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Study the effects configuration and design parameters on the performance of earth to air heat exchanger used in poultry houses

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ABSTRACT

The main part of generated energy is consumed by cooling and heating systems. One of the promising approaches for heating and cooling applications is earth to air heat exchanger (EAHE) system. Usually, poultry houses are located in a remote area where there is no electricity, and where there is electricity, it is expensive, so resorting to these solutions is considered important solutions to save electrical energy and provide free cooling. This system is effective passive heating and cooling systems which can be used with poultry houses and buildings. This paper studies numerically the effect of design parameters and configuration on the overall performance of earth to air heat exchanger for poultry houses. The parameters (pipe diameter, pipe length, design shapes) are selected under environment of Nasiriyah city in the south of Iraq. The lengths of pipe selected (355 m,370 m,385 m,395 m and 410 m) and the diameters of pipe (2 in,3 in,4in and 6 in), the mass flow rate is constant (22948.2 Kg/s). The simulation results showed that the heat released by heat exchanger decrease with increase the outside temperature and increase with increasing the lengths of pipe. Also, reduction with increasing in the diameter, and the coil design gives higher value of heat released by heat exchanger. However, the overall performance factor of EAHEs decreases by the increase of length of pipe and increases with increasing in the diameter and it can be obtained that the grid design gives best overall performance factor.

KEYWORDS

Earth to air heat exchanger system (EAHEs), investigation of numerical, CFD, thermal of performance, poultry houses, parameters.

INTRODUCTION

The consumption of energy for heating and cooling loads improved through past years. Energy saving can be reached by relying on renewable energies such as solar, geothermal energy and wind. For heating and cooling buildings it can be reliant on the ground as heat source in the winter and as heat sink in the summer. The utilities of geothermal energy in heating and cooling spaces can be practiced by using earth air heat exchanger (EAHEs) or moreover named earth heat exchanger [1]. The poultry houses lay in arid areas and consumed high values of energy on air condition, therefore it's important to use removable energies such as geothermal energy for this puppy. Some academics have studied the earth air heat exchangers (EAHE) systems coupled with buildings as an operative inert energy source for heating and cooling systems like: F. Al-Ajmi et al. (2006) [2] developed the theoretical model to calculate an earth air heat exchanger temperature of air outlet and the potential of this cooling apparatus in a hot and arid climate. The model for a typical home of Kuwait City, in TRNSYS-IISIBAT environment was coded. They found that the EAHE had the ability to decrease home cooling energy request through the summer season by 30%.

Tudor et al. (2013) [3] analyzed and advanced the suitability of using the Earth to Air Heat Exchanger system as a passive method for heating and cooling of buildings under the climate for five cities of South – Eastern Europe. Their results showed that for all cities the systems of the Earth to Air Heat Exchanger are indeed active for use in South-Eastern Europe through all year. They found that the outlet air temperature from EAHE system recorded during July and August month was the maximum monthly average, while in January month was the minimum. Moreover, they discussed, best the thermal performance and the high heat gain record with using pipe diameter of 100 mm instead of 200 and 300 mm &17 m pipe length instead of 10 and 5 m, 2.5 & 3.5 m burial depth in its place of 1 m.

G.N. Tiwari. et al (2014)[4] experimentally estimate thermal conductivity of the soil, an Earth air heat exchanger (EAHE) has been designed ,dimension of room with improved values of radius of pipe, length of pipe, number of air variations, and depth at which(HE) be fixed under the surface of the ground. They observed that the outlet air temperature a decrease of 5 – 6 °C in summer for a number of 5 air changes with 0.10 m and 21 m optimized diameter and length of pipe respectively.

Trilok Singh Bisoniya,. et al.(2014) [5] studied decrease the cooling of energy demand of buildings are experimental in dry and hot climate Bhopal (Central India) . The model was advanced in CFD platform CFX 12.0. Used earth air heat exchanger system with PVC pipe of 0.1016m diameter and 19.228m length buried at 2m depth, for velocities of air flow of 2m/s to 5m/s diverse from 0.85 to 1.87 MW h .Observations of ; temperature was drop from 12.90 °C to11.30 °C and the gain energy of cooling of earth air heat exchanger improve 0.85 to 1.87 MJ h for the air flow of velocities of 2m/s to 5m/s.

Trilok Singh Bisoniya. et al (2014) [6] discussed the efficiently to reduce the heat energy request of buildings in dry and cold winter weather conditions by using EAHE. Pipe length of burial assembly is 19.228 m 0.1016 m diameter and buried at a depth of 2 m in a flat ground. Experimental results showed that heating potential varied from 0.59 to 1.22MJ h for air of flow velocities of 2–5 m/s ,also correlation coefficient and root mean square of percent deviation of 2.1% and 0.999.

Nitish Shrestha1. et al.(2015) [7] performance analysis of EAHE at different atmospheric conditions, Experimental that system consist of finned tube to explain the influence of finned tube in heat transfer for cooling mode enhance the thermal of performance. observed that in cooling mode the inlet temperature of the air decreases with increase in the pipe length. The temperature reduction for a length of 1.2m differs from 1-3 °C at velocity 6.5m/sec.

The effect of the thermal performance of EAHE by its design parameters are studied numerically by Thakur et al. (2015) [8]. They used two cases to compare between the performances of EAHE system, in one case they used finned pipe while the second case in finless pipe. The model was made from aluminum material for pipe and constructed by ANSYS workbench, 60 m pipe length ,0.1 m pipe diameter and 239 fins number. based CFD software and ANSYS fluent are solved Naver –Stocks equations numerically to define the results. From result their displayed that the thermal performance improved with using finned pipe wherever the air temperature was recorded drop about 20.5 ˚C compared with 17.7 ˚C when the pipe is finless.

Hiresh. et al. (2016) [9] performed an experimental operate to investigate the performance of earth to Air Heat exchanger. The material pipe of used as a model studied was made from PVC with pipe diameter, pipe length and burial depth (,0.106 m, 19.2 m and 2 m)respectively. They saw that about 261.5 W was the maximum amount of heat transfer from air to surrounding soil at 5 m/s the velocity of air. Also, they explained from the results that with temperature of inlet air changing from 32 ˚C to 40.3 ˚C the outlet air temperature increased by 4.5 ˚C at 5 m/s.

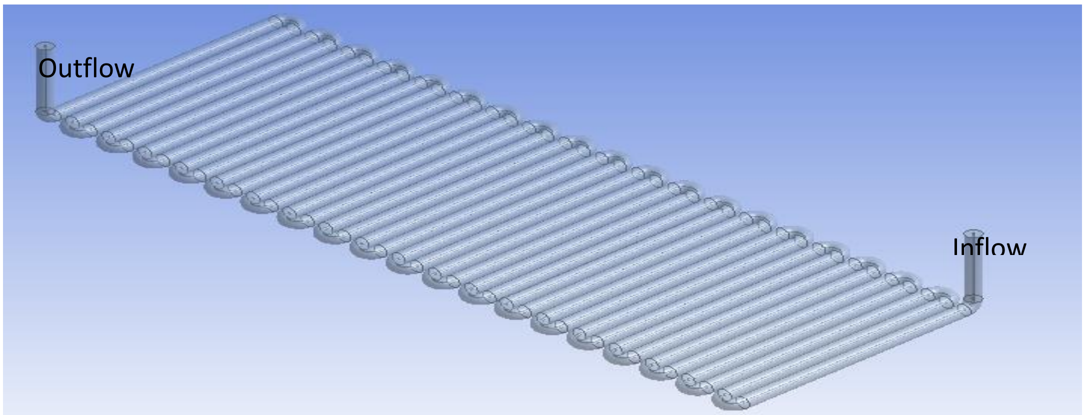
Mushtaq I. Hasan and Sajad W. Noori. (2018)[10] performed a numerical study about the potential decrease in the request of energy and the overall performance of (EAHE) system for heating and cooling of the house buildings by EAHE system of southern of Iraq in Nasiriyah city. length of 30 m and 0.008 m 2 constant with a diameter of 4 in (0.1016 m). They proved that, the suitable to use and the overall performance advances is circular shape of the EAHE channel is with increased pipe diameter and moisture of soil. Additionally, they showed that more appropriate to use is the EAHE system of case 2 compared with case 1 and case 3 II (consist of one layer buried with 3 m depth of EAHE system and the EHAE of this case3 II buried with depth of 4 m)with saving in energy 17.84% of winter at January months and 9.33 % of summer months at August month.

Kamal Kumar A.et al.(2018)[11] studied the moisture contented and its effect on the pipe of length and the thermal performance necessary for selected temperature increase in the winter season. The system comprises of two parallel buried pipe of EAPHE system at a depth of 3.7 m (one for wet soil, other for dry soil). The knee point for dry of EAPHE system is found at a pipe length of 40 m , while in the wet EAPHE system knee point is found at 27m, 28 m and 26 m with 10%, 5%, and 15% soil of moisture levels correspondingly, after 12 h of continuous process. They saw that the coefficient of performance and the average heat transfer rise up to 26.1% and 26.0% correspondingly, for 15% the moisture contented at 30 m length pipe of EAPHE as compared to the dry system.

