Analysis The Performance of Parallel Flow and Heat Transfer in Concentric Tube Heat Exchanger using Computational Fluid Dynamics

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Abstract: - *To transfer the energy of heat between a fluid and a solid surface an important engineering device known as heat exchanger are used in different process process industry . A major problem facing in the design of double tube heat exchanger because of unavailable data regarding the fluid flow behavior & heat transfer. To determine the pattern of fluid flow by varying different types of parameters such as various temperatures, diameter of pipe & coil in a double concentric tube HE this research project has been presented. This research work is focused towards the modelling of double tube parallel flow heat exchanger in solidworks 2017 and then flow simulation is been set up by implementing conditions of boundary, run the calculation, inserting the parameters of surface, using cut plots and to visualize the flow field results flow trajectories have been used. The major aim of this research is to get more deep understanding about the process of heat transfer when flow of fluid occurs in double concentric tube HE. Extending the range from laminar to turbulent flow for various types of fluid flow is covered in this research work. The materials for this project were decided, water as coolant and ethanol as hot fluid has been taken and copper and brass has been taken as an inner pipe and outer pipe material.*

Key Words:- **Double Tube Heat Exchanger, SolidWorks Flow Simulation, Results, Conclusion, Report.**

1.INTRODUCTION: -

The exchange of heat between flowing fluids is a major important thing of concern and in various types of installation such as in process industries, power plants, food processing, air conditioner and refrigeration different types of heat exchangers are used. Between a solid surface and fluid thermal energy are transferred by a heat exchangers device. There are normally no collaborations between external work and heat. Through a divider wall transfer of heat happens between fluids in a way of transient in most heat exchangers. Fluids are differentiated in most heat exchangers by heat transfer surface and in a perfect world they don't break and exchangers are called as direct type of exchanger. A heat exchanger whose exchange of heat through heat energy storage are intermittent between hot and cold fluids such type of heat exchangers are known as indirect heat exchangers. In this type of exchangers fluid leakage usually have due to the divergence of pressure and rotation/valve switching matrix. Conduction, convection, and radiation are the three principles by which the transfer of heat takes place. The transfer of heat in the heat exchanger through radiation have not taken into account as it is very less when compared with conduction and convection. When heat flows through the surrounding solid wall from the higher temperature fluid conduction takes place. Generally, by the process of conduction the transfer of heat in a wall separating of a recuperator takes place. In process industries most widely used device are the heat exchangers. So, therefore the requirement for the performance of heat exchangers are usually high. However, the performance improvement may result in the size reduction of heat exchangers which can give an increased rate of heat transfer and also enables efficient utilization of thermodynamic availability which results in difference of temperature. Because of low coefficient of heat transfer through a plain tube for parallel flow so, this is however true particularly for laminar flow. In a heat exchanger through the wall of the pipe forced convection transfers the heat from one moving stream to another stream. In case of forced convection, from the hotter fluid the heat remove by the cooler fluid as it flows.

THE FLOW DIRECTION:

- **Parallel Flow**
- **Cross Flow**
- **Counter Flow.**

i. **Parallel Flow Heat Exchanger: -**

In Heat exchanger parallel flow, the two flow of fluids in parallel and same direction to each other.

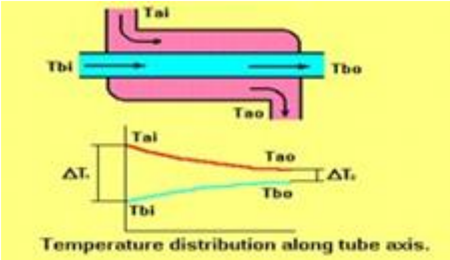


Fig-01: Parallel flow heat exchange

ii. **Cross Flow Heat Exchanger: -**

In a heat exchanger cross flow, the fluid direction are perpendicular to each other

