PERFORMANCE ANALYSIS OF EARTH-AIR-HEAT-EXCHANGER (EAHE)

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A B S T R A C T
The present work is carried out on the working of EAHE systems on CFD. The study is carried out analytically in developing a 3d model is developed of a spiral structured EAHE systems. Variation in the inlet temperature, velocity and pipe diameter is done in the proposed model. Results are calculated for temperature difference and velocity of fluid at the outlet and comparison is done among all the cases. Validation of the proposed model is also done as per the reference model taken from literature survey.
Keywords: EAHE, CFD, spiral, 3d model

1. INTRODUCTION

Dependency of air conditioners on CFCs, HCFCs and others has increased the effect of global warming too by depletion in ozone layer. All these factslead to changing the source of cooling and most importantly the energy. Earth air tunnel heat exchanger (EATHE) isone such solution to all of the problems mentioned against air conditioners. EATHE is a pipematrix arrangement led underground, in which ambient air is passed. The temperature of soil being lesser than summer air along with the air in winter. This cooled air in summer or hot air in winter is then directed inthe houses or buildings. To attain thermal comfort condition several other techniques have been discovered. One of the most agreeing methods is earth-air heat exchanger (EAHE) that can come in use much efficiently to heat the air in winter as well as cooling the air in summer.

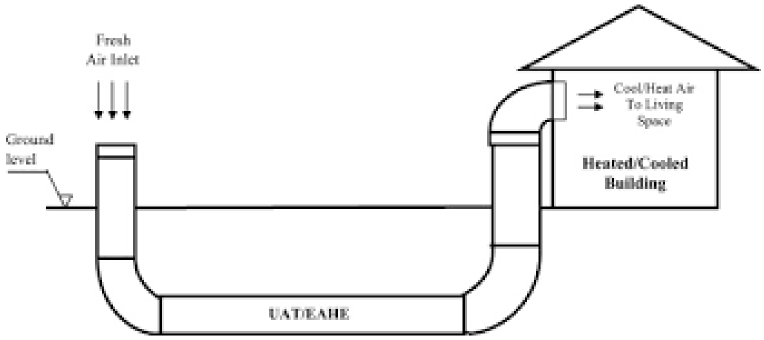


Fig.1 Basic model of earth–air heat exchanger system

Factors affecting the thermal performance of the EAHE systems

The work ability of the earth air pipe (EAP) framework has been mostly influenced by a small number of parameters, for example; pipe materials as well as geometric dimension along with the air velocity as well as EAPHE design in addition with the depth of buried pipe along with temperature of the air as well as temperature of soil along with different type of soil.

1. **Pipe Materials-** Pipe material has been mentioned earlier, as the parameter that has been affecting the work ability of the EAPHE framework. it is as clear as it seems that the selection of the pipe was basically made on the basis of their availability as well as their cost. The materials which have high value of

thermal conductivity are tend to be have high value of heat transfer rate as well. And with the help of that they can reduce the outlet sensation of heat of the concealed pipe with much more powerfully.

2. **Geometric dimension and design of the EAHE pipe system-** For shaping the thermal work ability of the framework, the pipe framework of EAHE plays a major role in designing as well as Geometric dimension.
3. **Air flow-** The thermal work ability of EAHE framework is mostly affected by the air flow and the volume rate of the flow and its parameters.
4. **Site characteristic-** The work conducted on the frame work of EAHE research is concluded from all over the world. Different sites are offering difference in the climate condition which is responsible for affecting the work ability of the EAHE as well as suitable application.

Heat exchangersMost probably in heat exchangers, the transfer of heat occurs by the means of divided partition internally and externally with respect to time. Mostly in heat exchangers, by the surface of heat transfer fluid are divided in partition, and they don't mix up as well as there is no leakage. This kind of exchanger is direct kind of exchanger. Heat exchangers can be further classified into direct contact heat exchangers and the indirect contact heat exchangers.

