Earth Tube Heat Exchanger Heating & Cooling Buildings

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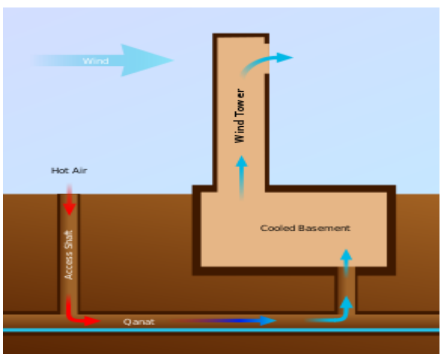
The heating and cooling of buildings requires huge power and intern increases the price of electricity day by day also it has to meet the comfort requirements of individuals. So there is a need to reduces them by utilizing the natural resources i.e, 1.5m to 3.0m temperature underneath the earth crusts, which would be a better choice to utilize. An earth tube heat exchanger may be the solution for heating and cooling all alloy the year reducing the GWP. Earth tube heat exchanger is a device used to produce heating effects in winter and cooling effects in summer using the ground or soil as a source or sink. The atmosphere air is drawn into the pipes through the blower and heat exchange takes place between pipes and soil and it gives the cooling or heating output depending on climate. In this thesis modeling and 3-dimensional flow simulation of a earth tube heat exchanger is carried out using CATIA software and simulation done in ANSYS software to understand the inside flow characteristics and to determine prominent factors such as Pressure drop, mass flow rate by using CFD analysis at different velocities (i.e. 20m/s, 30m/s). Temperature and heat flux is calculated in thermal analysis. Aluminum alloy and copper alloy materials used for earth tube heat exchanger at different temperatures (i.e. 350c, 380c, 400c).
Keywords: GWP, CFD, CATIA, heat exchanger, Earth tube, different temperatures.

1. Introduction

At a given depth from Earth's surface, it's known that the ground is chilly in summer, but hotter in winter than the surrounding air. Using ground temperature gradients for both cooling and heating purposes [1] may be an option for future study. In light of the limited energy resources available, it is basic to distinguish elective energy sources in order to preserve conventional fuels for the future and save space. It is thought that ground- to-air heat exchangers are a reasonable choice to warming or cooling structures. Metal, plastic, or substantial lines are covered at a specific profundity in the earth to serve as conduits. Fans are used to circulate fresh air through the pipes. Inside the pipe, heat may be moved from the beginning the air contingent upon the temperature differential. To get the most performance out of the system, it has to be well-designed. Therefore, the crosssectional size and kind of pipe, wind speed, and soil condition all have a significant effect in the system's efficiency. In order to reduce pollution and conventional energy usage, use environmentally friendly, renewable sources of power. It is found It is found that the soil at some depth from earth surface has a property to remain cold during summer and relatively hotter during winter days from the atmospheric temperature. Due to limited sources of energy, it is very essential to find out the another alternative sources of energy to save the conventional fuels available in nature to save energy of universe. The energy consumption of buildings for heating and cooling purpose has significantly increased during the decades. Energy saving is the major concern everywhere, particularly challenge in desert climates. The comfort conditions for human being are temperature between 200 to 260 and relative humidity in between 40% to 60% . This can be achieved by conditioning air[4]. The system used in now a days, air is passed through a buried pipe by fan. In summer the supply air to the building is cooled due to the fact that the ground temperature around the heat exchanger is lower than the ambient temperature. During winter, when the ambient temperature is lower than the ground temperature the process is reversed and the air gets preheated. The earth air heat exchangers are considered as an effective replacement for heating or cooling of buildings. This is basically metallic, plastic or concrete pipes buried underground at a particular depth. Through pipes the fresh atmospheric air pass with the help of blower. According to the temperature difference the heat transfer takes place between soil and air in pipes. The efficient design of the system is necessary to ensure good performance. In that accordance the cross section area and type of cross section of pipe, velocity of air and nature of soil plays key role in efficiency of system. This uses green and clean energy in order to minimize pollution and to minimize conventional energy consumption.There are two major types of Earth Air Heat Exchangers system exist.



2. Survey of Research

Rohit Misra, Vikas Bansal,Ghanshyam Das Agrawal et al. [2013] has expressed that with increase in length of pipe, the outlet air temperature from EAHE decreases. The decrease in air temperature was sharp for the first 10 meters length of pipe and it became moderate afterwards. So, increasing the length of pipe more than 20- 30m did not cause any significant rise in performance and improvements began to stabilize, indicated these values could be optimal design values for hot and dry climatic conditions of Bhopal. It was observed that with increase in pipe diameter, the outlet air temperature of EAHE increases because the convective heat transfer coefficient at inner surface of pipe as well as overall heat transfer coefficient at earth- pipe interface decreases at higher pipe diameters. With increase in depth of pipe burial, outlet air temperature of EAHE system decreases. So, pipes of EAHE system should be installed as deeply as possible but it increases excavation cost. So, it is advised to keep depth of pipe burial about 2m in order to limit the initial/installation cost of EAHE system. The outlet air temperature of EAHE system increases with increase in air flow velocity. This is because of the fact that as the air flow velocity is increased, the time to which air remains in contact with ground is reduced. The performance of EAHE cannot be increased only by decreasing the air flow velocity because the cooling capacity of EAHE system depends both on air flow velocity and temperature difference. So, both air flow velocity and temperature difference should be considered at the same time.[5]

Capozza A, De Carli M st al. [2012]has expressed that the heat transfer to and from Earth tube heat exchanger system has been the subject of many theoretical and experimental investigations. By having a review on previous research papers published by many authors we can have an idea on how it works. A one-dimensional numerical model to check the performance of EAHE installed at different depths. It was concluded that EAHE systems alone are not sufficient to create thermal comfort, but can be used to reduce the energy demand in buildings in South Algeria, if used in combination with conventional air conditioning system. a simplified analytical model to study year around effectiveness of an EAHE coupled greenhouse located in New Delhi, India. They found the temperature of greenhouse air on average 6- 7 °C more in winter and 3-4 °C less in summer than the same greenhouse when operating without EAHE. A developed thermal model for heating of greenhouse by using different combinations of inner thermal curtain, an earth air heat exchanger, and geothermal heating. the performance analysis of EAHE for summer cooling in Jaipur, India. They discussed 23.42 m long EAHE at cooling mode in the range of 8.0-12.7 °C and 2-5 m/s flow rate for steel and PVC pipes. They showed performance of system is not significantly affected by the material of buried pipe instead it is greatly affected by the velocity of air fluid. They observed COP variation 1.9- 2.9 for increasing the velocity 2-5 m/s.[6]