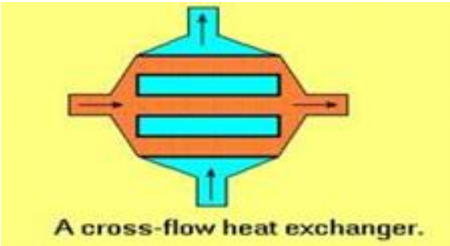


Fig-02: Cross Flow Heat Exchanger

iii. **Counter Flow Heat Exchanger: -**

Counter flow exchanger is also known as countercurrent exchanger as shown in this figure-03. The two flow of fluids are parallel to each other within the core but in opposite. Direction. The variation of temperature of two fluids may be idealized in one-dimensions in an exchanger. The most efficient arrangements of counter flow which is thermodynamically superior to other arrangements of flow capable to produce the change of highest temperature in each fluid when compared to other arrangements of fluid flow for a given rate of fluid flow, inlet temperatures of fluid, overall thermal conductance (UA).Moreover, the maximum difference in temperature across the wall thickness exchanger either the cold fluid or hot fluid end is the lowest, to perform equivalently in comparison with other arrangements of flow.

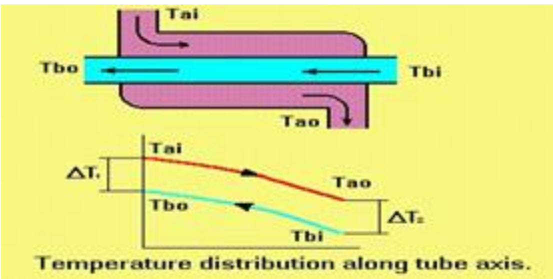
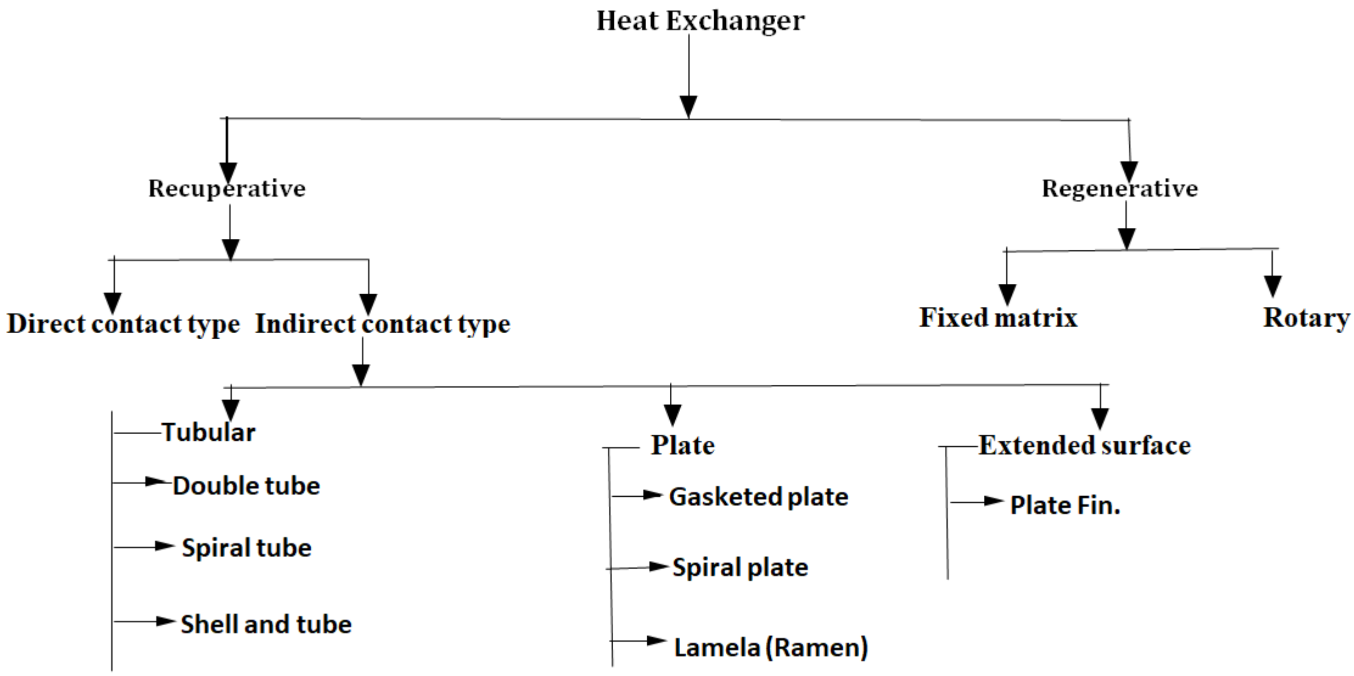


Fig-03: Counter Flow Heat Exchanger.