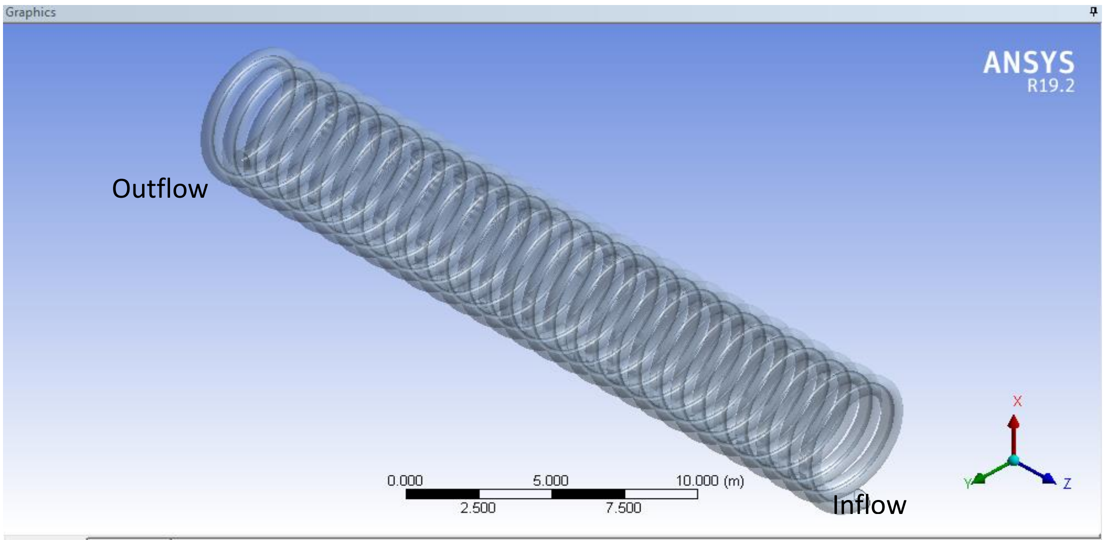
Nasreddine Sakhri1. et al.(2020) [12] introduced experimental investigation on the performance of a coupled system: earth-to-air heat exchanger and a solar chimney. PVC was the material made of pipes earth-to-air heat exchanger of (thicknesses: 0.002 m, length: 60 m, , diameter: 0.11 m) with a thermal conductivity coefficient 0.2 W m−1 K−1, a depth of 1.5 m under land) as an arid region in the North-west of the city of Bechar, Algeria. They showed results the ability of the system to rise the outlet air temperature exit the system by 14 °C and produce a heating mode. The inlet temperature increased ,then, the system travelled to a cooling mode by decreasing this temperature of air by 11.6 °C (from 36.2 °C at the inlet to 24.6 °C at the exit).

PROBLEM DESCRIPTION

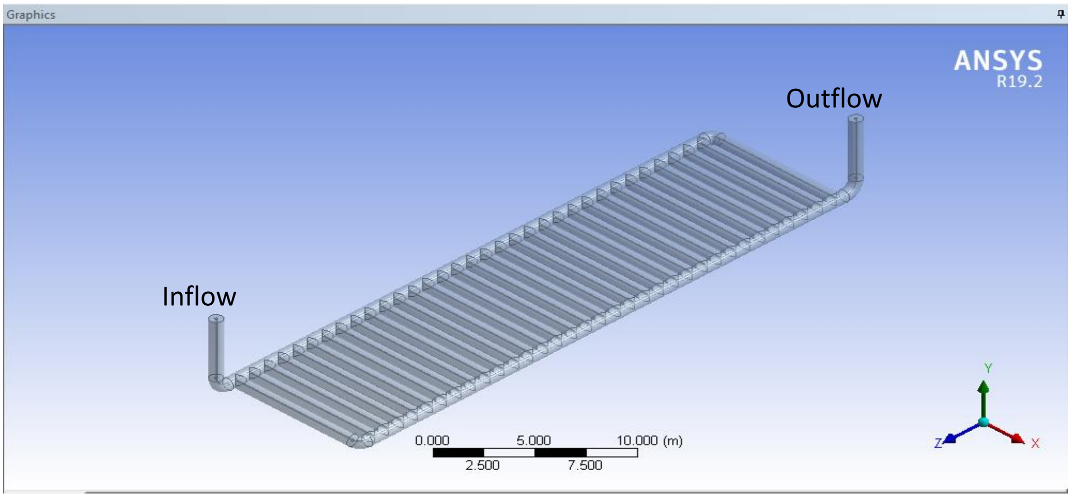
The model used in this research is 3D earth air heat exchanger system buried under earth surface by internal tube diameters of (2in,3in, 4in and 6in) and lengths of (355, 370m, 385m, 395m and 410m). Fig (3) displays the pipe of EAHEs by thickness of disturbed soil with different proposed designs (a. coil design, b. spiral design and c. grid design). PVC is the material were certain for study and draws by Ansys 19.2 software .



A. Coil



B. Spiral



C. Grid

Figure 1. (A-C) schematic of EAHE system model studied

Disturbed soil

The layer of soil nearby surface of earth air heat exchanger pipes is influenced with the transfer of heat and this soil named thermally disturbed soil as shown in Fig (2). There is no law for calculating the thickness of disturbed soil, several academics claimed that the thickness of disturbed soil equaled to the tube diameter [2], four times of pipe radius [12], twice of pipe diameter [14],and 10 times of tube diameter [15], also several studies establish out that the influence of disturbed soil on performance of earth air heat exchanger systems can be reduced by running the system in winter and summer seasons [16]. The thickness of disturbed soil is equivalent to four times of the pipe diameter is assumed in this research as stated by [17].

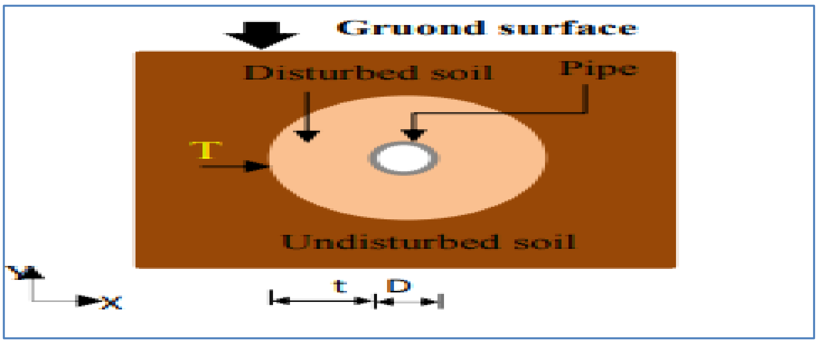


Figure 2. Cross sections of EAHE pipe.

MATHEMATICAL MODEL

Assumptions of flow

The assumptions were made through the building of mathematical model [18] :

1- Steady state &Turbulent flow.

2- velocity of Inlet of flow is uniform and constant.

3- The physical properties of soil are constant.

4- The fluid is incompressible by constant thermal conductivity ,specific heat and density.

Governing equations

The following equations of heat transfer and fluid flow are used in this study [19]

The equation of continuity:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad (1)$$

Momentum equations:

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\mu\rho\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right) \quad (2)$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial y}+\mu\rho\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right) \quad (3)$$

$$u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial P}{\partial z}+\mu\rho\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right) \quad (4)$$

Energy equation:

$$\rho Cp\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right) \quad (5)$$

For defining the overall performance factor of EAHE systems. the overall performance factor (η*) is used, which symbolizes the relation of heat transfer of rate between soil and air to the pumping power requisite [20], [21], [22].

$$\eta = Q/p.p \quad (6)$$

Where:

$$Q = m\ cp\ \Delta T \quad (7)$$

Where P.P is the pumping power and calculated from :

$$p.p = \Delta p.\ V. \quad (8)$$

To find type of the flow from the following equation:

$$\mathrm{Re}=\frac{\rho\ wD_h}{\mu} \quad (9)$$

Where:

D_h is the hydraulic diameter

To calculate the pressure drop from the subsequent equation:

$$\Delta p = p_{out} - p_{in} \quad (10)$$

Modeling the poultry house

After studying and specifying the appropriate design parameters for establish and work the EAHE, a poultry house with selected area(length=90 m, width=11m , the side height =2.7 m and the middle height= 4 m) and plan is selected to illustrates the potential saving in the consumed energy for cooling and heating of this selected poultry house when it is coupled with EAHE system. Atypical poultry house model has been chosen as a case study with area and plan as commonly used in Iraq of (31.7 N° Latitude and 45.8 E° Longitude). The case study consists of a house with floor area of (990 m^2) and plan as showing in fig (3). The overall heat transfer coefficient of the walls is (U = 2.356 w/ m^2 .k) and. The roof of poultry houses no roof insulation (U = 1.209 w/ m^2 .k) and the area of roof (1994.3 m^2). The infiltration airflow rate is assumed to be constant and equal to ten air change per hour. the energy of poultry house (11880), 20 ventilation from the back side of the poultry house (diameter 120 cm), 2 ventilation from the side of the poultry house(diameter 70 cm).

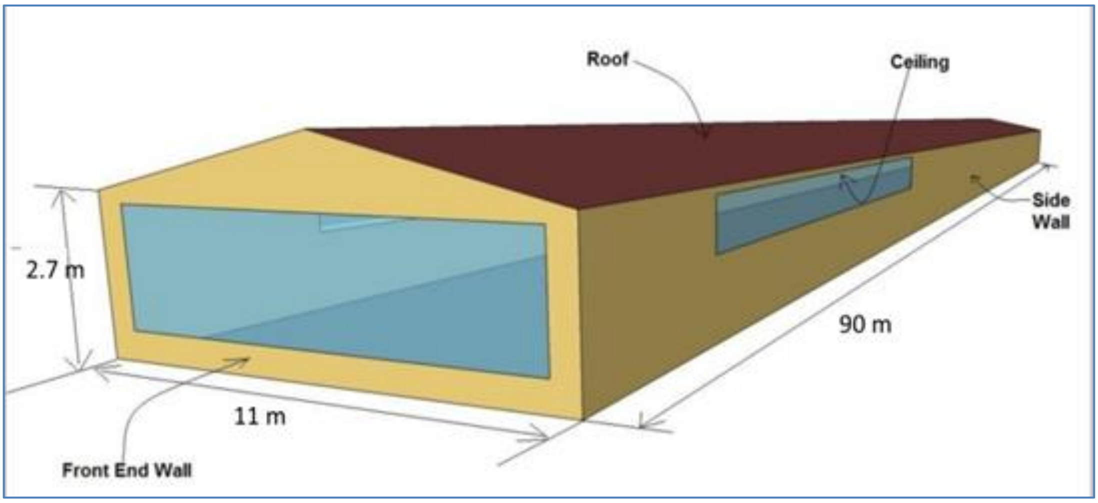


Figure 3. Modeled poultry House Geometry

Boundary conditions

The inlet boundary condition

On inside segment of heat exchanger of earth air pipe, the inlet dry bulb temperature (Tin) is constant and the velocity of air constant were used with turbulent flow and subsonic. The values of dry bulb temperature which used for example the boundary conditions were certain for winter and summer seasons a according to south of Iraq in the Nasiriya city.

The boundary condition in outlet

The pressure was taken at exit equivalent to the atmospheric pressure.

Wall

At walls, the horizontal section of earth air heat exchanger pipe is in thermal exchange with thickness of disturbed soil as in fig (2). At the outside superficial of disturbed soil with distance from pipe wall (t = 0.2032 m), the temperature of soil is constant and equivalent to (T soil = 26.3˚C) which agree to the temperature of undisturbed soil which was measured an experimental by depth of 3 m in south of Iraq [23]. But, assumed thermally isolated were the two vertical sections since the rises in air temperature for each of them (inside and exit) are equivalent and its assumed isolated to simplify the numerical solution thus cancel both other [24].