2. LITERATURE REVIEW

ŁukaszAmanowicz et al. (2018): In this paper the experimentally acquired flow features of multi-pipe earth-to-air heat exchangers (EAHEs) were used to validate the EAHE flow working ability numerical model set by means of CFD software Ansys Fluent.The meshing type resembling cut-cell along with the turbulence model having realizable k-ε equation comprised of coefficient value which is default and helps in advancement in the treatment of wall was utilized. The entire pressure is lost by each and every pipe of multi-pipe exchanger which is examined by both the ways experimentally and numerically.The outcome of each and every pipe of multi-pipe EAHE structure shows that the airflow in each pipe is not equal.For designing of multi-pipe EAHEs properly from the point of view of flow characteristics, the validated numerical model can be used for designing.

SaniAliyu et. al. (2018) For the ventilation under the surface for pre cooling and pre heating through exploring the soil temperature a system has been developed which is known as Earth air heat exchanger (EAHX). The work ability is completely dependent upon the climatic condition and condition of the soil of an earth air heat exchanger. An Earth air heat exchanger (EAHX) has been designed first after that was constructed and later on, it has been installed for the evaluation of its actual working ability has been described in this paper.The outcome of the earth air heat exchanger has recommended that it not adequate on its own for creating the thermal comfort, but it can surely help in the important portion for heating the load.In the cold of Hamadan, when the average was taken for the coefficient of performance (COP) the outcome was 3.2.During the season of winter, the earth air heat exchanger has the ability to increase the cold atmospheric air by 3.40C.

D Darius et. al. (2017) It is very crucial to attain the thermal comfort and ensure it that the thermal work ability of earth air heat exchanger can be study through the parameters whose working has been effected by the materials of the pipe, length and diameter of the pipe , the length of the pipe is buried and soils which are different.From last few decades, to develop the numerical model for analyzing the EAHE framework, many researches has been performed by the researchers.During 1990s, the numerical models has been replaced by the two-dimensional models and recently the analysis system has been more advanced for the three dimensional models and most probably for the simulation of computational Fluid Dynamics (CFD) and its analysis through the help of earth and heat exchanger framework.Many earlier models have been analyzed by the earth and air heat exchanger framework reviewed by this paper and the limits of work which are being affected through the EAHE and its thermal performance as of February 2017.Through earlier search it has been found that the performance of earthy and air heat exchanger has been affected by the parameters which has been already discussed and presented.It is concluded that with the advent of CFD methods, the work of investigation has been increased through simulation and modeling because it helps in saving time and is also does not cost much.

NitishShrestha et al(2016): Thefins provided on the tubes are responsible for heat transfer effectively and results in cooling effect. This improves the thermal performance of finned tubes. The outcome obtained by the experiment is compared by the simulation of work done in experiment.The state of the atmosphere is achieved by the state of the experiments which are simulated in ANSYS. Soil diffusivity of $\mathbf{0.84}-\mathbf{2.36}\times\mathbf{10}^{-\mathbf{6}}\boldsymbol{m}^{\mathbf{2}}/\boldsymbol{s}$ at depth of 5ft with 17 fins.It has been perceived that if the length of the pipe is increased by its length that it will help in decreasing the temperature in the cooling mode of the inlet air. The reduction of the temperatureoccurs at the length of 1.2m which keeps differing from 1-3 °C at velocity 6.5m/sec.

Mayank Bhardwaj et al (2016) To achieve a linear EATHE frame work , the four configuration, design and the operating parameters that are the pipe length, inlet air velocity and inlet air temperature have been considered at four different levels in Taguchi method. This method is used to achieve air temperature at maximum drop and heat transfer rate.

JyotirmayMathuret. al. (2015) On the work ability of the earth air tunnel heat exchanger the effect of thermo-physical feature of the soil has been presented through this paper. An evaluation has been done through the usage of 3-dimension, transient numerical model for the three soils which are different from each other.The governing equations, depending on the model ofk–ε as well as equation of energy were utilized to determine the transfer of heat as well as process of turbulence and were calibrated by the means of finite volume method.After completing the operation which was of 12 hours and operating it continuously many more comparison has been done in terms of temperature drop, heat transfer rate and COP of the EATHE system.It has been known from the studies that after the period is over of being continuously operated the each and every soil exhibits different rate of heat dissipation and thermal saturation which is affected by the work ability of EATHE.