1.1. Classification of Heat Exchanger: -



1.2.Tubular Heat Exchanger: -

Tubular Heat exchanger are built of circular tubes. In case of tubular heat exchanger one fluid flows inside the tube and the other flows on the outside of the tube. The diameter and the number of tubes, the length of tube, the pitch and the arrangements of tubes can be changed in tubular heat exchanger. Therefore, in their design there is flexible consideration. This type of heat exchanger are used for liquid to liquid (phase changing like condensing or evaporation) heat transfer.

1.3.Double Tube Heat Exchanger:-

In case of double concentric tube HE, one pipe is concentrically placed inside another pipe of larger diameter with the flowing of one fluid through the inner pipe and the another through annulus b/w the pipes. As shown in these fig-04 to meet the pressure drop and requirements in mean temperature difference arrangements of double concentric tube heat exchanger into different series and parallel arrangements can be possible. For sensible cooling and heating of fluid process where small areas of heat transfer are required double concentric tube heat exchanger are used.

The double concentric tube heat exchanger are very flexible and also because of its smaller diameters it can be designed for higher pressures applications if required. This type of heat exchangers are expensive, bulky and heavy but this type of heat exchangers are easy to clean and dismantle. So, therefore this type of heat exchangers can be used for the dirty services. Generally, in the form of modular concept double concentric tube heat exchangers are built. “Hairpins” can be easily added in various process conditions in series-parallel combination to accommodate changes. In this project work, a study on the effect of Prandtl, Nusselt, and Reynolds no. on the pattern of flow have been done and also research on the flow types in circular straight pipes has been carried out. In this study, two basic conditions of boundary are constant temperature and constant heat flux of the wall are faced in the application.

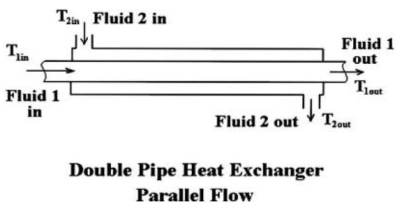


Fig-04: Schematic diagram of HE.

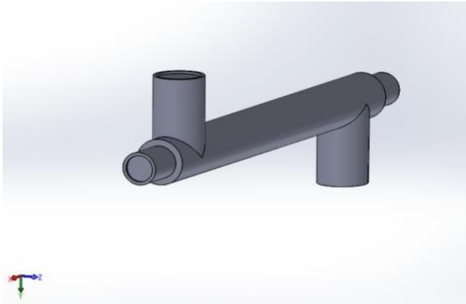


Fig-05: Double Concentric Tube HE.

1.4.Advantages of Double Tube Heat Exchanger:-

Double concentric tube heat exchanger is of various advantages such as:-

- To build and operation of concentric tube heat exchanger are extremely easy.
- This type of heat exchanger can be used at a higher temperature and pressure.
- It is easy to clean, repair, and maintenance.
- Simple construction of double pipe HE leads to easy cleaning inspection and replacement element of tube.
- Design of modular concentric tube heat exchanger of sections of rearrangement for new services.

1.5.Disadvantages of Double Tube Heat Exchanger:-

- The limitate of HE is its complicated design and it is used in low heat duties.
- Various hairpin sections of heat exchanger are not competitive at all times with a heat exchanger of shell and tube.

1.6.Application of Double Concentric Tube Heat Exchanger:-

Heat exchanger helps in many industrial process to utilize the wasted heat from one processes to another process while helps efficiently to save a lot of money.

In industries where heat exchangers are used include:-

- Treatment to waste water.
- Refrigeration.
- Making of wine and beer.
- Refining petroleum.