The physical properties of the soil, pipe material(PVC) and air are assumed constant and their values are listed in table (1). [2] [25] .and the relation between pipe diameter and thickness of disturbed soil is shown in table (2).

Table 1. Properties of used materials

Material	ρ(kg/m^3)	Cp(J/kg K)	K(W/m K)
Air	1.225	1006.5	0.0242
Soil	2050	1840	0.52
PVC	1380	900	0.16

Table 2. The diameters selected of the EAHE pipe and the disturbed soil thicknesses

Diameter of pipe (in)	**Diameter of pipe (m)**	**Thickness of disturbed soil (m)**
2	0.0508	0.1016
3	0.0762	0.1524
4	0.1016	0.2032
6	0.1524	0.3048

NUMERICAL SOLUTION

The governing equations are numerically solved by using the finite volume technique. The flow is improving and the computational fluid dynamics modeling (CFD) is used to solve 3D Navier stock equations and the continuity.

CFD modeling

Presently, the computational fluid dynamics modeling (CFD) is very general for behaviors analysis and modeling of earth air heat exchanger system.[15] .The aim of using CFD is to discover the performances of air in an EAHEs pipe for agreed set of boundary conditions. To predict the turbulence inlet the pipe, simple k–ε model by natural wall treatment is certain as energy equation and turbulent classic is furthermore solved as the reckonings involved the transfer of heat. The values of air flow characteristics can be found from computational fluid dynamics modeling by great number of points in the earth air heat exchanger systems. In the form of numerical grid will these points are normally linked together. The value to the convergence criteria for energy and momentum equations is used 1×10^{-6} .

Grid independence check

To fine the quality of advanced CFD model with great precise solution the test of grid independent was conducted, since a mesh attempt has been made, also the results of solution were unchanged. Table (3) consists the refinement of meshes, this table illustrations the different meshes certain and during this table it can be shown understood that, after attempts of mesh the solution of independent of mesh size after the third mesh. Hence, for calculating later solutions the fourth mesh will be used . ANSYS software 19.2 has been used to work the numerical solution

Table 3. Grid independent check

Element size	**Outlet temperature(K)**
mesh1(732546)	299.6732
mesh2(1317730)	299.5664
mesh3(1994518)	299.436
mesh4(2536351)	299.4

RESULTS AND DISCUSSIONS

To test the validly of the used numerical model a confirmation was built by solving the numerical model. This model is validated with a numerical model obtained in [25]. An earth air heat exchanger system involves of a pipe with 50 m length,0.1016 m diameter, so PVC is material made up. The temperature air of outlet EAHEs with three air velocity (1, 3,5,7, and 9 m/s) were measured with inside air temperature of 50 C° and disturbed soil temperature of 26.3 C °.[25]. **Fig 4.** displays the relationship between the simulation results of present model with the simulation results of [25] for variant of the air temperature of outlet with air velocity. From this figure it can be noted that, the agreement between the simulation results of the present model with that of [25] is suitable with the average error of 3%. Then, the present numerical model is dependable and can be used with suitable precision.

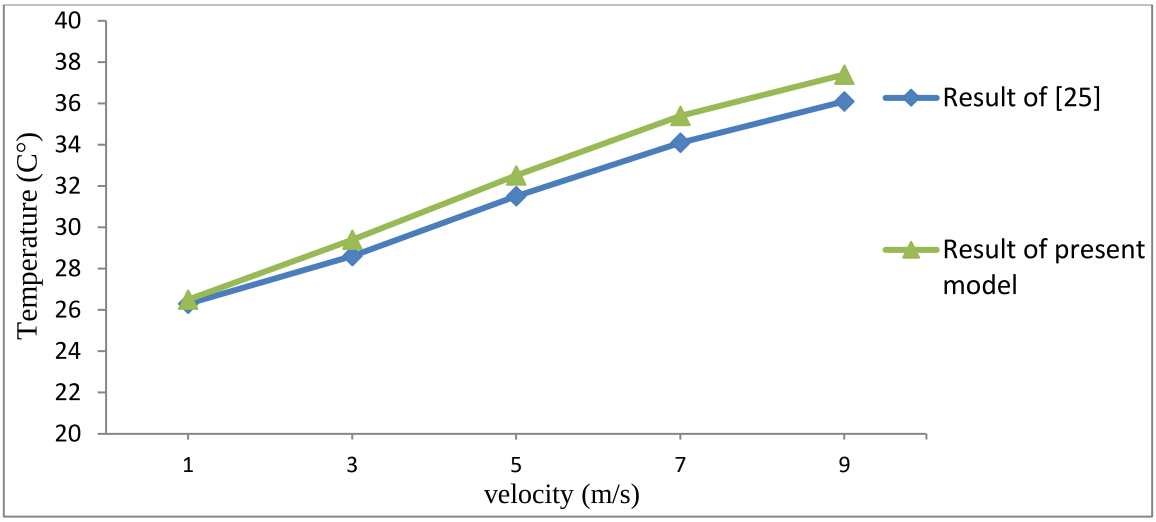


Figure 4. Changing of outlet temperature with velocity for Earth air heat exchanger as comparison between result of present model for air [25].

Results of coil design

Effect of length

Fig.5. explains the variation of heat released by HE with outside temperature of Earth air heat exchanger of air for all studied lengths of pipe of EAHE pipe at mass flow rate (22948.2 m^3/s). From this figure It can be understood that the heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate due to increase the entering temperature of air to space by increasing outside temperature. Also, larger length gives higher heat released by heat exchanger due to rising the amount of heat transferred as a result of increasing the area of heat transfer. Fig.6. indicates the variation of heat released by heat exchanger with lengths of pipe of Earth air heat exchanger for all studied outside temperature of air at mass flow rate (22948.2 m^3/s). It can be seen from the figure that the heat released by heat exchanger increase with increasing lengths of pipe due to decrease the temperature of air outside from pipe. Also, as a result of heat transfer enhancement result it's from increasing the residence of air in pipe and it's heat transfer area and lead to give high temperature difference (ΔT).

Fig.7. displays the variation of pressure drop with outside temperature of air for all studied lengths of EAHE pipe at mass flow rate (22948.2 m^3/s). From this figure, it can be seen that the pressure drop is constant with increasing outlet temperature of air due to mass flow rate is constant along the pipe and constant properties, whereas the larger length gives higher pressure drop, also pressure drop (ΔP) increase with increasing lengths of pipe due to increasing the frictional losses with increasing the pipe length, where the inlet mass flow rate to pipe is constant and high length gives higher pressure drop. Fig.8 indicates the variation of pumping power with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s). For the length of a single pipe it can be noted that the pumping power is remain constant with increasing outlet temperature of air due to the pressure drop is constant as discussed in fig (7). Moreover, the higher length gives higher pumping power. While, the p.p increased by increasing of length of pipes due to increase in pressure drop of constant mass flow rate for all lengths .

Fig.9. illustrates the variation of overall performance factor with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s). It can be obtained that overall performance factor decreased with increasing of outside temperature of air due to increase of pumping power and due to decline in temperature difference (ΔT). So, the overall performance factor is proportionate inversely with the pressure drop, so from the figure the shorter pipe give higher overall performance factor. While, overall performance factor also decreased with increasing length of pipes at mass flow rate (22948.2 m^3/s) in Fig.10 due to the pumping power is higher than heat released by heat exchanger and it can be known that the maximum performance factor can be obtain at the lowest length of pipe due to have few pumping power that depends on the pressure drop.

Fig.11. shows the variation of supply temperature from the pipe of EAHE with lengths of pipe for all studied outlet temperature of air. From this figure it can be known that the supply temperature decreased by increasing lengths of pipe due to increase in the heat transfer area and due to increase retention inside the pipe whenever increase the length of pipe., whereas that the short length of pipe gives high supply temperature inlet to the space.

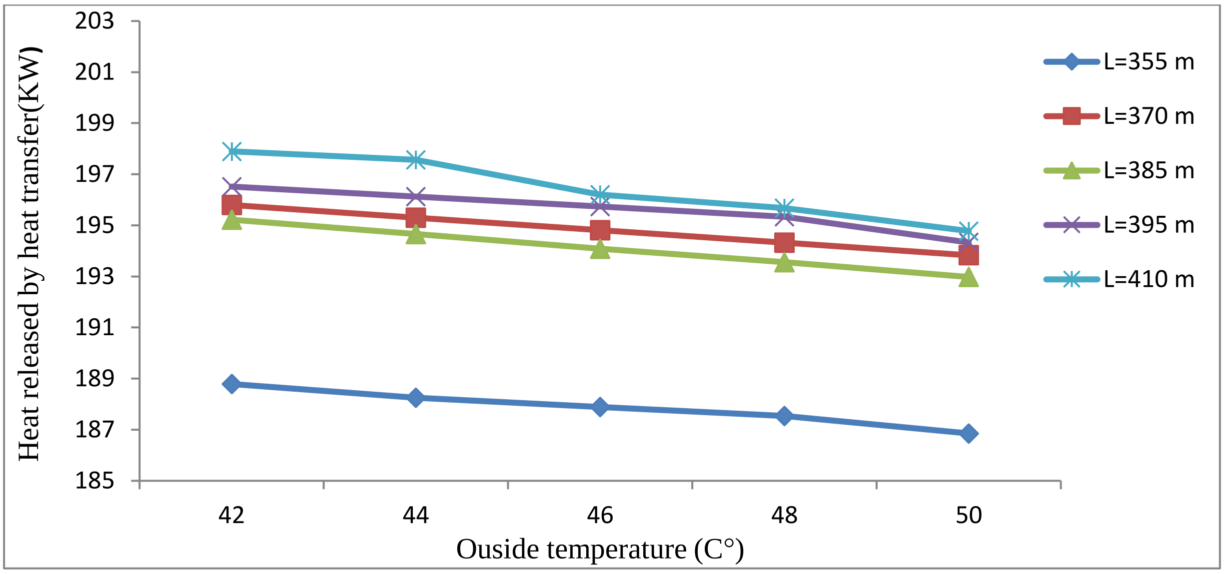


Figure 5. Variation of heat released by heat exchanger with outside temperature for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s)