3. AIMS & OBJECTIVES

These are the following aims and objectives in the present work:

1. Validation of the model and results are done as per the base paper
2. All the simulations and modeling of the EAHE system is performed analytically using CATIA V5 and ANSYS software tools
3. Variation in the inlet temperature, velocity and pipe diameter is done in the proposed model by the following design of experiments:
4. Results are calculated for temperature difference and velocity of fluid at the outlet and comparison is done among all the cases.

Parameter			
Velocity (m/sec)	6	8	10
Pipe Diameter (m)	0.1	0.2	0.3
Inlet Temperature (degree Celsius)	42.6	43.6	44.6

4. METHODOLOGY

4.1. SOFTWARE USED FOR THE STUDY IN THIS RESEARCH ARE

CATIA V5

The present study deals with the analytical study using CAD software called CATIA V5 which provides the best platform to create the model of the system. It also acquires some other features for mechanical as well as other fields of engineering. It provides the better platform for manufacturing with feature CAM Engineering with CAE and also provides the better interface to analyze the product in 2D as well as in 3D architecture.

ANSYS

ANSYS is used to solve an analytical simulation calculation. Ansys programming is utilized to design items and semiconductors, and in addition to make simulation to test a product's durability, temperature appropriation, fluid motions, and electromagnetic properties. Ansys influences various acquisitions for other building to configuration organizations, securing extra innovation for fluid dynamics, electronic design, and different material science examination.

4.2. Model Creation-

The 3D model shown in the figure below is made in CATIA V5.

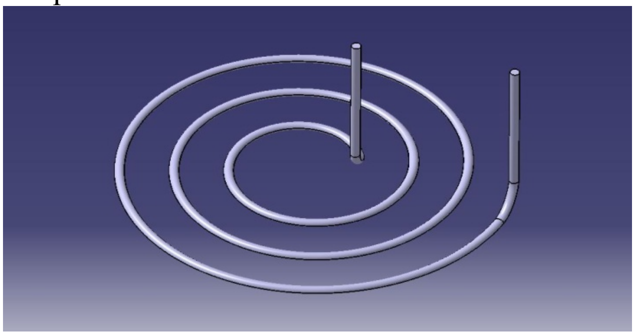


Figure 2: 3D model of spiral EATHE

4.3. STEPS OF ANSYS ANALYSIS

The various analysis steps are used to solving the problem in ANSYS are as follow.

Pre-process

The preprocessor is the first step to solve any calculation. In this step the geometry is created in giving design parameters. The CATIA is used in present study and after designing the model it is imported in ANSYS workbench and then the boundary conditions and loading conditions are applied.

4.4. Meshing

This is the progression before applying the boundary conditions in which the mesh is generated with the whole body in such a way that the complete body gets separated into nodes and element for accuracy of the outcome. It is practically observed that the fine mesh take much time due to large number of nodes and elements as compared to the coarse mesh.

The number of nodes are 587643 and number of elements are 2481086

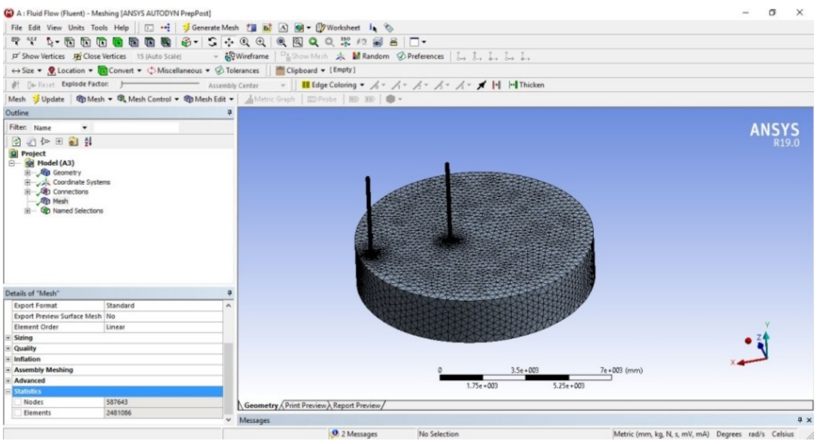


Figure 3: Mesh model of spiral EATHE

4.5. Applying name selection

Name selections are given to the CAD model in ANSYS mainly as;