2. LITERATURE REVIEW:-

Transfer of heat enhancement is gaining an importance in industry especially in heat exchanger as because it provides the opportunity to reduce the heat transfer area for heat exchanger. To produce energy, cost saving to material and process related to heat exchanger can be provided by the increase in the performance of heat exchanger. A device which uses a separating wall of cylinder for the transfer of heat from hot fluid to cold fluid are named as heat exchangers. Due to their small diameters the application to higher pressure and temperature are primarily adapted. Hence, enhancement in the transfer of heat in a double concentric tube heat exchanger can be achieved by different methods for the given length and design of exchanger. In their research work by Chen et.al., as the modification on the inner tube to the heat transfer dimples have been used by them. According to the research work by Bhuiya et. al.,[1] uses equipped circular tube with twisted tape inserts with different configurations to enhance the transfer of heat through the tubes. By increasing the convection coefficient from the surface of HEs to the fluid intensifying the transfer of heat is possible and also by increasing the area of surface across where the occurrence of convection takes place. Radical or longitudinal fins as a form of extended surface can be used to increase the heat transfer between the adjacent fluid whenever there is a need.

"An experimental study done by S.k.Saha & A.Dutta et.al.,[2] has experimented that oil of servotherm flows into an acrylic circular tube which are fitted in an insulated stainless steel with twisted tape insert. The effect of varying length and pitch of twisted tape has been studied with different twist ratios on the rate of heat transfer and friction factor. The important outcomes that revealed in the study were short length of twisted tapes reduces the pumping loss but also reduces the rate of heat transfer and maximum rate of heat transfer is given by uniform pitch twisted tape". By Agarwal et.al., a study have been done on the magnitude of transfer of heat and laminar flow in an annular finned tube, in their study by varying parameters of flow and geometries drop in the pressure and characteristics of heat transfer of the fins are found in the fully developed region. Geometrical parameters which are obtained in this study are radius ratio of annulus (0.3 to 0.5), height of the fin (0.33 to 0.7), and spacing the fin (2 to 5). With a plain tube having Reynolds number, volume flow rate and having same length of fins & also flow parameters such as Reynolds number (100 to 1000), and Prandtl number (1 to 5) a comparison has been made in their research report. In their research work they found that as because pressure drop increases is more as compared to increase in heat transfer as a result Prandtl numbers are less than 2. In their research work, the increase in heat transfer are increased to 3.1 when Reynolds number and Prandtl numbers are 1000 and 5. While the increase in pressure drop are seen at a factor of 2.3.

A CFD study have been done by Salman et.al.,[3] on the increasement of heat transfer by parabolic cut and classical twisted tape using nanofluid(Water-Copper Oxide) and best performance has reportedly done by parabolic cut twisted tape. According to the experimental study by Zhi-Minlin, Liang-Bi Wang, [4] they used plexiglass circular tube in which there is a tape of twist insert which is made by stainless steel through which air flows. Various ratios of twisted tapes are used. In their research work they concluded that 3-4 times of friction has increased by tape. With ratio of small twist, as compared to greater twist ratio higher transfer of heat is achieved. According to the study done by Garcia et.al.,[5] has revealed that there is decrease in temperature of wall with the increase in coefficient of heat transfer for three coils of different wire and twisted tape insert for solar collector.