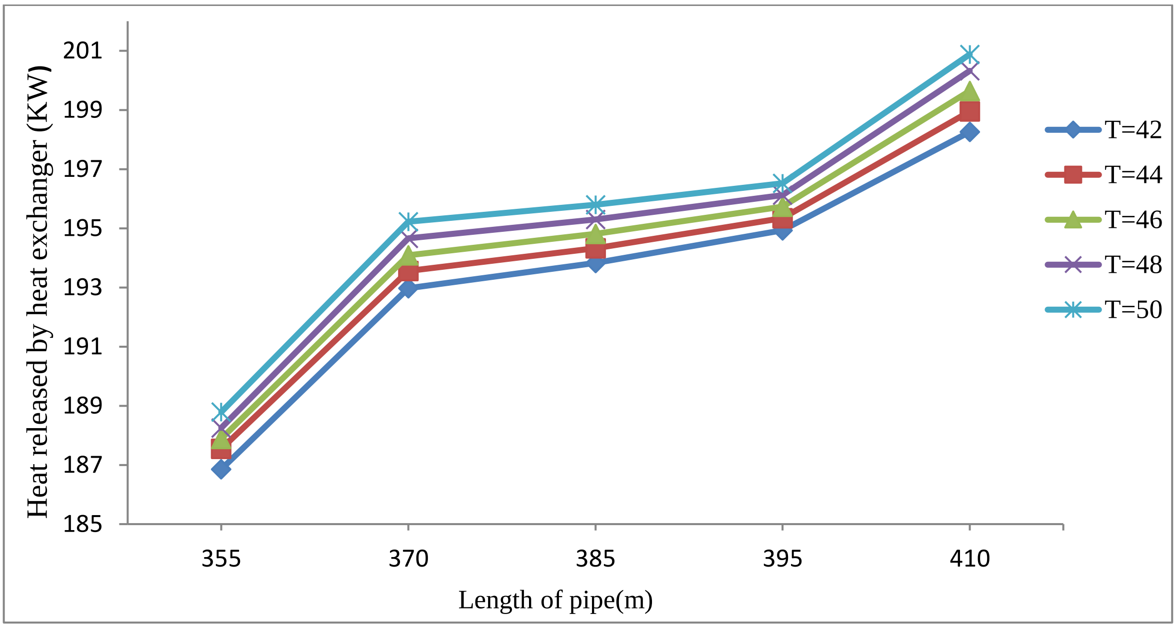


Figure 6. Variation of heat released by heat exchanger with lengths of pipe of Earth air heat exchanger for all studied outside temperature of air at mass flow rate (22948.2 m^3/s)

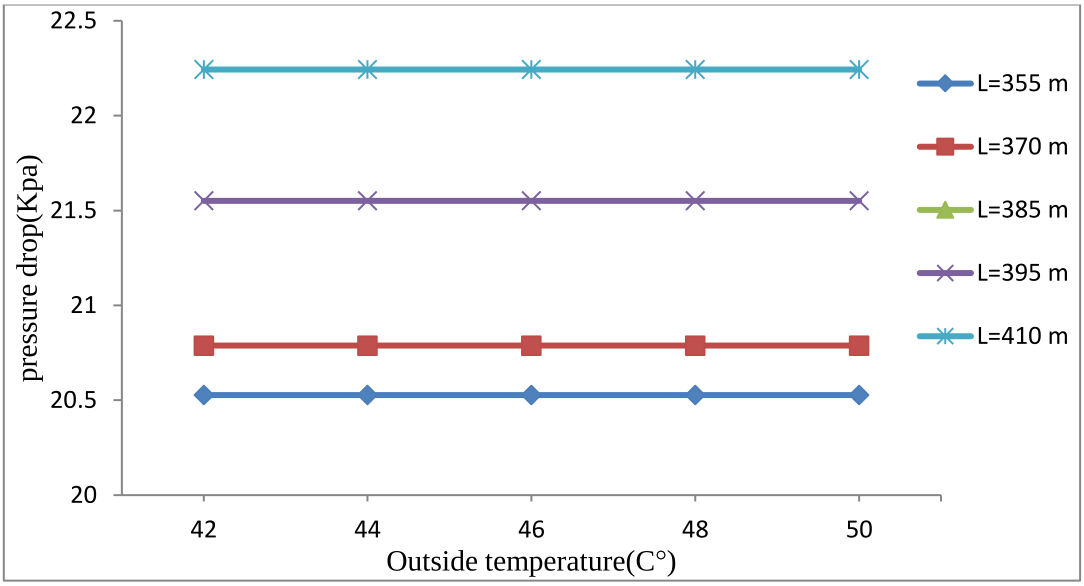


Figure 7. Variation of pressure drop with outside temperature of air of pipe for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s)

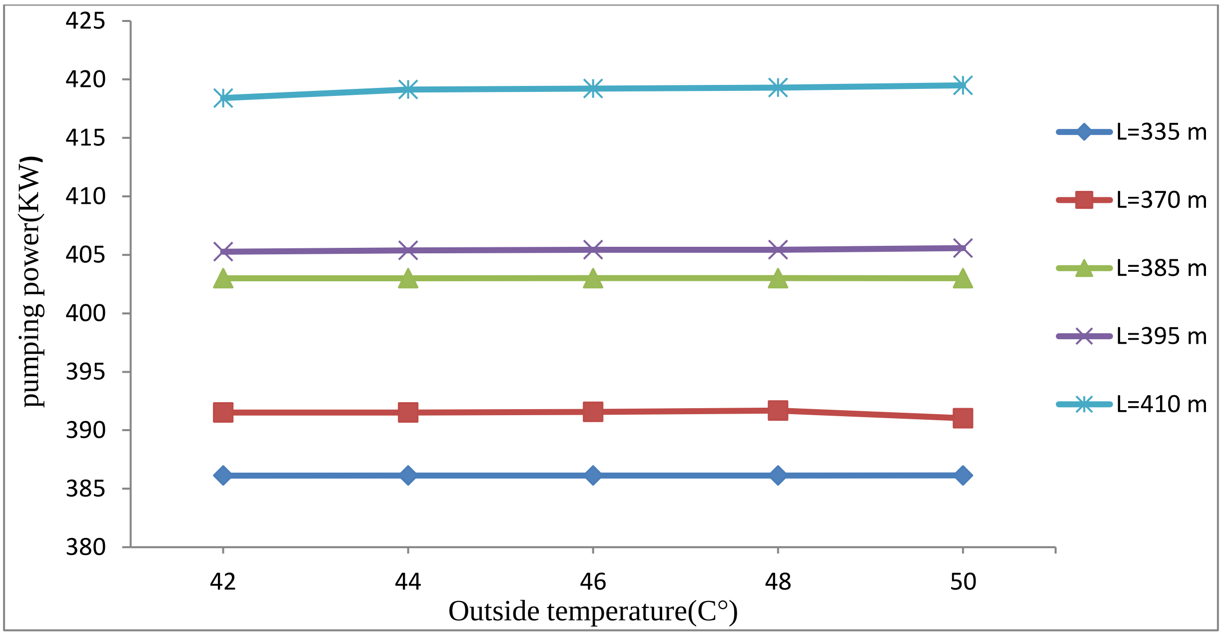


Figure 8. Variation of pumping power with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s)

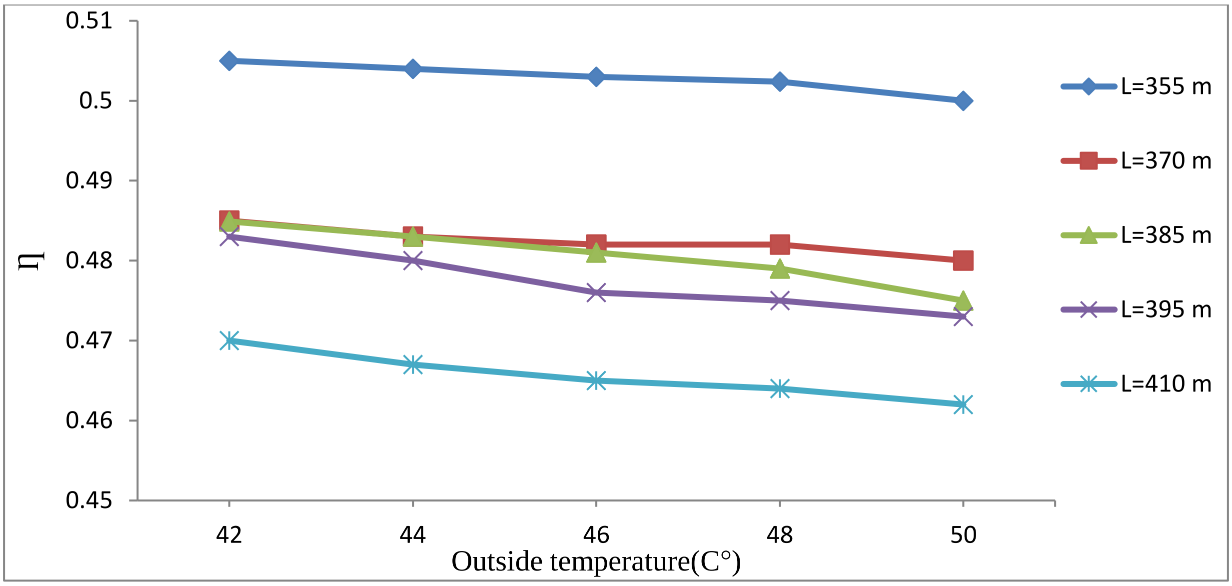


Figure 9. Variation of overall performance factor with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate ($22948.2\ m^3/s$)