- A – Inlet
- B – Outlet
- C – Pipe
- D – Soil

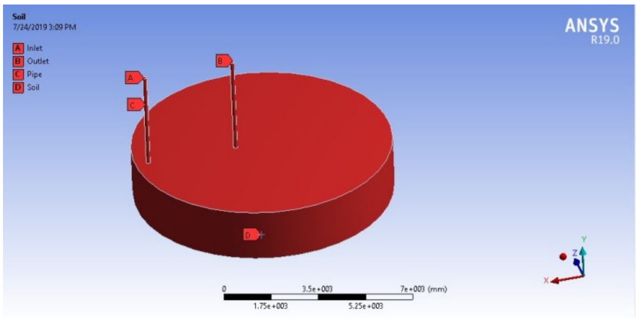


Figure 4: Name selection of spiral EATHE

After providing the name selection, the model is further analyzed by carrying out number of iterations to obtain the results.

4.6. Material used

The material used for heat exchanger pipes is HDPE. Properties of HDPE material is shown below, also with the property of soil at the site are discussed.

Table 1: Properties of HDPE material

Thermal conductivity (W/m K)	0.52
Specific heat (J/kg K)	568.75
Density (kg/m^3)	1600
Thermal diffusivity (mm^2/s)	0.57

Table 2: Properties of Soil

Thermal conductivity (W/m K)	0.476
Specific heat (J/kg K)	2093
Density (kg/m^3)	958

4.7. DESIGN OF EXPERIMENTS

The design of experiments involves three parameters each of pipe diameter, inlet velocity of fluid and temperature. Depending upon these three parameter as input, the remaining analysis calculations are done

.

Table 3: Design of experiments (DOE)

Parameter			
Velocity (m/sec)	6	8	10
Pipe Diameter (m)	0.1	0.15	0.2
Inlet Temperature (°C)	42.6	43.6	44.6

Depending on the DOE above the following cases for results are made.

Table 4: Different cases with varying parameters

Fluid Velocity (m/sec)	**Pipe Diameter (m)**	**Inlet Temperature (°C)**
6	0.1	42.6
6	0.15	43.6
6	0.2	44.6
8	0.1	43.6
8	0.15	44.6

8	0.2	42.6
10	0.1	44.6
10	0.15	42.6
10	0.2	43.6

5. RESULTS AND DISCUSSIONS

The results are calculated and validated as per the reference base paper.The present study consistsof design and analysis of an earth air tunnel heat exchanger having spiral structure.

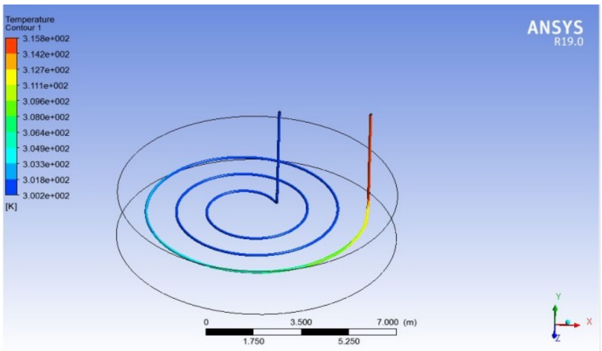
The 3D model is initially created in CATIA V5 with the required dimensions and further, it is converted in to .STP format. This makes the file compatible with ANSYS platform.

