Compressor Current	1.5
10	Compressor Voltage	240
11	Air Inlet Temperature (DBT)	33
12	Air Inlet Temperature (WBT)	24
13	Air Outlet Temperature (DBT)	19
14	Air Outlet Temperature (WBT)	14
15	Ambient Temperature	38

Table 3. Observation of Air Conditioner System on 06-05-18 at 1:00 PM Using EATHE System at Velocity 6 m/s

Time / Temp.	11:00 A.M.	12:00 P.M.	01:00 P.M.	02:00 P.M.	03:00 P.M.	04:00 P.M.
T_1 °C (Inlet temp.)	37	38	39	39	38	37
T_7 °C (outlet temp.)	34	34	33	33	34	35

Table 4. Observation Table of EATHE system at Inlet Velocity 5 m/s on 07-05-18.

Sr. No	Description	Readings
1	Condenser Pressure	114
2	Evaporator Pressure	30
3	Rotameter Flow Rate	43
4	Condenser Inlet Temperature	59
5	Condenser Outlet Temperature	33
6	Evaporator Inlet Temperature	9
7	Evaporator Outlet Temperature`	20
8	Time for 10 impulses for compressor energy consumption	13
9	Compressor Current	1.5
10	Compressor Voltage	240
11	Air Inlet Temperature (DBT)	33
12	Air Inlet Temperature (WBT)	24
13	Air Outlet Temperature (DBT)	19
14	Air Outlet Temperature (WBT)	14

Table 5. Observation of Air Conditioner System on 07-05-18 at 1:00 PM Using EATHE System at Velocity 5 m/s

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Time / Temp.	11:00 A.M.	12:00 P.M.	01:00 P.M.	02:00 P.M.	03:00 P.M.	04:00 P.M.
T_1 °C (inlet temp.)	38	39	40	40	39	38
T_7 °C (outlet temp.)	34	35	33	33	33	34

Table 6. Observation Table of EATHE at Inlet Velocity 4 m/s on 08-05-18.

Sr. No	Description	Readings
1	Condenser Pressure	114
2	Evaporator Pressure	30
3	Rotameter Flow Rate	46
4	Condenser Inlet Temperature	60
5	Condenser Outlet Temperature	33
6	Evaporator Inlet Temperature	9
7	Evaporator Outlet Temperature`	20
8	Time for 10 impulses for compressor energy consumption	13
9	Compressor Current	1.5
10	Compressor Voltage	240
11	Air Inlet Temperature (DBT)	33
12	Air Inlet Temperature (WBT)	24
13	Air Outlet Temperature (DBT)	19
14	Air Outlet Temperature (WBT)	14
15	Ambient Temperature	38

Table 7. Observation of Air Conditioner System on 08-05-18 at 1:00 PM Using EATHE System at Velocity 4 m/s

IV. RESULTS & DISCUSSION

	Amb. Temp. °C	(COP) Th.	(COP) Carnot	(COP) actual
Base Case	35	5.79	6.65	1.4
	36	5.65	6.5	1.45
With using EATHE at vel. 6 m/s	37	6.25	7.93	1.72
	40	6.15	7.96	1.65
With using EATHE at vel. 5 m/s	38	7	8.39	1.83
	41	6.85	8.15	1.7
With using EATHE at vel. 4 m/s	38	7.4	9.06	1.9
	40	7.29	9.04	1.8

Table 8. Result Table

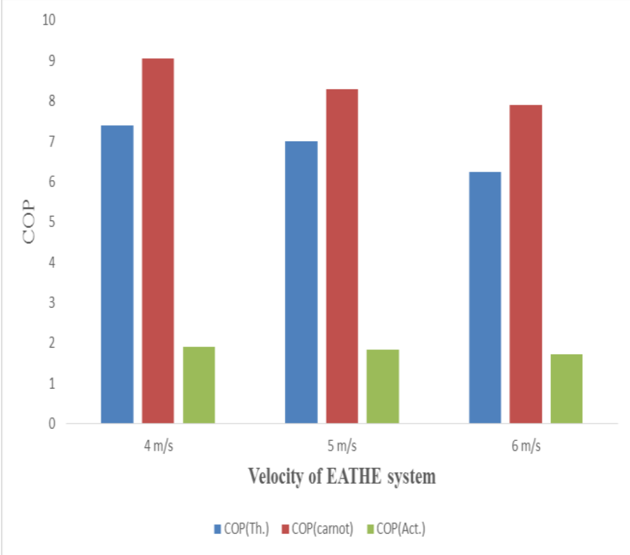

Fig 4:- Graph of Velocity of EATHE System Vs COP of Air Conditioning System

Figure 4.1 shows that the graph of COP of AC system with respect to the variations of velocity of EATHE system. At velocity 4 m/s the Theoretical, Carnot, and Actual COP is high as compared to velocity 5m/s & 6 m/s. With the increase in air velocity, This also reduces the duration to which the air remains in contact with the ground. Therefore, COP of air conditioning system decreases at air velocity 6 m/s as compared to 4 m/s and 5 m/s.

V. CONCLUSION

Number of methods are utilized to enhancing performance of Air Conditioning system. EATHE system 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 split type air-conditioning system which have wide spread application.

- Temperature difference between ambient temperature and outlet temperature of EATHE system at velocity 4 m/s is 6 °C.
- Temperature difference between ambient temperature and outlet temperature EATHE system at velocity at 5 m/s is 5 °C.
- Temperature difference between ambient temperature and outlet temperature of EATHE system at velocity at 6 m/s is 4 °C.
- The results are improved when the earth air tunnel heat exchanger is coupled with air conditioning system which increases the coefficient of performance of the system by nearly 11% and also reduces the power consumption of the system nearly 15%.

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