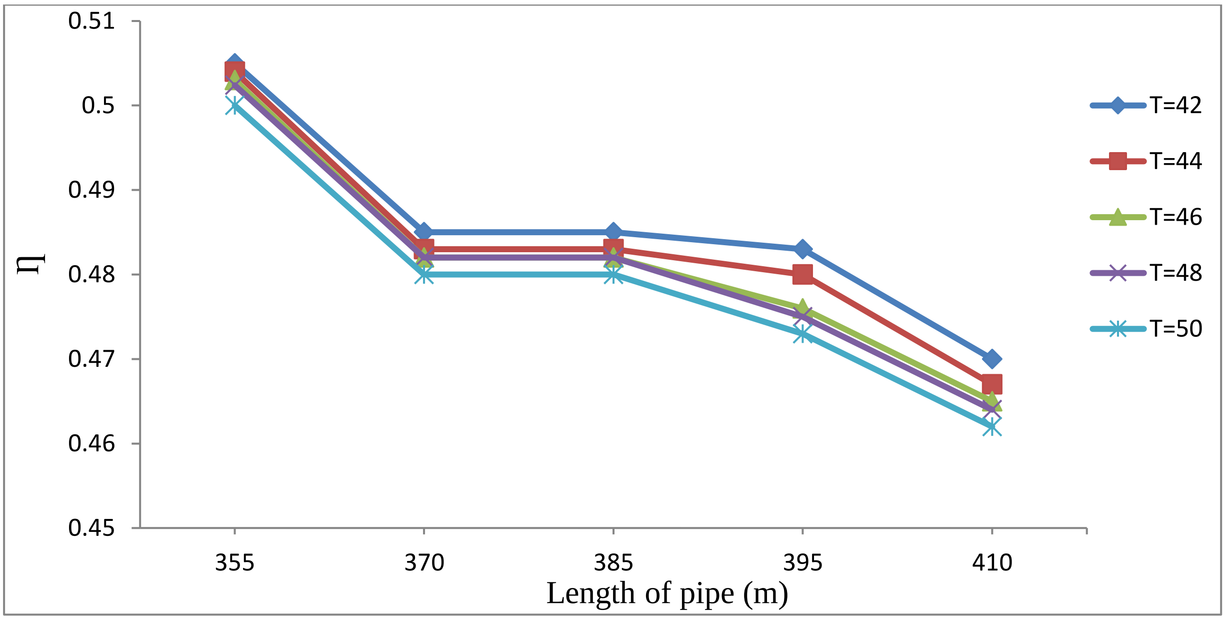


Figure 10. Variant of overall performance factor with lengths of pipe for all studied outlet temperature of air of EAHEs at mass flow rate ($22948.2\ m^3/s$)

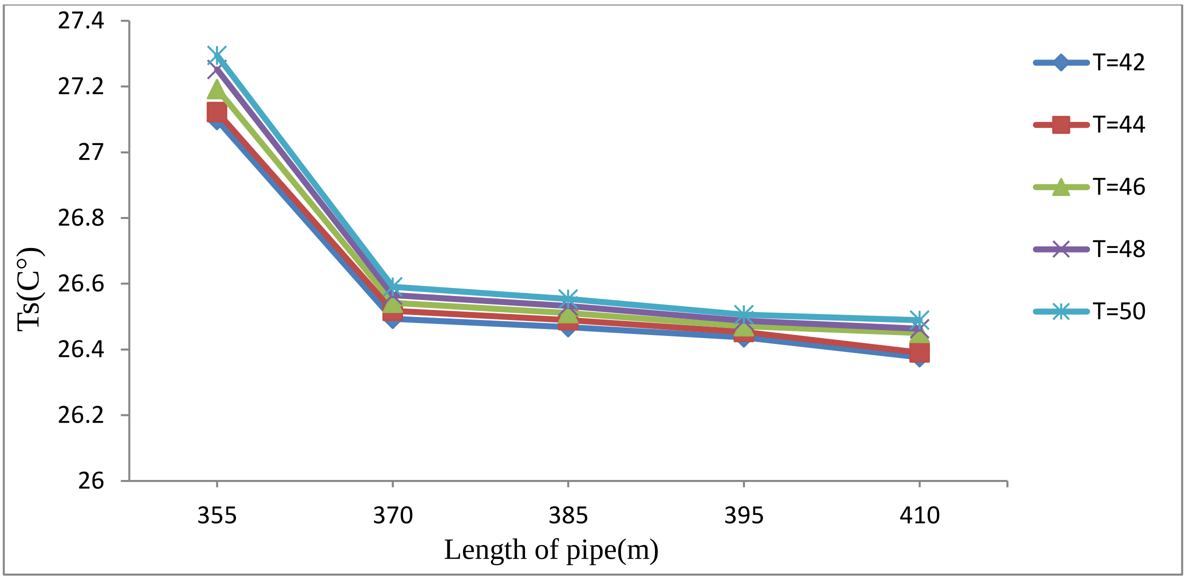


Figure 11. Variation of supply temperature with lengths of pipe of Earth air heat exchanger of air for all studied outside temperature of air at mass flow rate (22948.2 m^3/s.

Effect of diameter

Fig.12. explains the variation of heat released by heat exchanger with outside temperature of air for all studied diameters of pipe of EAHE pipe at length (410 m) and mass flow rate (22948.2 m^3/s). From this figure, It can be understood that the heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate due to increase the entering temperature of air to space by increasing outside temperature. Also, less diameters gives higher heat released by heat exchanger due to temperature difference (ΔT) is high than others diameters as a result of increasing the ratio of area to volume which lead to enhance the heat transfer process. Fig.13. displays the variant of pressure drop with outside temperature of air for all studied diameters of pipe of EAHE pipe at length (410 m) and mass flow rate (22948.2 m^3/s). From this figure, it can be seen that the pressure drop is constant with increasing outside temperature of air due to mass flow rate is constant along the pipe and constant properties, whereas the less diameters gives higher pressure drop, also pressure drop (ΔP) decrease with increasing diameters of pipe due to decreasing the frictional losses with increasing the pipe diameters, where the inlet mass flow rate to pipe is constant and high diameter gives lower pressure drop.

Fig.14. indicates the variation of pumping power with outside temperature of air for all studied diameters of pipe of EAHE at length (410 m) and mass flow rate (22948.2 m^3/s). For the diameter of a single pipe it can be noted that the pumping power is remain constant with increasing outside temperature of air due to the pressure drop is constant for a long of pipe. Moreover, the lower diameter gives higher pumping power. Fig.15. illustrations the variation of overall performance factor with outside temperature of air for all studied diameters of pipe of EAHE at length (410 m) and mass flow rate (22948.2 m^3/s). It can be obtained that overall performance factor decreased with increasing of outside temperature of air due to increase of pumping power and due to decline in temperature difference (ΔT), also due to increase by diameter of pipe. So, the overall performance factor is proportionate inversely with the pressure drop, so from the figure, the higher diameter pipe give higher overall performance factor due to the decreasing in pumping power for the same of lengths of pipe, performance factor can be obtain at the lowest diameter of pipe due to have few pumping power that depends on the pressure drop.

Fig.16 shows the variation of supply temperature to the poultry houses from the pipe of EAHE with outside temperature of air for all diameters of pipe studied at length (410 m) and mass flow rate (22948.2 m^3/s) . From this figure, it can be seen that the supply temperature decrease by decreasing diameters of pipe due to increase in the heat transfer area to volume retention inside the pipe whenever increase the diameter of pipe, whereas that the high diameter of pipe gives high supply temperature inlet to the space.

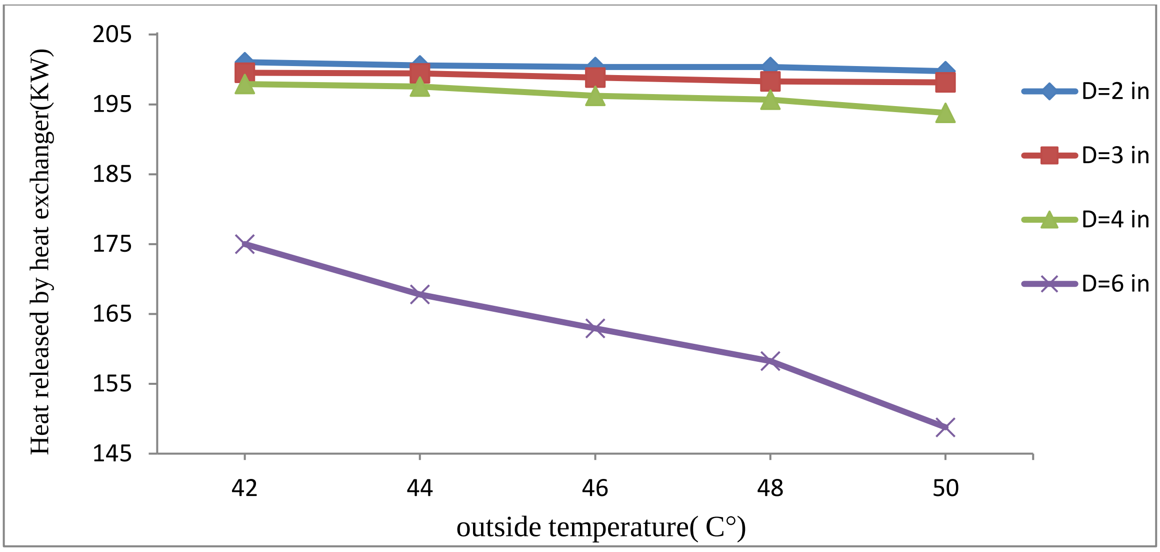


Figure 12. Changing of heat released by heat exchanger with outside temperature for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

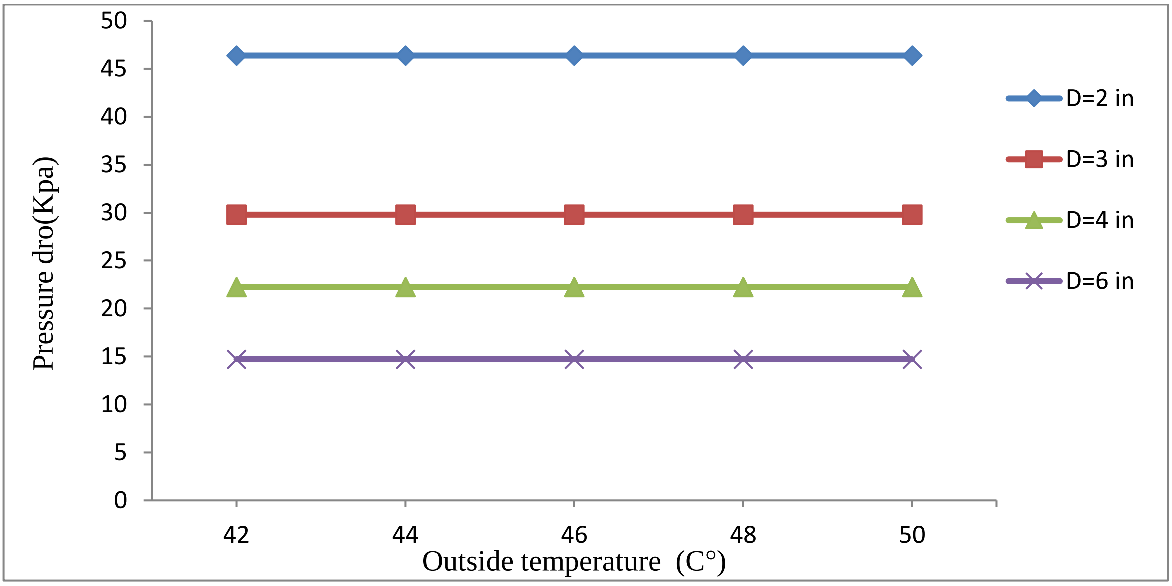


Figure 13. Variation of pressure drop with outside temperature of air of pipe for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