"By Watcharin Noothong et.al.,[6] an experiment has done to investigate the transfer of heat, study of friction factor and enhancement of efficiency for heat exchanger. In this study plexiglass material are used for concentric tube heat exchanger. Hot air as an inner fluid and as an annulus cold water are used as a medium. In the inner tube stainless steel tape are inserted with different twist ratios. They concluded that Nusselt number and efficiency increases with decreasing the twist ratio and friction factor increases with decreasing twist ratio. The portioning and blockage of the tube flow cross section by the tape, resulting in higher flow velocities. Convection heat transfer gets better due to the result of mixing twist and by tape twist secondary motion of fluids are generated". An experimental Investigation have been done by Akshay Kumar Magadum et.al.,[7] with parallel and opposite flow arrangements in tube heat exchanger. In their research work thus found that the rate of heat transfer are 30% more in counter flow in comparison with parallel flow. Graph of LMTD v/s efficiency and discharge for opposite and parallel flow has been presented in the research work. Their research work has been concluded that LMTD increases discharge and efficiency. A helical coil counter flow heat exchanger has been constructed and analyzed in the study by Swapnil Ahire et. al.,[8]. A coil of helical shape is given to tubes. Overall coefficient of heat transfer are used by using a technique called as Wilson plot technique. In their research work, they observed that due to curvature of tubes the centrifugal force leads to secondary development of flow, the rate of heat transfer are enhanced by secondary flow. According to their research project, the graph of Nu v/s Re and hi v/s Re is steeper than high Reynolds number for low Reynolds number. According to their research, they concluded that helical coils in low Reynolds number are more efficient. An experimental analysis by Alok Vyas et. al.,[9] has been conducted in their research study to predict the performance characteristics of heat exchangers such as difference in temperature and pressure drop, number of tubes, baffles and diameter of tube are being considered in this design as a factor. Performance affecting those factors were selected. To improve the performance of tubular heat exchanger CFD software are used for the analysis. According the research work by Jian-FeiZhang et. al.,[10] a shell and tube heat exchanger are developed with middle baffles overlapped and simulation model by using Fluent and GAMBIT as commercial code and grid generation program are used. An angle of helix is performed for degree-40 and in the result, and available experimental data has been shown. In a review paper by Durgesh Bhatt et.al.,[11] various conditions are involved where different parameters are changed at various conditions to get review performance. The parameter's which are considered to be changed are tube metallurgy and baffle spacing. There is a decrease in overall heat transfer coefficient and pressure drop due to increase in baffle spacing which have been concluded in their research work. A study by Balaram Kundu et.al.,[12] shows the designing of un-baffled shell and tube heat exchanger having attached a profile of longitudinal trapezoidal fins have been studied in their study.

It is important to calculate and paying attention towards the considering fluid flow and paths of the flow when built for the heat exchangers and designed with many fins for real industry. The body resistance leads to drop in the pressure. Survey of the literature reveals that while considering the heat flux constant most of the analysis have been carried out. The literature regarding the numerical method of enhancement in the characteristics of heat transfer for double tube heat exchanger using various configurations of internal longitudinal fins is still scare. Hence, the aim of the present work is to compare the characteristics of heat transfer to evolve with the best possible solutions for parallel and counter flow under various operating conditions using different temperatures and mass flow rate. Using Solidworks CFD package numerical simulations have been carried out. Characteristics of heat transfer such as variations in temperature, rate of heat transfer, and co-efficient of heat transfer for the models were presented and compared.

3. SOLIDWORKS INTRODUCTION:-

A solid parametric feature-based modelling design tool easily advantages to learn graphical user interface of windows using solidworks software tool which is the solidworks automation design software. By utilizing user defined relations models of 3D solid can be created automatically. The values of constraints which determines the geometry or shape of the assembly or model are referred by parameters, parameters may be either numeric or geometric parameters, numeric parameter's such as length of the line, diameter of circle etc. and geometric parameters like parallel, horizontal, or vertical or tangent etc. through the use of relation parameters of numerical can be associated with each other, which provides them the design intent to capture. The intent of design is the part that how the creator wants to update and change in respond.

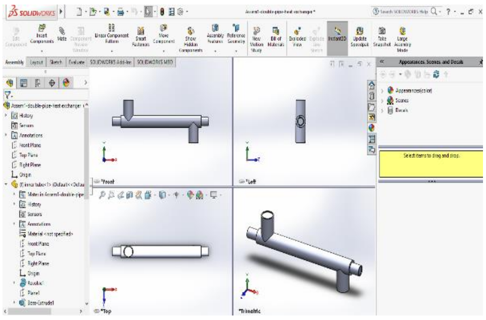


Fig-06: Different Views of Tube HE.

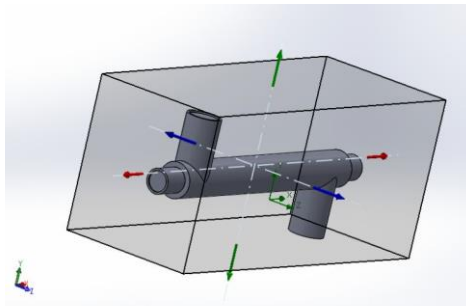


Fig-07: Computational Domain of HE.