N.K. Bansal, M.S.Sodha, S.P.et.al.[2012] has expressed that EATHE can be used as substitute for the conventional air conditioning systems EATHE-evaporating cooling hybrid systems can be used in summer for better results. More the thermal conductivity of soil better is the thermal performance of EAHE With increasing pipe length, decreasing pipe diameter, decreasing mass flow rate of flowing air inside buried pipe and increasing depth of ground up to 4 m performance of EAHE becomes better[7] According to Kim S K, Bae G O, Lee K et.al[2010] if the length of the pipe is so small and the blower is high voltage then the system is useless because the temperature difference between inlet and out let is very Less The material of pipe is not affected in the output result. If cooling or heating rate is more achieve, then the length of pipe kept at least 100 m and blower some around 400 W [8]

Bisoniya TS, Kumar A, Baredar P et.al [2014] has expressed that the earth–air heat exchanger is a promising technique which can effectively be used to preheat the air in winter and vice versa in summer. Many researchers have developed EAHE design equations and procedures. For a complete analysis of the EAHE system, For the initial design of an EAHE system, the use of basic heat transfer equations is more suitable to determine the geometrical dimensions of the system. In this paper, the author has developed a onedimensional model of the EAHE system. The method to calculate the EUT and more recently developed correlations for friction factor and Nusselt number are used to ensure higher accuracy in the calculation of heat transfer. The value of EUT for Bhopal (Central India) was calculated as 25.2 °C. It was observed that Nusselt number increases with increase in Reynolds number. The design of earth–air heat exchanger mainly depends on the heating/cooling load requirement of a building to be conditioned. After calculation of heating/cooling load, the design of the earth–air heat exchanger only depends on the geometrical constraints and cost analysis. The diameter of pipe, pipe length, and number of pipes are the main parameters to be determined. With an increase in length of pipe, both pressure drop and thermal performance increase. A longer pipe of smaller diameter buried at a greater depth and having lower air flow velocity results in an increase in performance of the EAHE system.[9]

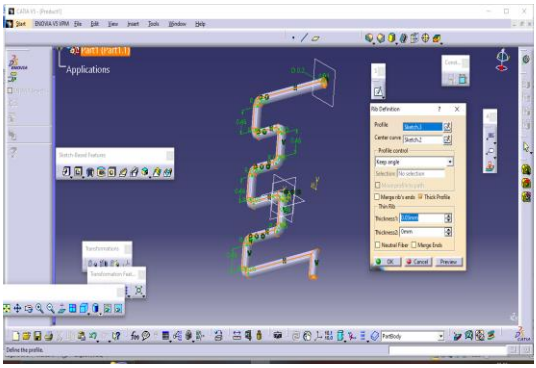
Thankur, A., Sharma et.al [2015] has expressed that the finned mild steel pipe of 1.2m and diameter 0.0889m inside the earth produced a temperature fall till 3°C for various daily temperatures. For higher inlet temperature and the outlet temperature difference recorded is mostly from 2- 3°C. The COP of the heat exchanger ranges from 0.928 – 2.785 for temperature difference of 1°C - 3°C respectively. Higher COP can be obtained when temperature difference is greater and this can be achieved by using longer pipe for more heat transfer. With a pipe of 1.2m the decrease in temperature is recorded mostly by 1-3°C.

3. Proposed Methodology

The systems are long metallic, plastic or concrete pipes that are laid underground and are connected to the air intake of buildings, particularly houses. From inlet the atmosphere air is forced by using blower in the pipe during the movement heat gets transferred from hot soil to cold air in winter and cold soil to hot air in summer and it changes the air temperature accordingly. The pipe outlet is given where the space needs to be air conditioned in industrial or livestock buildings etc. By taking benefits of this costless energy we can reduce our energy consumption for air conditioning of space hence a very useful technique it is.

- The main problem we faced in existing model is space, purification of air.
- In this project copper material is used because it has higher thermal conductivity

  (385 w/mK) and more durability.
- Make the copper pipe into coil shape. Due to this we can reduce the space required for implementing the project.



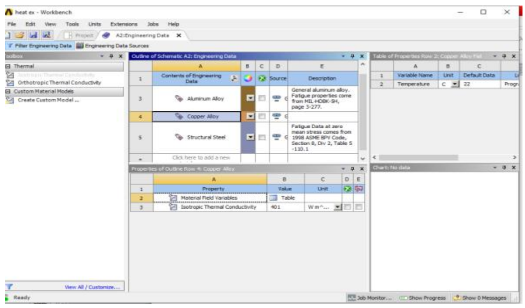
ANSYS DESIGN

The ANSYS software package is a versatile tool for conducting finite element analysis (FEA) with a wide range of applications. The Finite Element Analysis technique involves the utilization of numerical methods to break down intricate systems into minute components, referred to as elements, which are of a size specified by the user. The software utilizes mathematical equations that dictate the behavior of the individual elements and subsequently solves them, resulting in a comprehensive elucidation of the system's collective behavior. Subsequently, the outcomes can be exhibited in either tabular or graphical formats. This particular method of analysis is commonly employed in the process of designing and optimizing a system that is excessively intricate to be evaluated manually. Systems that could potentially fall under this classification exhibit a high degree of complexity as a result of their intricate geometry, scale, or governing equations. At numerous academic institutions, ANSYS serves as the conventional Finite Element Analysis (FEA) instructional resource in the Mechanical Engineering Department.

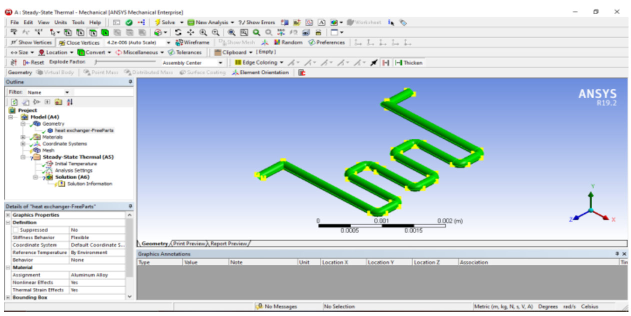
THERMAL ANALYSIS OF EARTH TUBE HEAT EXCHANGER MATERIALS -ALUMINUM ALLOY AND COPPER ALLOY

Researchers tested the impact and found that increasing the air velocity from 2.0 to 5.0 decreased the temperature of the air exiting the tube. Air contact with the ground is diminished 2.5 times, while the convective intensity move coefficient ascends by 2.3 times. To put it another way, the higher the wind speed, the smaller the temperature increases are since the latter impact is more dominating. At high speeds, the reduced contact time results in poor performance.