Cooling and heating thermal potential of straight and spiralEATHE system have been investigated by running the system atconstant 6 m/s air velocity. Experiments were performed from 01April to 30 June 2014 and 15 December to 17 February 2015 for 08 hduration from 9 a.m. to 5 p.m., covering the entire summer andwinter season respectively. The system was kept closed between 5p.m. and 9 a.m. allowing the soil to get regenerated.

Spiral EATHE system was also operated simultaneously alongwith straight EATHE system. The inlet, outlet airtemperature and system COP with operational days in summeroperational mode for spiral EATHE system.

Case 1

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
6	0.1	42.6



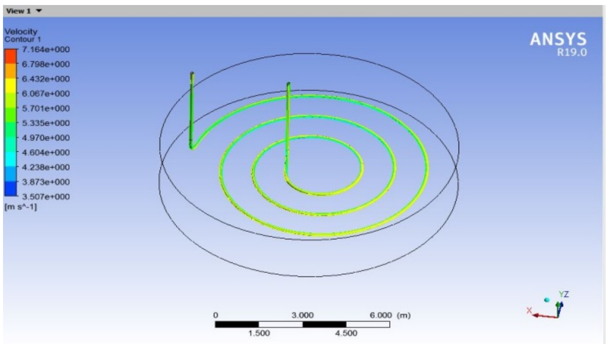
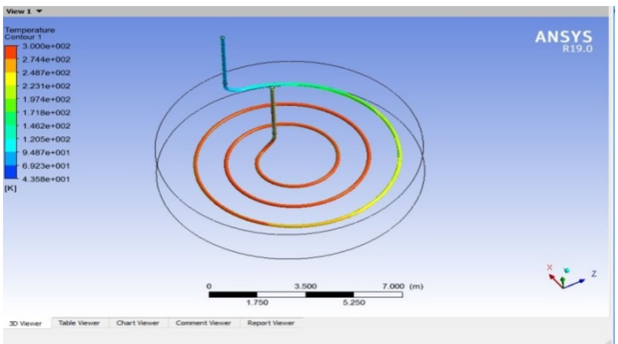


Figure 5: Temperature difference plot (case 1)

Figure 6: Velocity contour plot (case 1)

Case 2

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
6	0.15	43.6



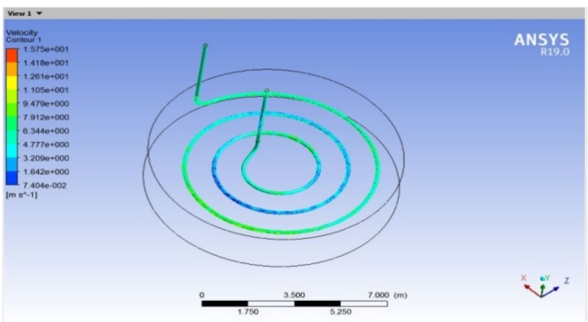


Figure 7: Temperature difference plot (case 2)

Figure 8: Velocity contour plot (case 2)

Case 3

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
6	0.2	44.6

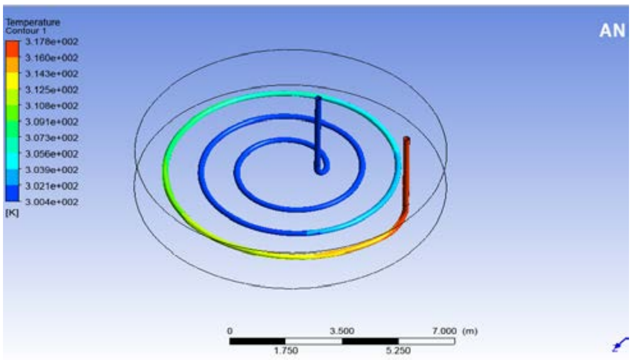


Figure 9: Temperature difference plot (case 3)