3.1. Flow Simulation:-

3.1.1.Introduction to Solidworks Flow Simulation:

Flow simulation in solid works software 2017 is an analysis of fluid flow which is available for solidworks to obtain the full solution of navier stokes equation which governs the fluids motion. Solidworks motion and simulation of solidworks are the other packages which can be added in solidworks. An analysis of fluid flow using flow simulation are shown in the flowchart in following figure in which a number of following steps are involved:

Fig-08: Flow Chart for Analysis of Flow Simulation in Solid works.

3.1.2.Flow Simulation Project:-

The process to setup a flow simulation project in solidworks software includes the general steps of setting in the following order: selecting the fluid and solid by choosing analysis type by setting wall condition by choosing initial and ambient condition. Any problem regarding the fluid flow which can be solved using the flow simulation must be categorized either as internal bounded or flow of external unbounded.

3.1.3.Flow Simulation of Concentric Tube Heat Exchanger:-

In this solidworks flow simulation project for concentric tube heat exchanger between the hot inner tube flow and water as a coolant for outer flow in the annulus transfer of takes place. The thickness for outer hot jacket is taken as 3.99mm i.e., outer diameter is 30.23 and inner diameter is 26.22mm. the thickness for inner tube is taken as 2.5mm i.e., outer diameter is 20.0182 and inner dia. is 17.52mm. The mass flow rate of water in the annulus (outer hot Jacket) is 0.02kg/s with an inlet temperature of 10.00C or 283K and the mass flow rate of ethanol in an inner tube is 0.02kg/s at an inlet temperature of 78C or 351K. the distribution of temperature along the concentric tube heat exchange from the result of flow simulation have been shown.

FLOW SIMULATION:

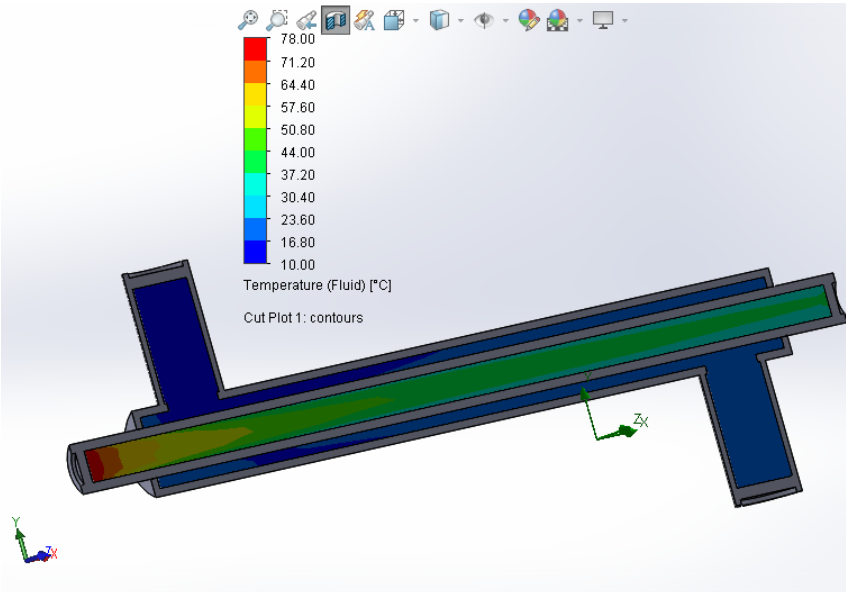


Fig-09: Temp of Fluid in Concentric Tube in HE.

4.RESULTS AND DISCUSSION:-

INSERTING SURFACE PARAMETERS:

In the analysis tree of flow simulation click right on the surface parameters and then select the environmental pressure in the flow simulation analysis for boundary condition.

The minimum temp. of fluid is 283K at inlet and 351K at the outlet and the maximum temp. of solid is 298.24K.