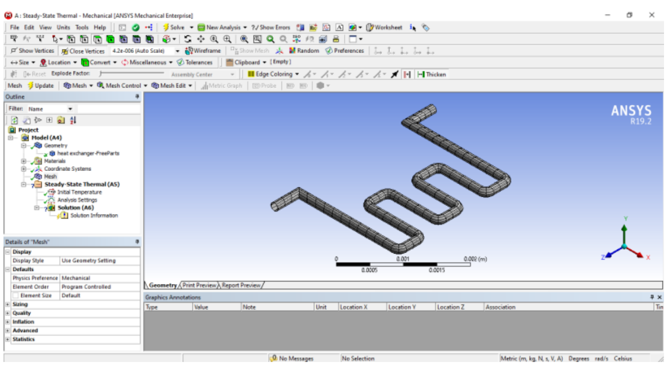
Material selection



Import geometry



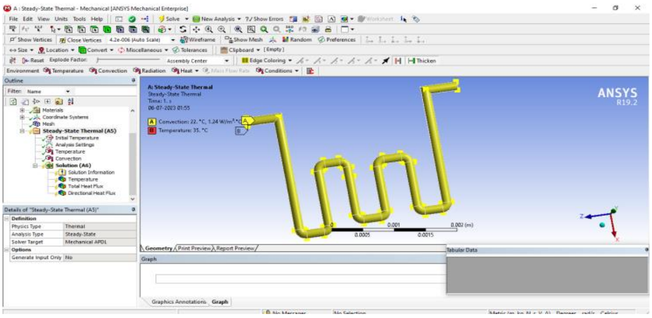
Meshing



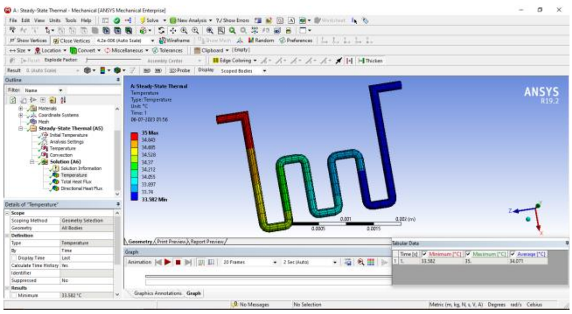
Boundary conditions

Temperature 35^0c

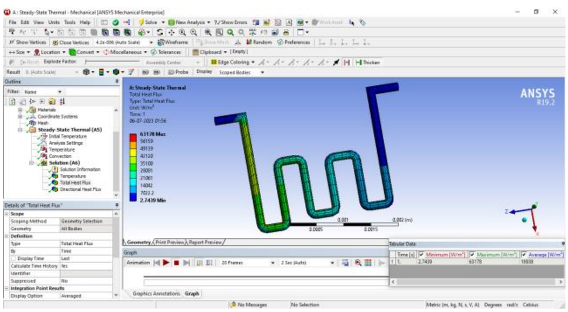
Material aluminum alloy



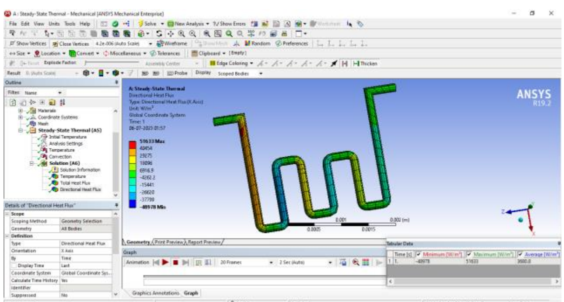
Temperature distribution



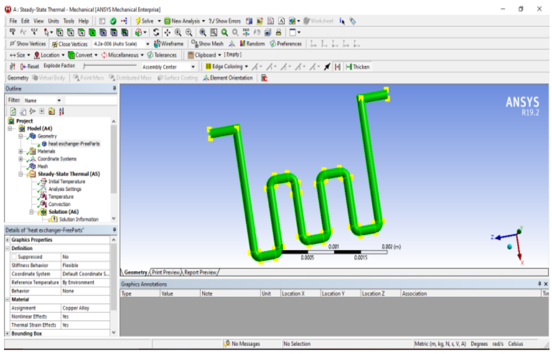
Heat flux



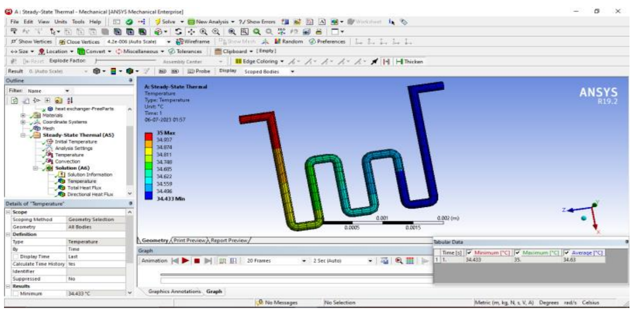
Directional heat flux



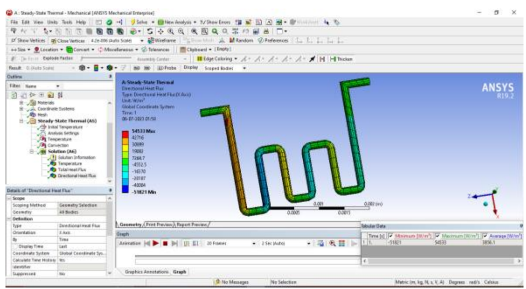
Copper alloy



Temperature distribution

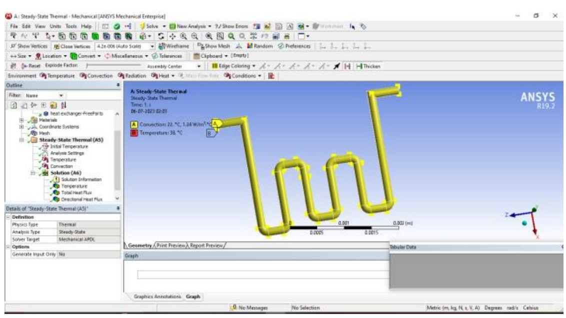


Directional heat flux

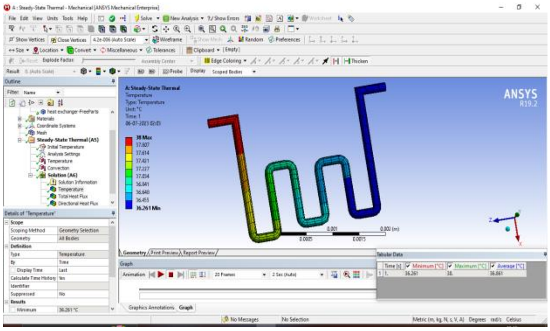


At 38^0c

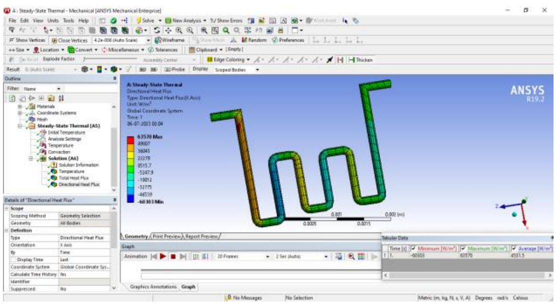
Aluminum alloy



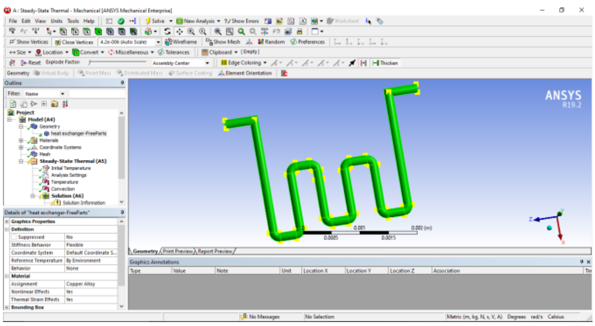
Temperature distribution