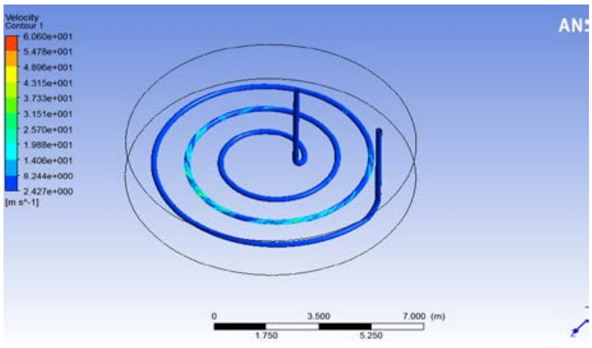


Figure10: Velocity contour plot (case 3)

Case 4

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
8	0.1	43.6

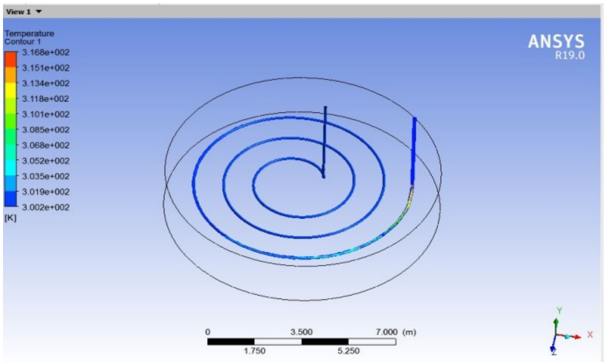


Figure 11: Temperature difference plot (case 4)

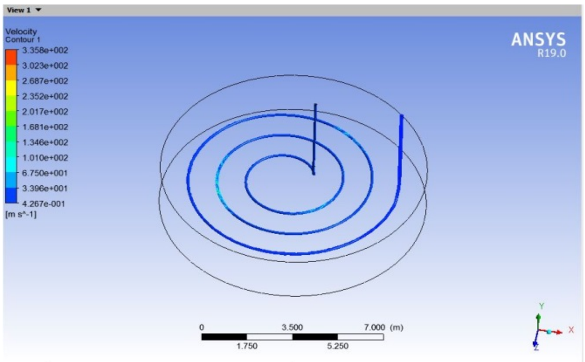


Figure 12: Velocity contour plot (case 4)

Case 5

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
8	0.15	44.6

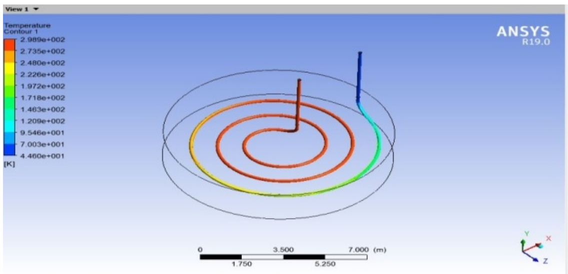


Figure 13: Temperature difference plot (case 5)

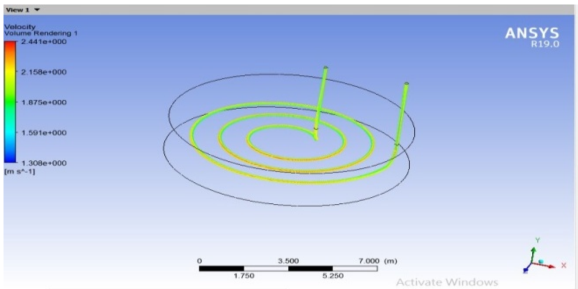
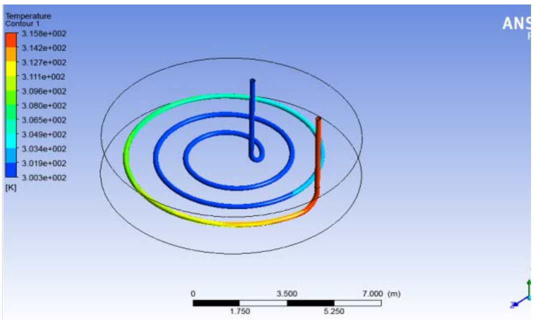


Figure 14: Velocity contour plot (case 5)