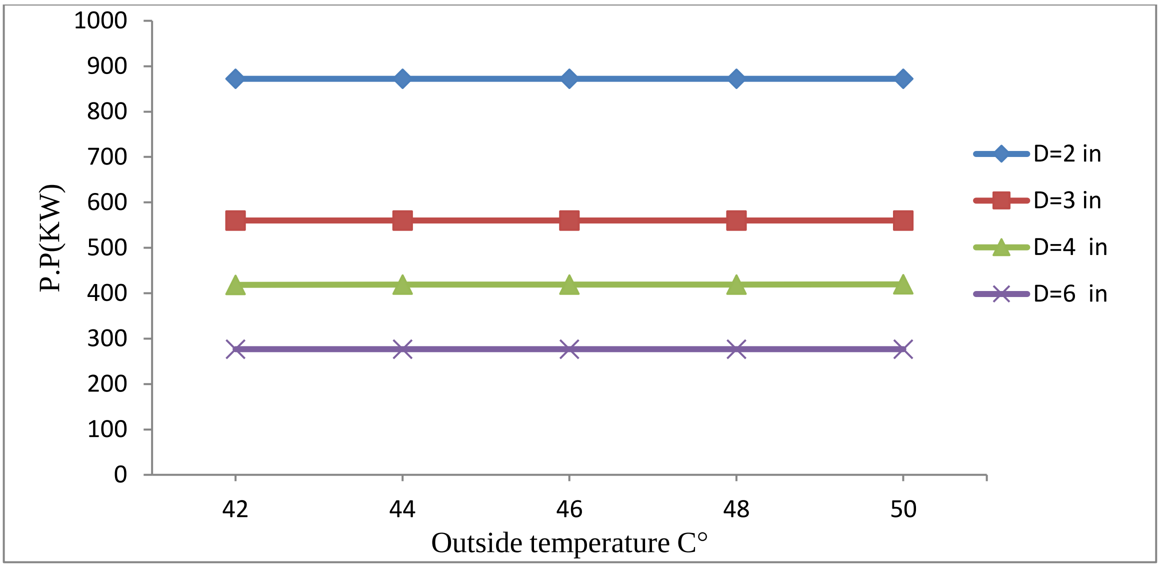


Figure 14. Variation of pumping power with outside temperature of air for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

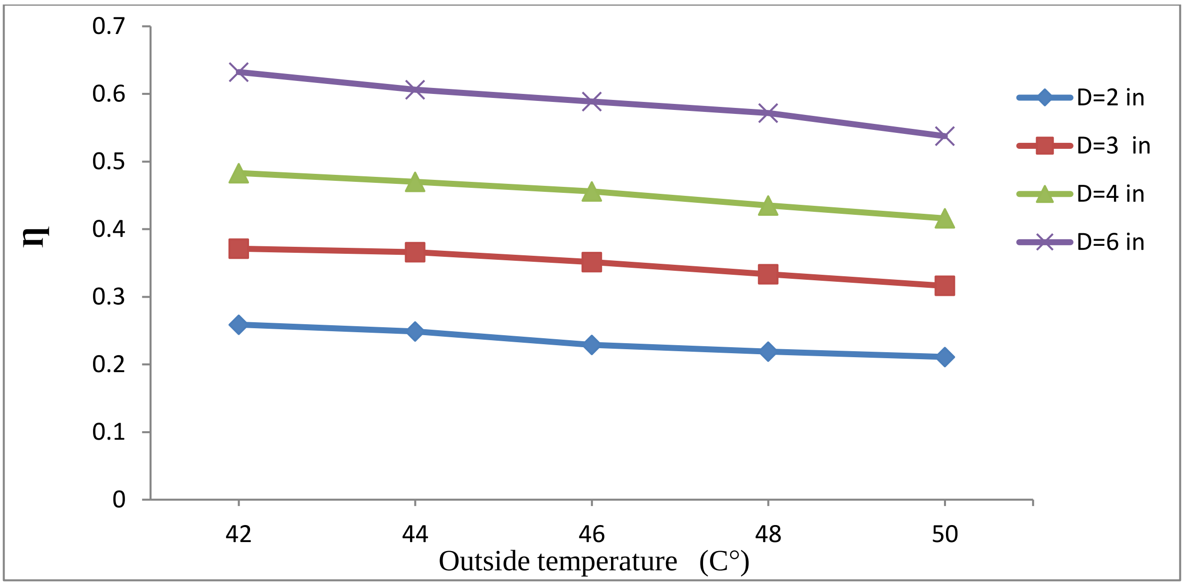


Figure 15. Variant of overall performance factor with outside temperature of air for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

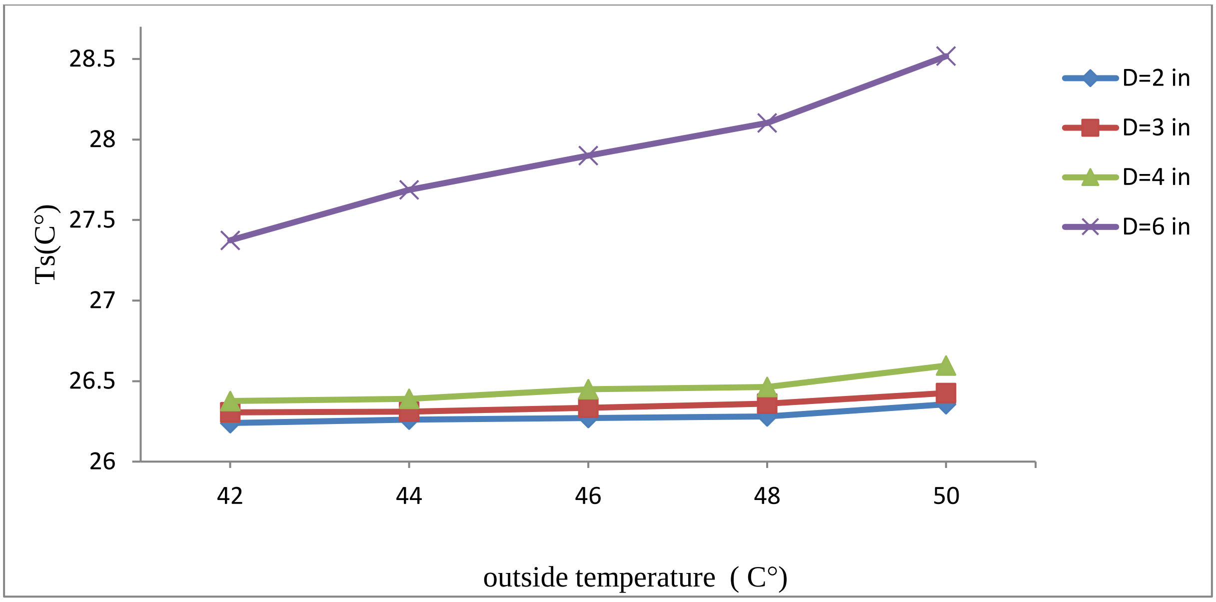


Figure 16. Variation of supply temperature with outside temperature of Earth air heat exchanger of air for all studied diameters air at mass flow rate (22948.2 m^3/s.

Results of spiral design

Effect of length

Fig.17. explains the variation of heat released by heat exchanger with outside temperature of Earth air heat exchanger of air for all studied lengths of pipe of EAHE pipe at length (410 m) and mass flow rate (22948.2 m^3/s). From this figure, It can be understood that the heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate due to increase the entering temperature of air to space by increasing outside temperature. Also, large length gives higher heat released by heat exchanger due to rising the amount of heat transferred as a result of increasing the area of heat transfer. Fig.18. illustrates the variation of overall performance factor with outside temperature of air for all studied lengths of pipe of EAHE at length (410 m) and mass flow rate (22948.2 m^3/s). It can be obtained that overall performance factor decreased with increasing of outlet temperature of air due to increase of pumping power and due to decline in temperature difference (ΔT). So, the overall performance factor is proportionate inversely with the pressure drop, so from the figure the shorter pipe give higher overall performance factor. Compared with overall performance factor for coil design is higher for all lengths of pipes in fig.(8).

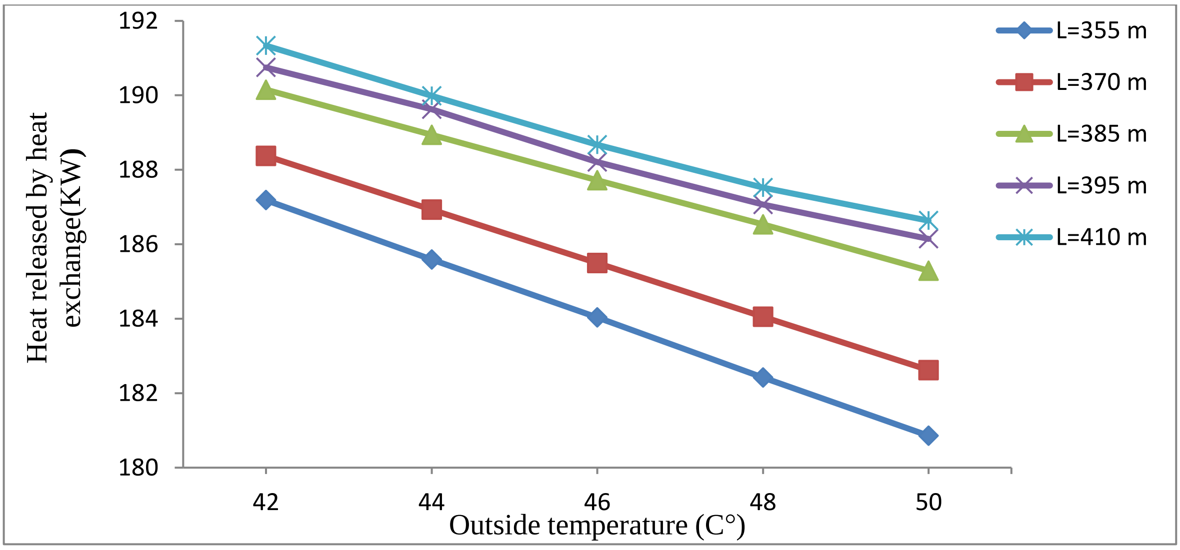


Figure 17. Varaition of heat released by heat exchanger with outside temperature for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3 /s