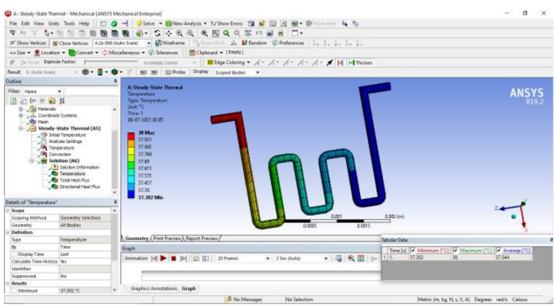
Directional heat flux



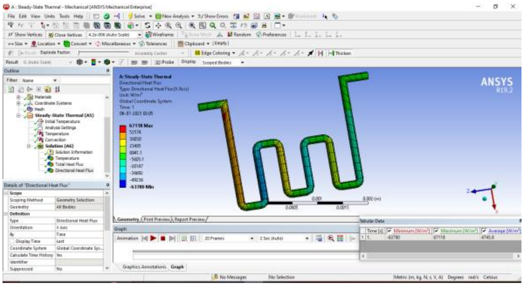
Copper alloy



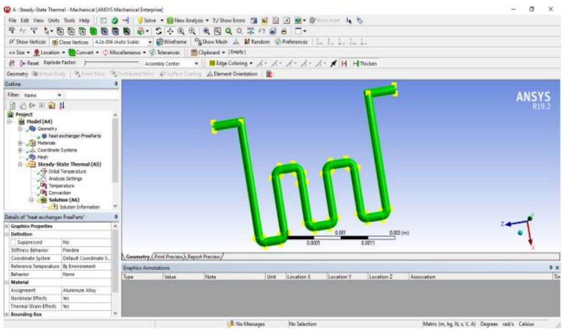
Temperature distribution

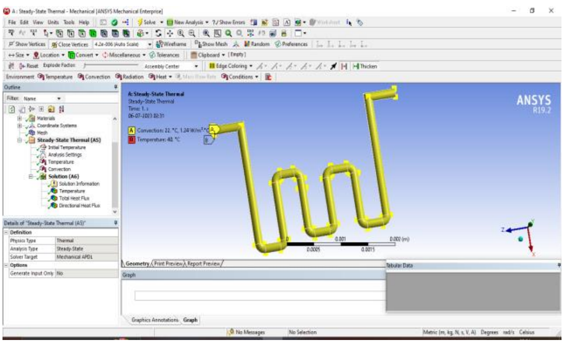


Directional heat flux

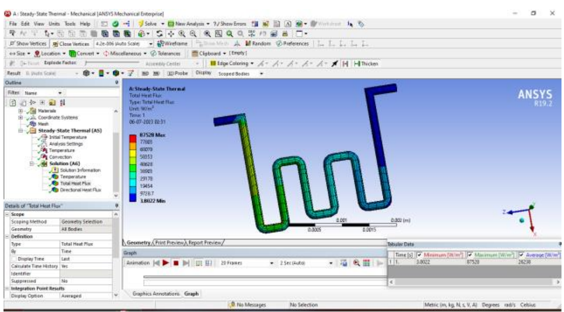


At 40^0c aluminum alloy

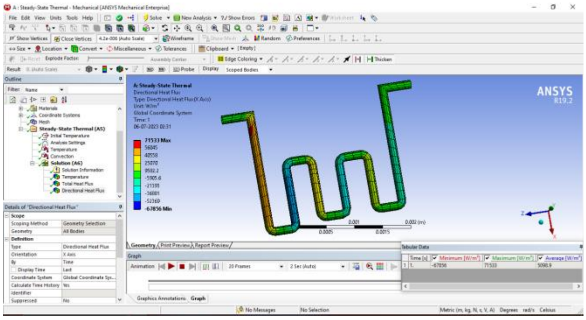




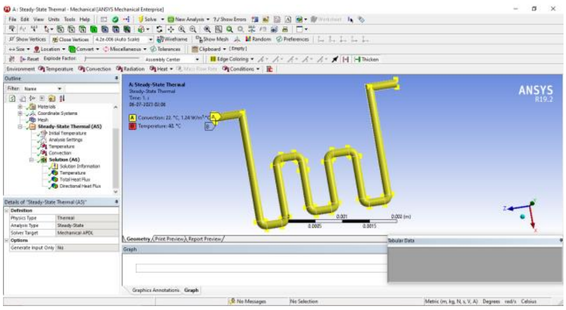
Temperature distribution



Directional heat flux



Copper



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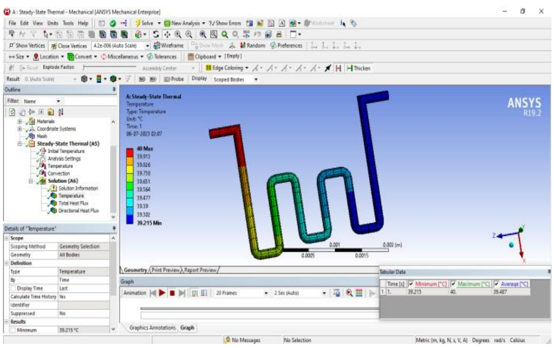
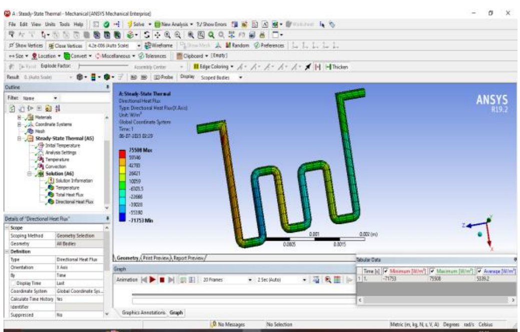


Directional heat flux

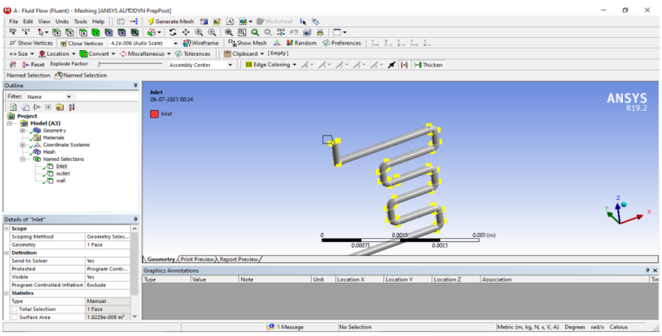


CFD ANALYSIS OF EARTH TUBE HEAT EXCHANGER

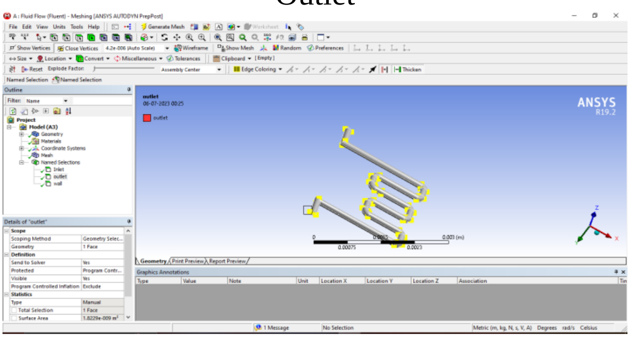
Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