Case 6

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (°C)
8	0.2	42.6



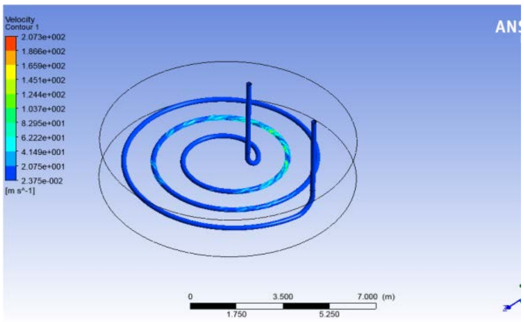
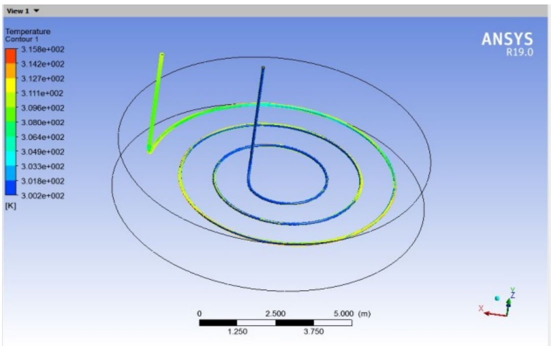


Figure 15: Temperature difference plot (case 6) **Figure 16: Velocity contour plot (case 6)**

Case 7

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (°C)
10	0.1	44.6



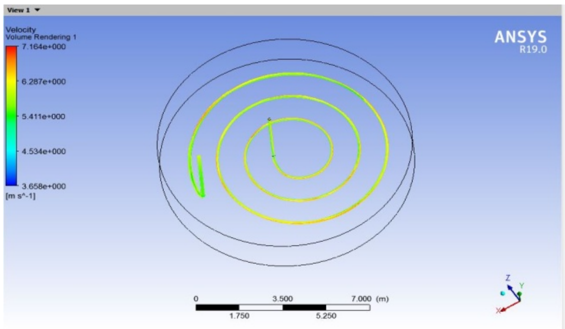
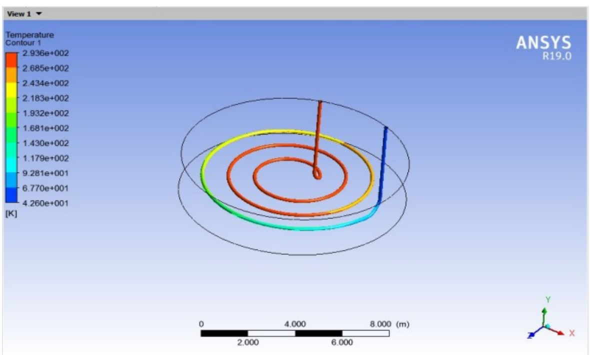


Figure 17: Temperature difference plot (case 7) **Figure 18: Velocity contour plot (case 7)**

Case 8

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (°C)
10	0.15	42.6



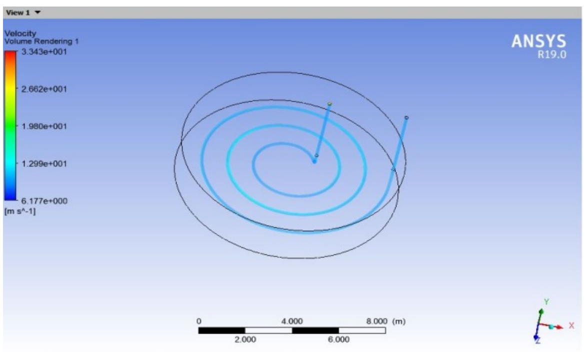
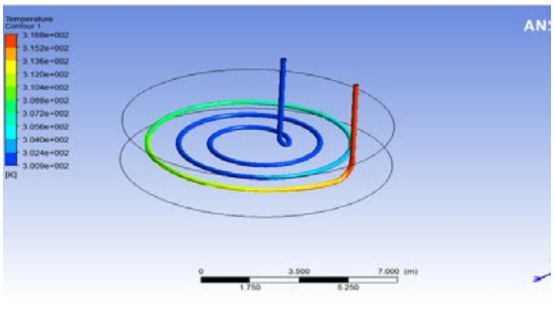