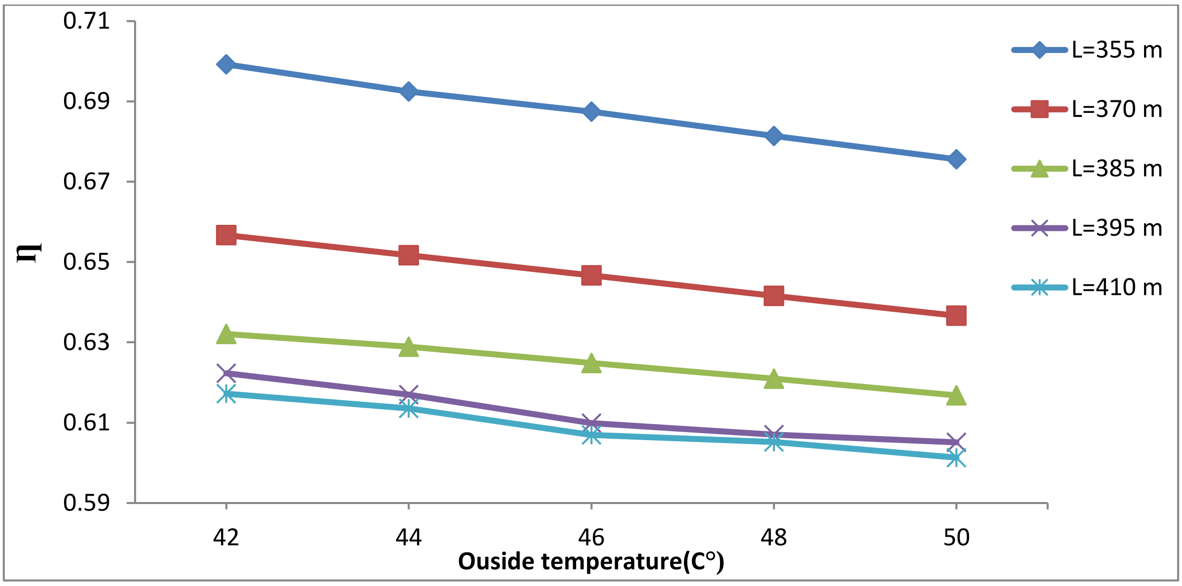


Figure 18. Variant of overall performance factor with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3 /s).

Effect of diameter

Fig.19. explains the variation of heat released by heat exchanger with outside temperature of Earth air heat exchanger of air for all studied diameters of pipe of EAHE pipe at length (410 m) and mass flow rate (22948.2 m^3 /s). From this figure, It can be understood that the heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate due to increase the entering temperature of air to space by increasing outside temperature. Also, less diameters gives higher heat released by heat exchanger due to temperature difference (ΔT) is high than others diameters as a result of increasing the ratio of area to volume which lead to enhance the heat transfer process. Fig.20. illustrations the variation of overall performance factor by outside temperature of air for all studied diameters of pipe of EAHE at length (410 m) and mass flow rate (22948.2 m^3 /s). It can be obtained that overall performance factor decreased with increasing of outside temperature of air due to increase of pumping power and due to decline in temperature difference (ΔT). So, the overall performance factor is proportionate inversely with the pressure drop, so from the figure, the higher diameter pipe give higher overall performance factor due to the decreasing in pumping power for the same of lengths of pipe, performance factor can be obtain at the lowest diameter of pipe due to have few pumping power that depends on the pressure drop.

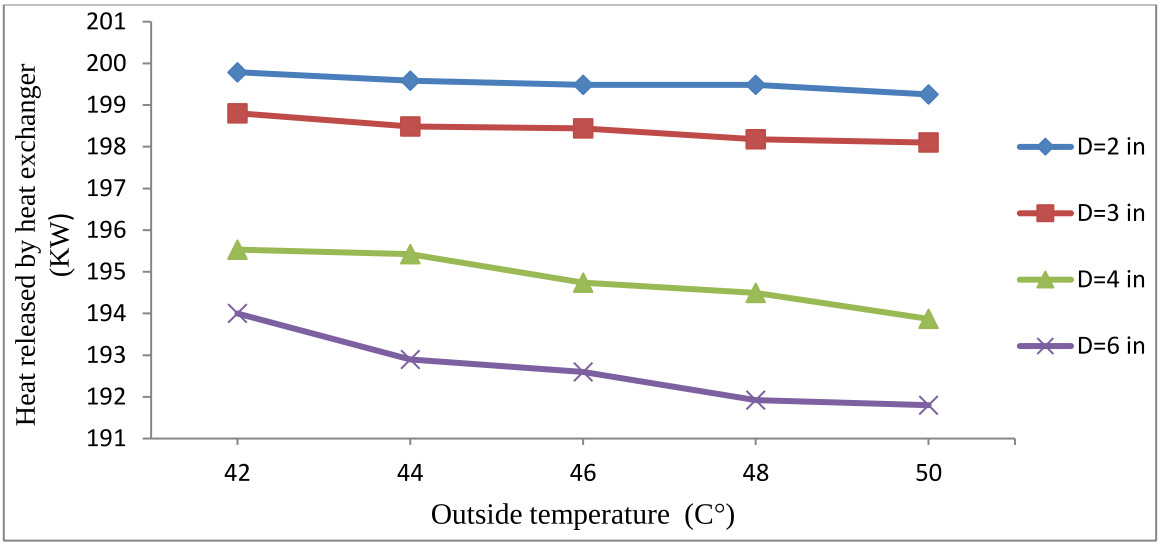


Figure 19. Varaition of heat released by heat exchanger with outside temperature for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

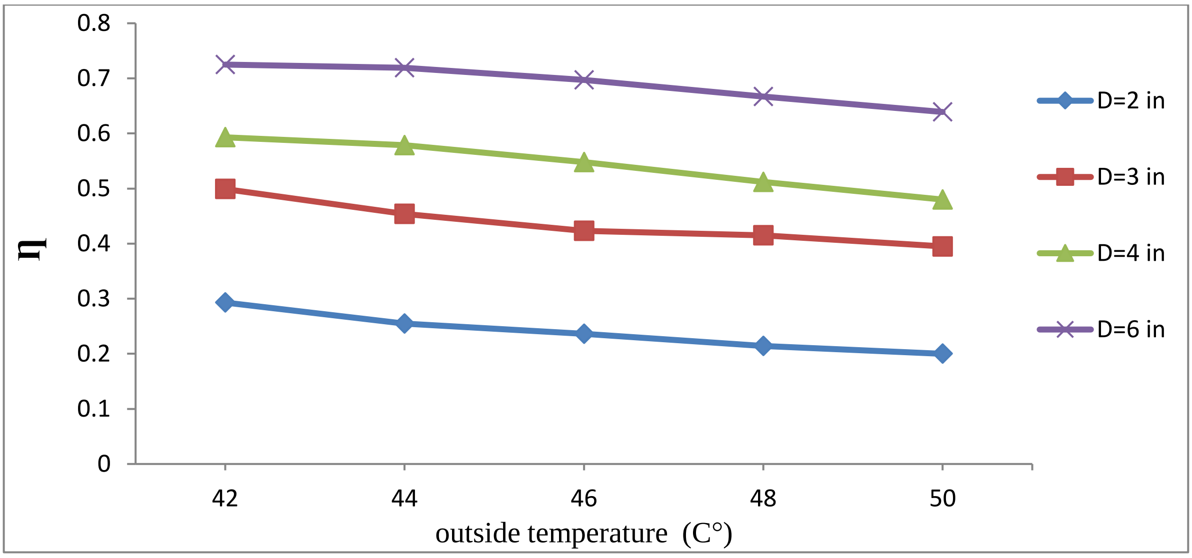


Figure 20. Variation of overall performance factor with outside temperature of air for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s).

Grid design

Effect of length

Fig.21. explains the variation of heat released by heat exchanger with outside temperature of Earth air heat exchanger of air for all studied lengths of pipe of EAHE pipe at mass flow rate (22948.2 m^3/s). From this figure, it can be understood that the heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate due to increase the entering temperature of air to space by increasing outside temperature. Also, larger length gives higher heat released by heat exchanger due to rising the amount of heat transferred as a result of increasing the area of heat transfer.

Fig.22. shows the variation of overall performance factor with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s). It can be obtained that overall performance factor decreased with increasing of outside temperature of air due to increase of pumping power and due to decline in temperature difference (ΔT). So, the overall performance factor is proportionate inversely with the pressure drop, so from the figure the shorter pipe give higher overall performance factor.