At velocity 20m/s and 30m/s

Inlet

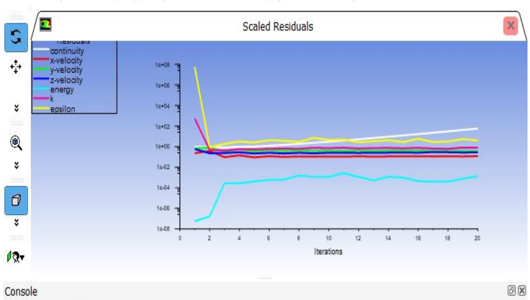


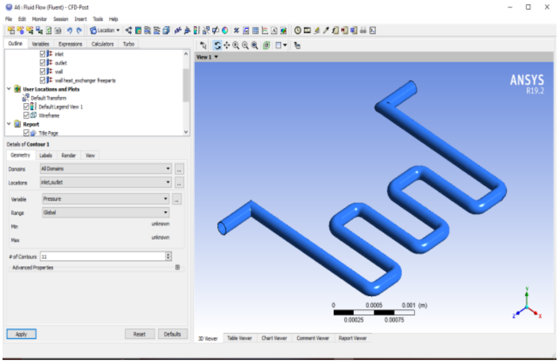
Outlet



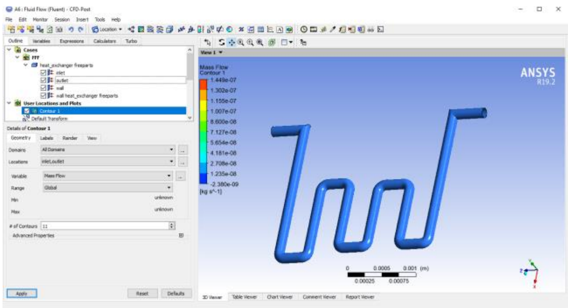
Boundary conditions

Inlet velocity 20m/s

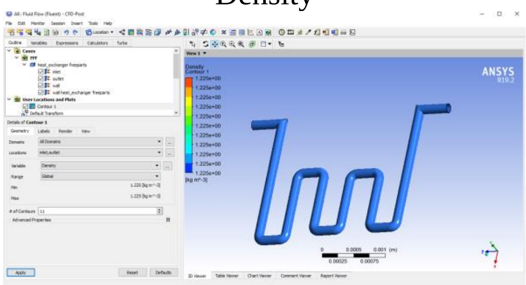




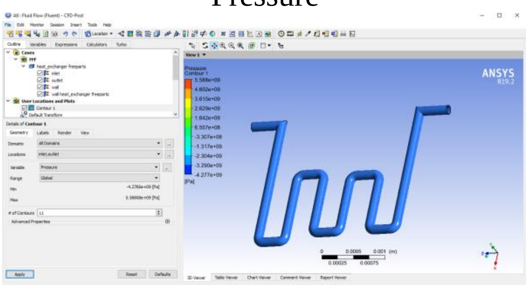
Mass flow rate



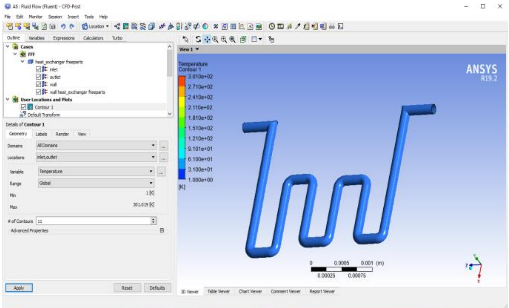
Density



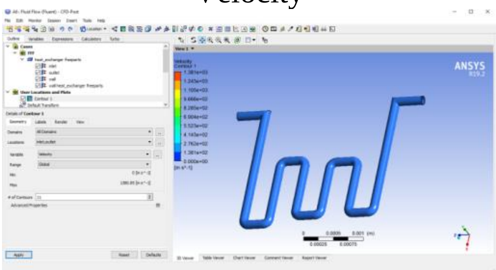
Pressure



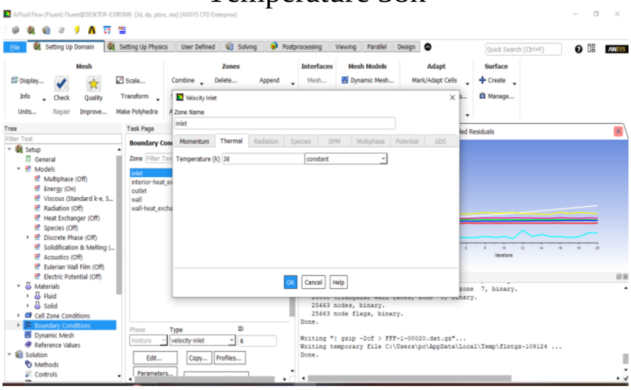
Temperature



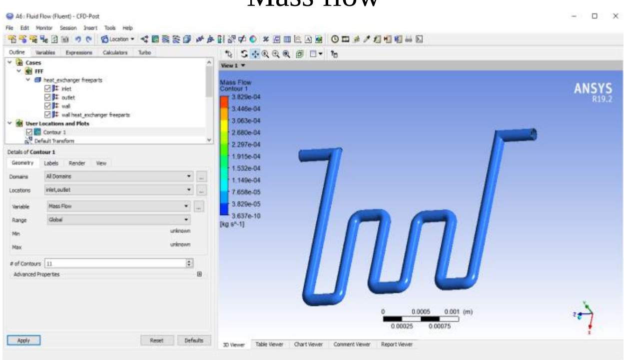
Velocity



Temperature 38k



Mass flow



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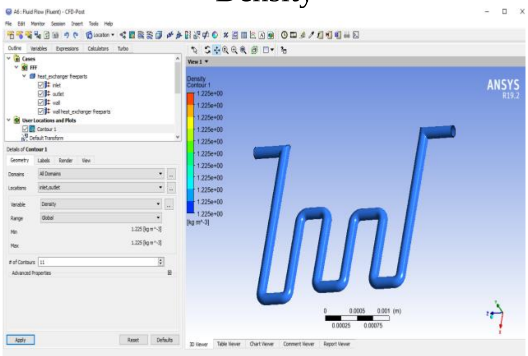

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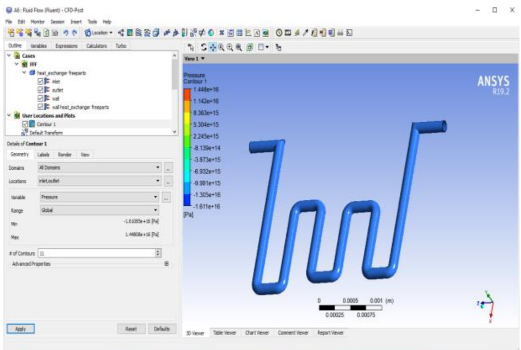
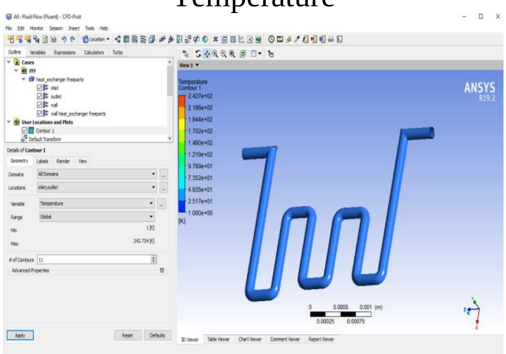
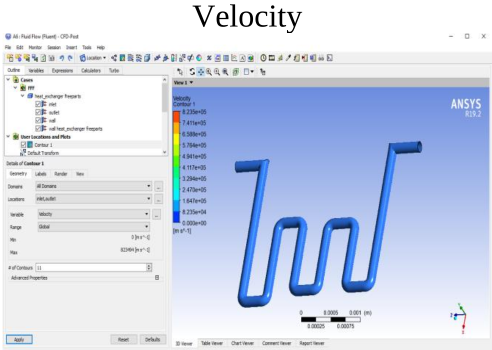


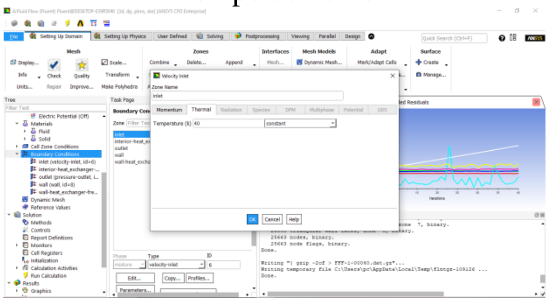
Temperature



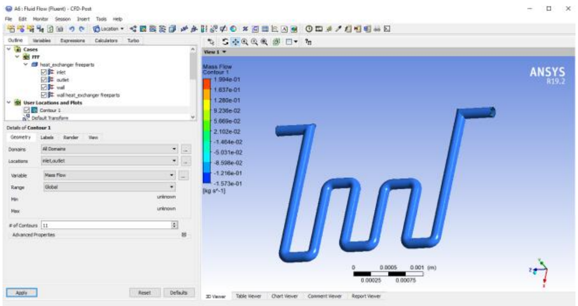
Velocity



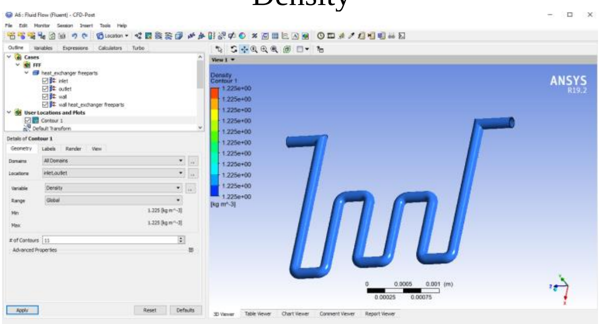
Temperature 40



Mass flow



Density



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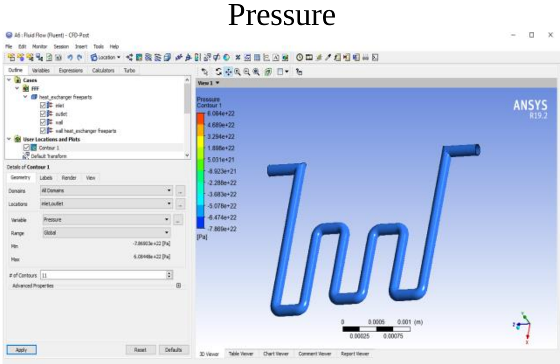