The average value of fluid at inner tube region is 337K and the average value of fluid at outer hot jacket is 290K.

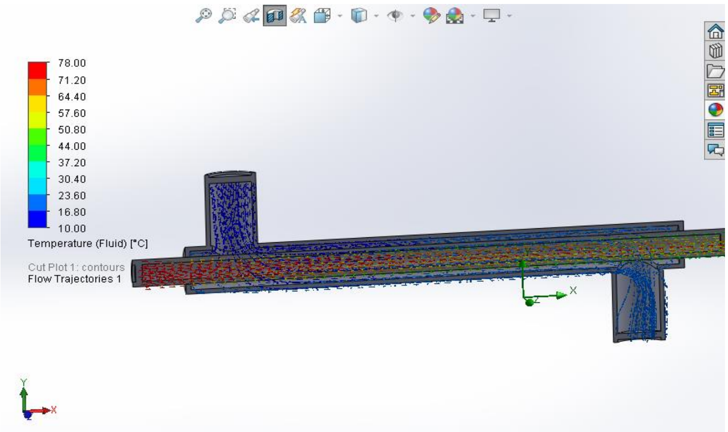


Fig-10: Flow Trajectory in Concentric Tube HE.

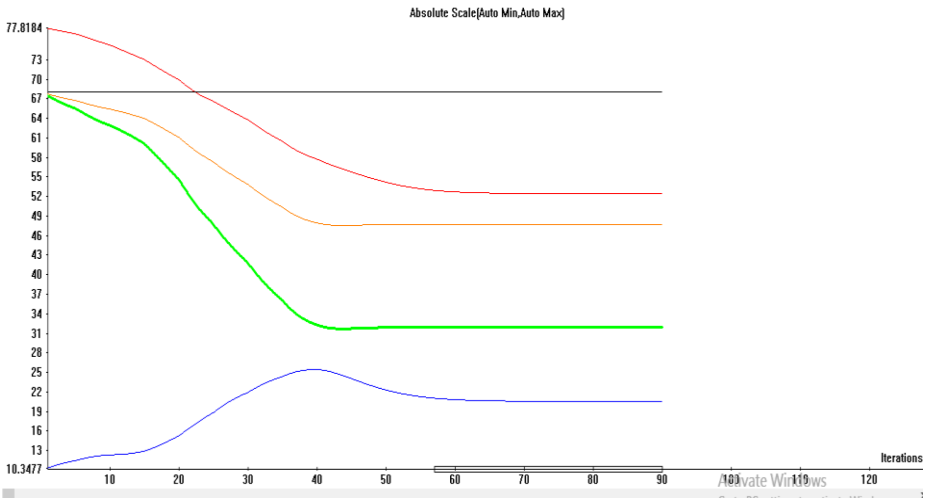
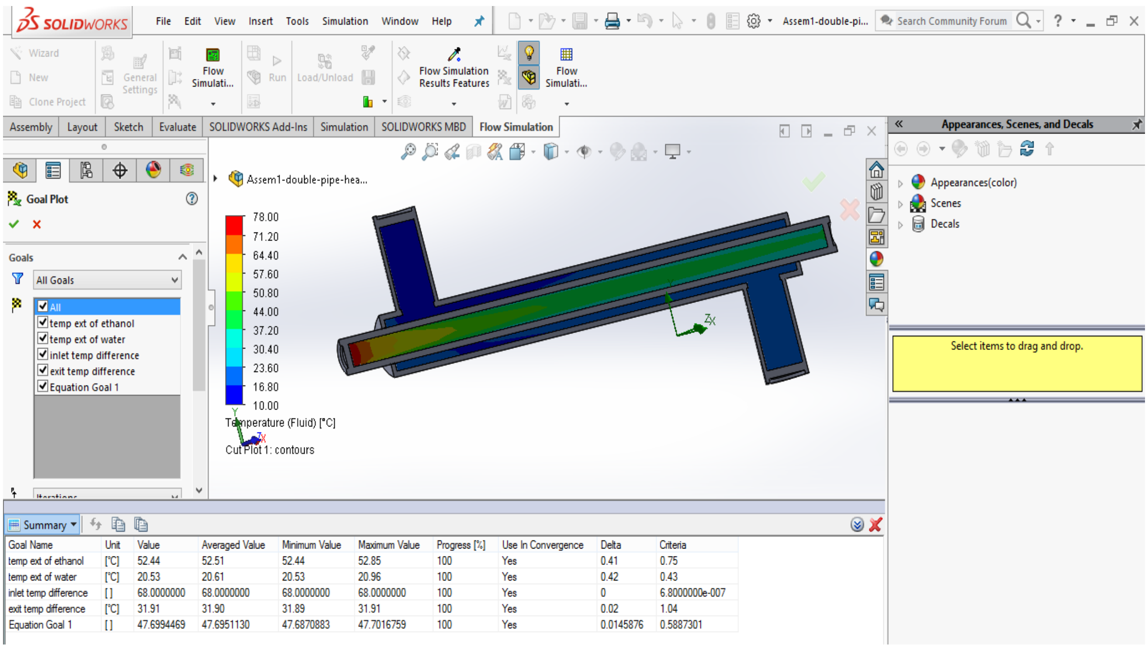