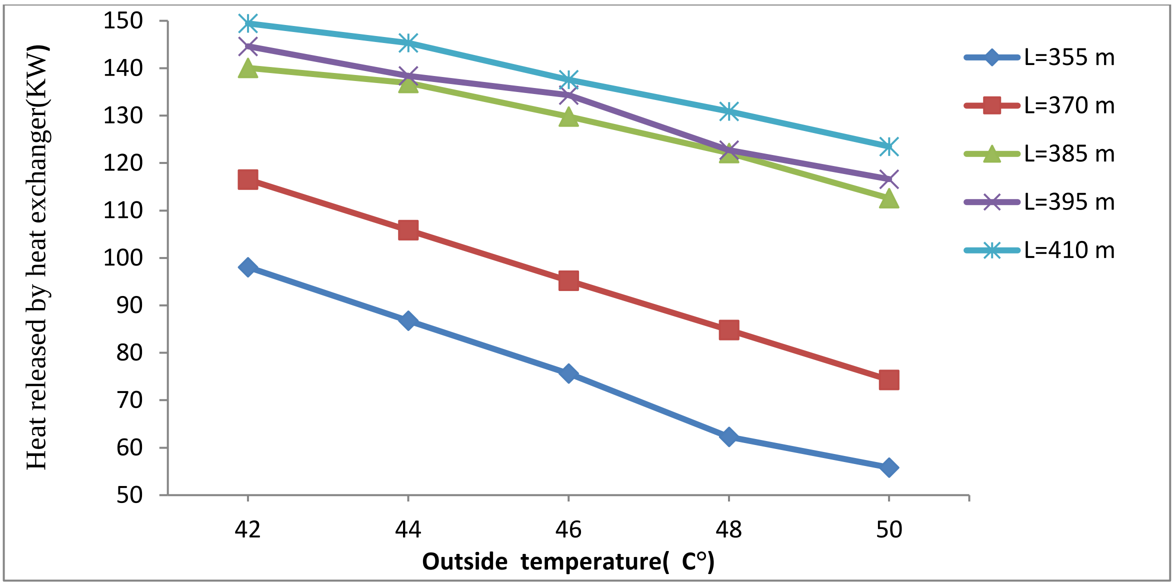


Figure 21. Variation of heat released by heat exchanger with outside temperature for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s)

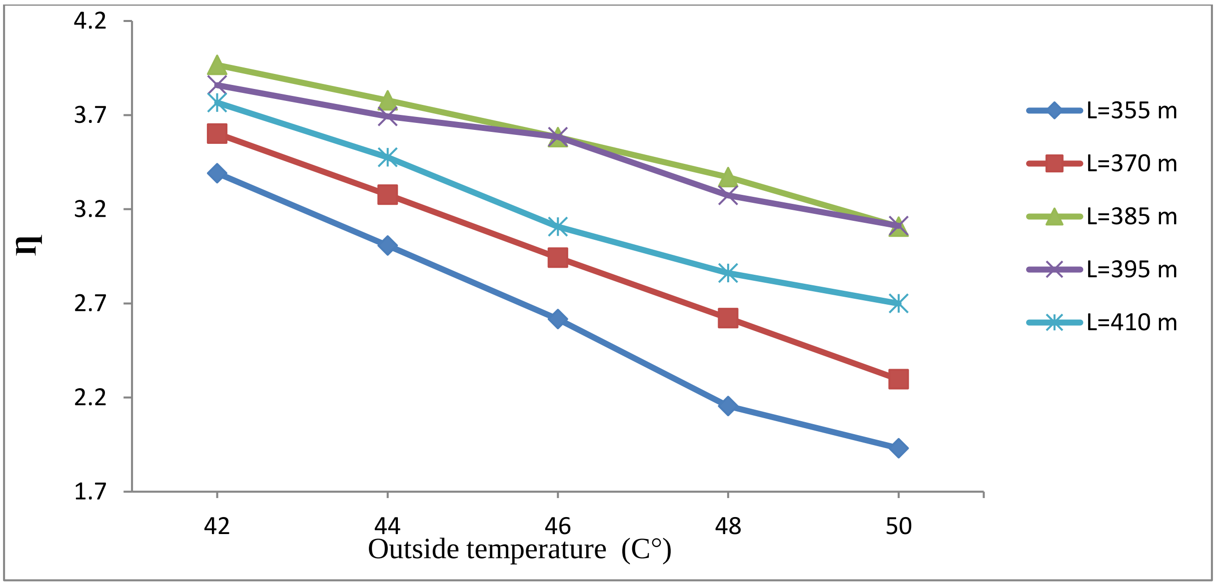


Figure 22. Variant of overall performance factor with outside temperature of air for all studied lengths of pipe of EAHE at mass flow rate (22948.2 m^3/s

Effect of diameter

Fig.23. explains the variation of heat released by heat exchanger with outside temperature of Earth air heat exchanger of air for all studied diameters of pipe of EAHE pipe at length (410 m) and mass flow rate (22948.2 m^3/s). From this figure It can be understood that the heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate due to increase the entering temperature of air to space by increasing outlet temperature. Also, less diameters gives higher heat released by heat exchanger due to temperature difference (ΔT) is high than others diameters as a result of increasing the ratio of area to volume which lead to enhance the heat transfer process.

Fig.24. illustrates the variation of overall performance factor by outside temperature of air for all studied diameters of pipe of EAHE at length (410 m) and mass flow rate (22948.2 m^3/s). It can be obtained that overall performance factor decreased with increasing of outside temperature of air due to increase of pumping power and due to decline in temperature difference (ΔT). So, the overall performance factor is proportionate

inversely with the pressure drop, so from the figure the higher diameter pipe give higher overall performance factor due to the decreasing in pumping power for the same of lengths of pipe, performance factor can be obtain at the lowest diameter of pipe due to have few pumping power that depends on the pressure drop.

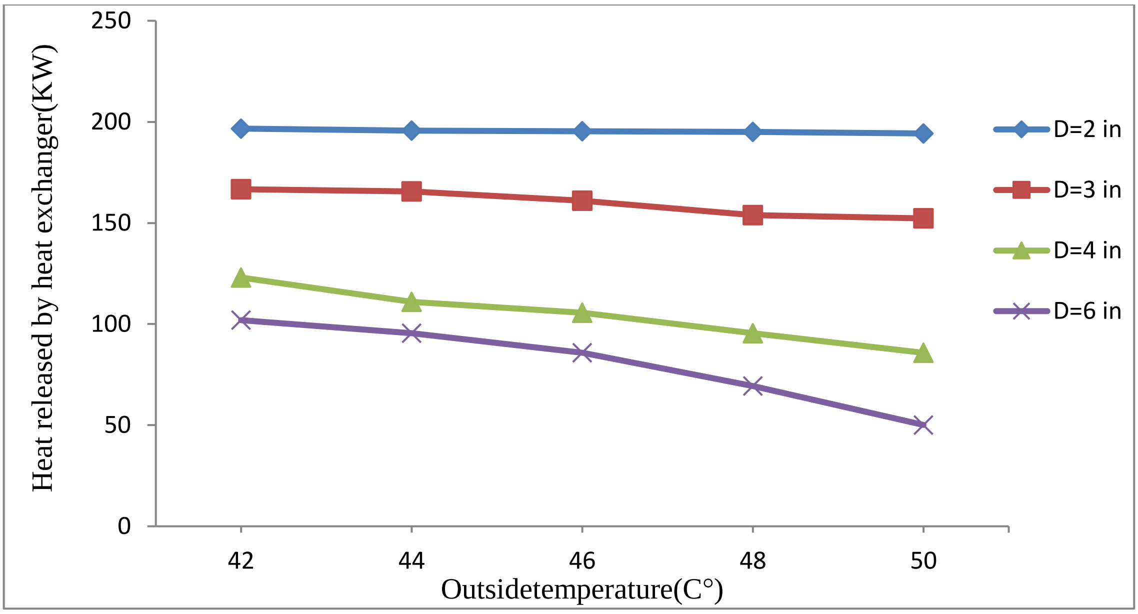


Figure 23. Variation of heat released by heat exchanger with outside temperature for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

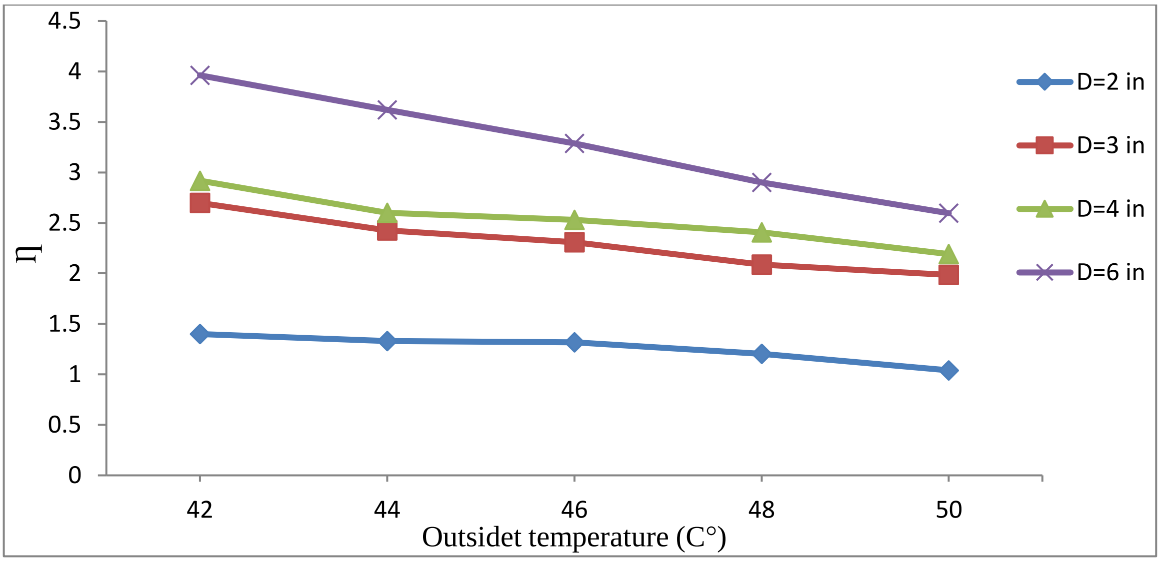


Figure 24. Variation of overall performance factor with outside temperature of air for all studied diameters of pipe of EAHE at mass flow rate (22948.2 m^3/s)

CONCLUSIONS

A numerical model is designed simulated and tested in this study to show the influence of pipe lengths, diameters and designed configurations on the overall of performance of Earth air heat exchanger system for cooling poultry houses. The model is tested under climatic conditions of in Nasiriya city in the south of Iraq using of poultry houses as a case study. From the simulation results of presented framework, the following conclusions can be listed:

1. The heat released by heat exchanger reduced with increasing outside temperature of air for constant mass flow rate and less diameter gives higher heat released by heat exchanger. While, large length gives higher heat released by heat exchanger. The coil design gives higher value of heat released by heat exchanger

2. The pressure drop is increased by increasing the lengths of pipe, and by increasing and remains constant along the length of pipe and less with increasing in the diameters. Whereas, grid design gives less pressure drop compared with others designed configurations.

3. Pumping power is increased with increasing the lengths of pipe, also with increase pressure drop lead to increase pumping power. While ,the pumping power decrease with increasing in the diameters of pipe. The coil design gives higher value of pumping power compared with others designed configurations.

4. The increase in pumping power lead to reduction in overall performance factor.

5.The overall of performance factor of the EAHEs is improved once it is working as the cooling system in less length of pipe and it can be obtained that the grid design gives best overall performance factor compared with others designed configurations.

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