Figure 19: Temperature difference plot (case 8) **Figure 20: Velocity contour plot (case 8)**

Case 9

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
10	0.2	43.6



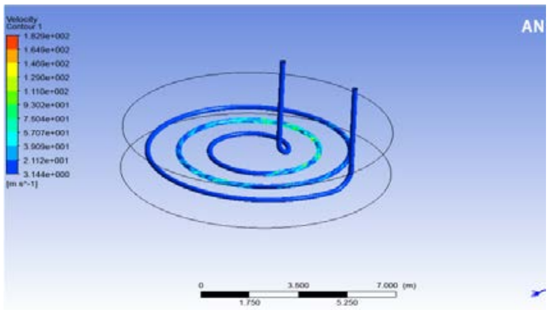


Figure 21: Temperature difference plot (case 9) Figure 22: Velocity contour plot (case 9)

6. CONCLUSIONS

Analysis of spiral tube earth air tunnel heat exchanger system is successfully evaluated and simulated analytically. The results are obtained for nine different cases of varying parameters such as inlet fluid velocity, inlet temperature and pipe diameter.

The following are the conclusions are drawn:
1. the configuration of pipe which has largest diameter
2. highest value of inlet temperature
3. lowest value for velocity shows the best performance for heat transfer in the heat exchanger.

Hence case number 3 is the best result obtained having values as follows:

Fluid Velocity (m/sec)	Pipe Diameter (m)	Inlet Temperature (^oC)
6	0.2	44.6

In case 3 the value for result contours obtained for temperature is 3.17 x 102 K. and maximum value for velocity contours obtained is 6.06 m/sec.

REFERENCES

1.Adeniyi, A. A., Mohammed, A. and Aladeniyi, K. (2012) 'Analysis of a Solar Dryer Box with Ray Tracing CFD Technique', 3(10), pp. 1–5.

2. Aktaş, M. et al. (2016) 'Analysis of drying of melon in a solar-heat recovery assisted infrared dryer', Solar Energy, 137, pp. 500–515. doi: 10.1016/j.solener.2016.08.036.

3. Aliyu, S., Musa, M. and Abdullahi, Y. (2018) 'Design , Construction And Performance Evaluation of Earth-To Air Heat Exchanger For Room Heating Applications', 15(1), pp. 22–26. doi: 10.9790/1684-1501012226.

4. Amanowicz, Ł. and Wojtkowiak, J. (2017) 'Experimental investigation and CFD simulation of multi-pipe earth-to-air heat exchangers (EAHEs) flow performance', 00002. doi: 10.1051/e3sconf/20172200002.

5. 'Applying CFD for designing a new fruit cabinet dryer' (2010).

6. Aseri, T. K. (2013) 'Thermal performance investigation of hybrid earth air tunnel heat exchanger', Energy & Buildings. Elsevier B.V., 49(July 2017), pp. 531–535. doi: 10.1016/j.enbuild.2012.02.049.

7. Asgharian, H. and Baniasadi, E. (2019) 'A review on modeling and simulation of solar energy storage systems based on phase change materials', Journal of Energy Storage. Elsevier, 21(July 2018), pp. 186–201. doi: 10.1016/j.est.2018.11.025.

8. Bansal, V. and Mathur, J. (2009) 'Performance enhancement of earth air tunnel heat exchanger using evaporative cooling', (August). doi: 10.1093/ijlct/ctp017.

9. Bhardwaj, A. K. et al. (2017) 'Experimental investigation of an indirect solar dryer integrated with phase change material for drying valeriana jatamansi (medicinal herb)', Case Studies in Thermal Engineering. Elsevier Ltd, 10, pp. 302–314. doi: 10.1016/j.csite.2017.07.009.

10.Bisoniya, T. S. (2015) 'Design of earth – air heat exchanger system', Geothermal Energy. Geothermal Energy. doi: 10.1186/s40517-015-0036-2.