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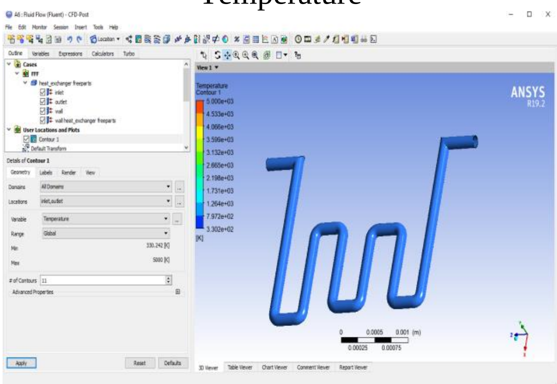
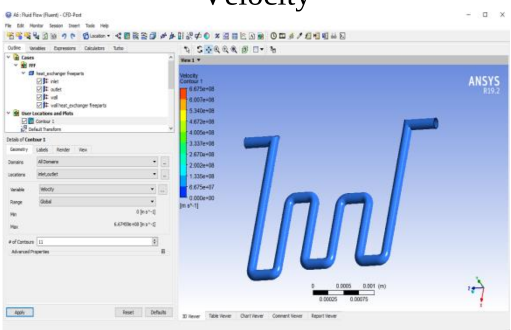
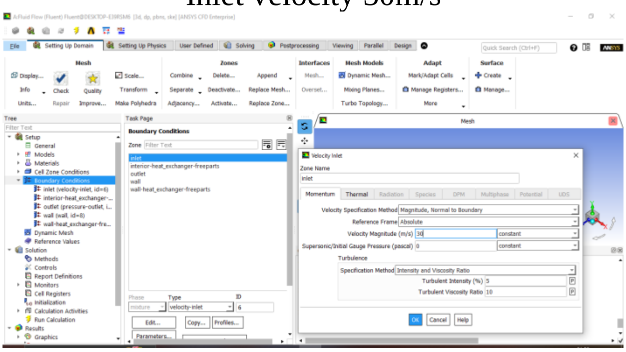