Fig-11: LMTD Equation Goal Plot of Tube HE.

5.REPORT:-



Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value	Progress [%]	Use In Convergence	Delta	Criteria
temp ext of ethanol	[°C]	52.44	52.51	52.44	52.85	100	Yes	0.41	0.75
temp ext of water	[°C]	20.53	20.61	20.53	20.96	100	Yes	0.42	0.43
inlet temp difference	[ ]	68.0000000	68.0000000	68.0000000	68.0000000	100	Yes	0	6.8000000e-007
exit temp difference	[°C]	31.91	31.90	31.89	31.91	100	Yes	0.02	1.04
Equation Goal 1	[ ]	47.6994469	47.6951130	47.6870883	47.7016759	100	Yes	0.0145876	0.5887301

Name	Unit	Value	Progress	Criteria	Delta	Use in convergence
temp exit of ethanol	°C	52.44	100	0.74618607	0.407933446	On
temp exit of water	°C	20.53	100	0.433152622	0.422615654	On
exit temp difference	°C	31.91	100	1.04044178	0.022300253 1	On
inlet temp difference		68.0000000	100	6.8e-007	0	On
LMTD EQUATION:-		47.6994469	100	0.588730112	0.014587611 9	On

5.1.Table: Analysis of Goals:-

6.CONCLUSION:-

The design and analysis of CFD has been done on concentric tube heat exchanger and the results has been find out. This study has shown the transfer of heat within the limits of error performance for configuration of parallel flow. Ethanol to water transfer simulation for heat characteristics have been done and for the same tube diameter, length and for same temperature input of annulus for cold inlet 283K and for hot inlet 352K. We observed that in parallel heat exchanger there is low temperature difference in output streams (hot outlet, cold outlet) as compared to difference in temperature in counter flow. Nusselt number which is calculated for parallel flow heat exchanger is 58.61.

For given design and length of concentric tube heat exchanger the increase in heat transfer is possibly achieved by several methods. Active and passive techniques are the two techniques. Some external input are induced in active methods for increase in the heat transfer like induced vibrations, suctions and injections of fluids, and impingement of jet etc. passive method is an another method which is done by an external power without simulation such as surface coating, surface roughness and external surface.

7.FUTURE SCOPE OF WORK:-

Industries uses CFD analysis whenever research and innovation are needed to carryout for new services and product. As per the bdemand for work, skill and expertise of subject different oppurtunities of job has been created for both medicine and large scale industries well establishement of CFD softwares and simulation bhave became very affordable due to an increase in computational power.

In this project further development have been done by considering different flow types such as cross, parallel, and counter flow. Also, in this project we have considered that radiation is negligible in comparison with conduction and convection where it will exist in practical situation. So, further extension of this project can be done in that path.

Next the analysis and design of concentric tube HE is done in solid. Works as because of its complexity of design concentric tube HE has more importance in various industries.

Here parallel flow has been considered, the temperature of fluid, solid temperature, and LMTD, thermal coefficient, heat flux are determined.

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