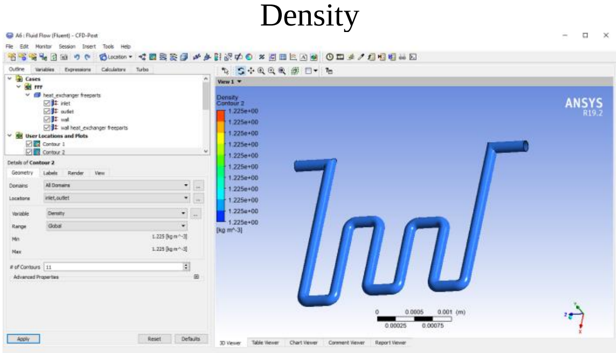
Velocity



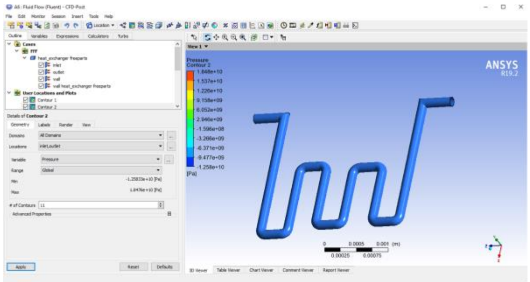
Inlet velocity 30m/s



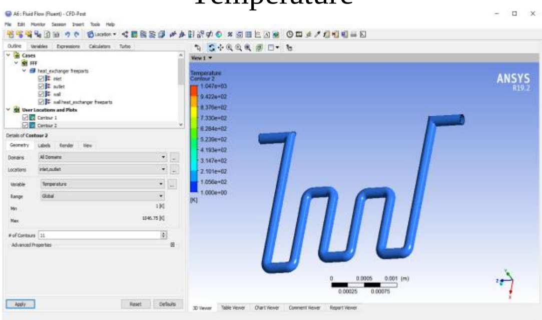
Density



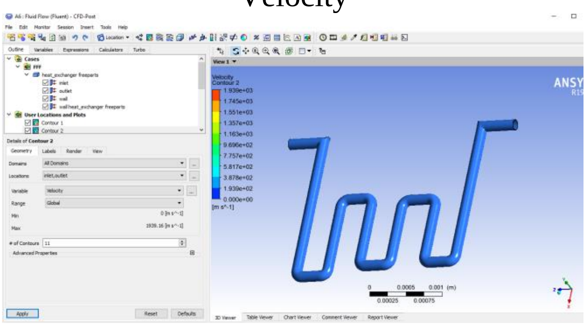
Pressure



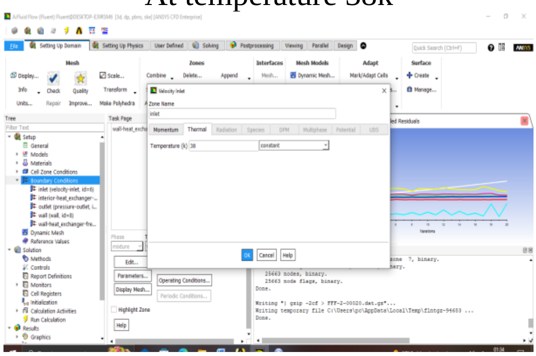
Temperature



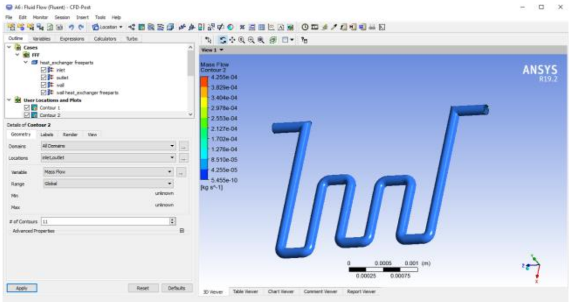
Velocity



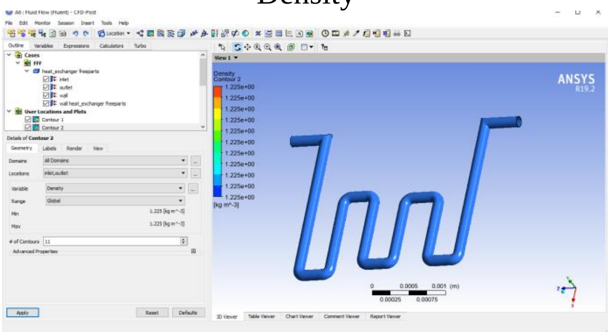
At temperature 38k



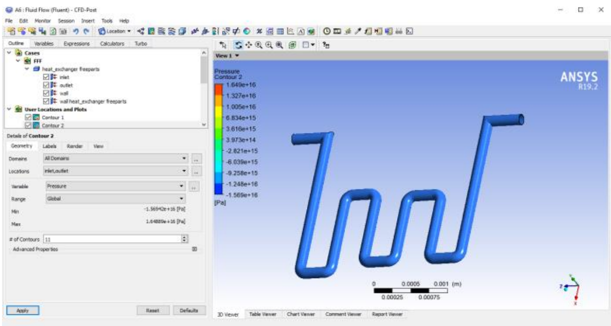
Mass flow



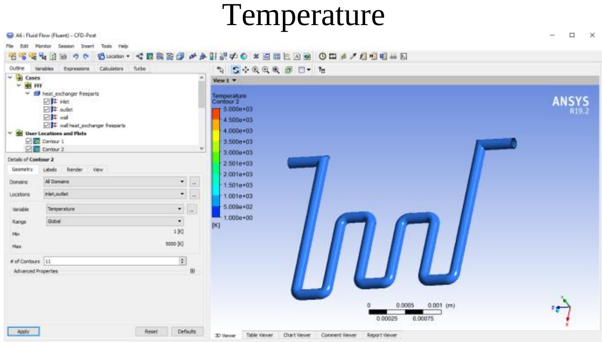
Density



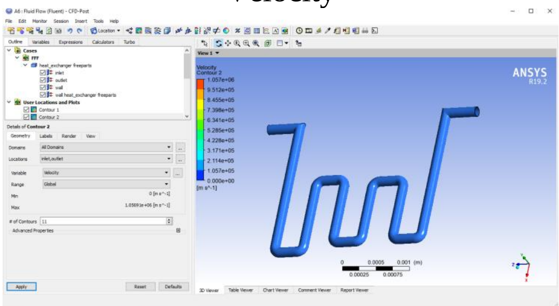
Pressure



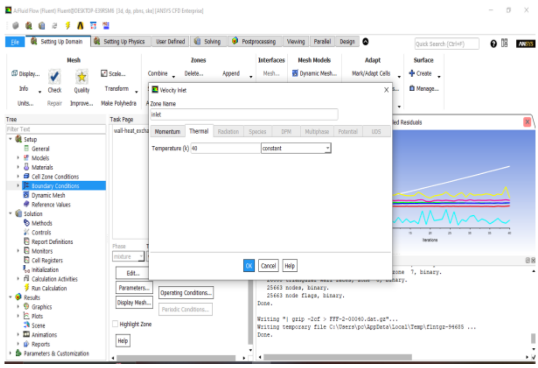
Temperature



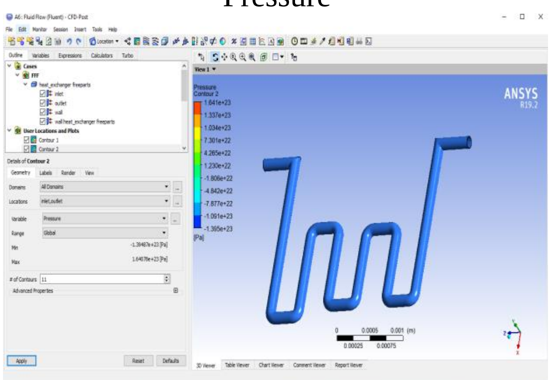
Velocity



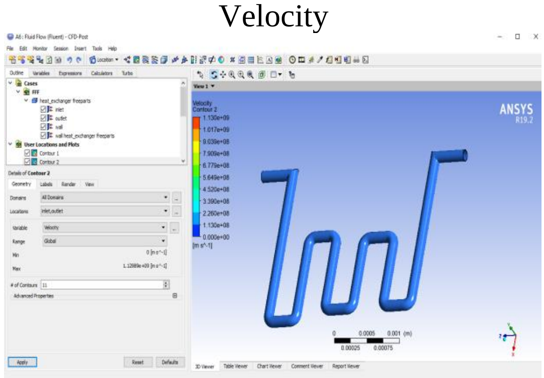
At 40 k



Pressure



Velocity



4. Results:

Thermal analysis results

Material	Input temperature (^{0}c)	Temperature distribution	Heat flux	Directional heat flux
Aluminum alloy	35	35	63178	51633
	38	38	77784	63570
	40	40	87528	71533
Copper alloy	35	35	66734	54533
	38	38	82134	67118
	40	40	92400	75508

CFD analysis results Fluid air:

inlet velocity	Temperature (k)	Mass flow	Heat flux	Pressure	Temperature	velocity
20	35	1.449e-07	2.546e+07	5.588e+09	3.010e+02	1.381e+03
	38	3.829e-04	3.943e+08	1.448e+16	2.427e+02	8.235e+05
	40	1.994e-01	1.495e+15	6.084e+22	5e+03	6.675e+08
30	35	1.321e-07	1.753e+09	1.848e+10	1.047e+03	1.939e+03
	38	4.255e-04	8.929e+12	1.649e+16	5e+03	0.57e+06
	40	7.842e-01	5.984e+16	1.641e+23	3.18e+02	1.130e+09

5. Conclusion

Earth tube heat exchanger is a device used to produce heating effects in winter and cooling effects in summer using the ground or soil as a source or sink. The atmosphere air is drawn into the pipes through the blower and heat exchange takes place between pipes and soil and it gives the cooling or heating output depending on climate. In this thesis modeling and 3-dimensional flow simulation of a earth tube heat exchanger is carried out using CATIA software and simulation done in ANSYS software to understand the inside flow characteristics and to determine prominent factors such as Pressure drop, mass flow rate by using CFD analysis at different velocities (i.e. 20m/s, 30m/s). Temperature and heat flux is calculated in thermal analysis. Aluminum alloy and copper alloy materials used for earth tube heat exchanger at different temperatures (i.e. 35^0c, 38^0c, 40^0c). By observing CFD analysis velocity and heat transfer rate co-efficient values are increasing by increasing the inlet velocity By observing thermal analysis heat flux and directional heat flux is increased by the increasing input temperature. Heat flux and directional heat flux is more for copper alloy compare to the aluminum alloy. So we concluded that copper alloy is better for earth tube heat exchanger.

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