CFD Analysis on Nickel and Titanium Double Pipe Heat Exchanger

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Abstract: **A heat exchanger is a device used to transfer energy from between two fluids, from a fluid and surface of solid, or from a fluid and particulates of solid, at distinctive temperatures and which are in thermal contact. Double pipe is general type of heat exchanger used in chemical Industries and especially where the heat transfer requirement is minimum. The most usual problem faced in the heat exchanger is the corrosion and fouling due the fluids flowing in the pipes. Nickel is highly resistive to corrosion and fouling in the heat exchangers which increases the thermal efficiency of the heat exchanger.**

The aim is to study the heat transfer of Nickel and Titanium Double Pipe Heat exchanger by Computational Fluid Dynamics (CFD) Using ANSYS 18.1 software by plotting temperature, Velocity contours from CFD Analysis. CFD is the very useful technique to simulate the heat transfer of the heat exchangers. It will predict the heat transfer of the heat exchangers without building the prototype, hence it reduces the cost, time etc. The results obtained from the CFD analysis is compared with the theoretical formulas of the heat transfer to validate the accuracy of the results.

Keywords: **Heat Exchanger, Computational Fluid Dynamics, Nickel and Titanium.**

I. INTRODUCTION

A heat exchanger is a device used to transfer energy from two or more fluids, from a fluid and surface of solid, or from a fluid and particulates of solid, at distinctive temperatures and which are in thermal contact. Heat exchangers are one of the essential devices in industries since the process capability and economy highly depend on heat exchangers performance. Double pipe is the type of heat exchanger used in chemical Industries and especially where the heat transfer requirement is minimum. The most usual problem faced in the exchanger is the corrosion and fouling due the fluids flowing in the pipes. Nickel is highly resistive to corrosion and fouling in the heat exchangers which increases the thermal efficiency.

A general double pipe exchanger contains of one pipe arranged concentrically inside other major diameter with alternate fittings to straight the flow from section one to next. A Double pipe exchanger can be arranged into different parallel and series placed to meet difference mean temperature and pressure drop requirements. Main use of double pipe exchanger is for sensible heating and process fluid cooling is required where small heat transfer areas (up to 50 m2). This configuration is also very suitable when one or both fluids are at higher pressure. If the Coefficient of heat transfer is less for annulus, axially finned inner tubes can be used.

The basic two boundary conditions that are faced in the applications are the constant of wall heat flux and constant temperature.

Nickel is a slight golden tinge with a silvery-white lustrous metal. Nickel belongs to the transition metal and is hard and ductile. To increase the surface area of reactive, shows a chemical activity of significant by pure nickel powdered, but larger pieces are slow to react with air under standard conditions because layer forms of an oxide on the surface and prevents further corrosion.

Titanium is a transition metal of lustrous, it is a silver colour, high strength, and low density. Titanium is resistant to corrosion in chlorine, sea water, and aqua regia. The metal useful properties of are strength-to-density ratio and corrosion resistance, the any metallic element highest. In its condition of unalloyed, titanium is as some steels as strong, but density less.

II. LITERATURE SURVEY

A. Patel et al a Review: On CFD Analysis and Performance Evaluation of Double Pipe Heat Exchanger. This type of heat exchanger is simple type of heat exchanger, commonly usage for the purpose of cooling or sensible heating. This study explained about the various techniques which may useful to increase the rate of heat transfer. Heat exchangers are changed in annular space using water. This type of heat exchanger is practically investigated and results are validated with Ansys CFD software.

B. Antony luki A, Ganesan M: "Analysis of Flow and Comparison of Characteristics of Double Pipe Heat Exchanger Using Enhanced Tubes" in this study investigation, the tube of a concentric tube heat exchanger with the enhanced area the tube side augmented surface has been achieved with dimples strategically located in a pattern along. Surfaces of augmented to increasing the coefficient of heat transfer with a in the friction factor consequent increase. In this study to change the inner tube of double pipe heat exchanger.

C. Usman C, Rehman Ur: Studied the heat transfer and flow distribution in a shell and tube exchanger and compared them with the experimental results. The model showed an average error of around 20% in transfer of heat and the pressure difference. This paper explained that the plane symmetry assumption worked good for the exchanger length but not the inlet and outlet regions. By using Reynolds Stress models instead of k-ε models the model could be improved. The heat transfer was found to be on the lower side as no more interaction among the fluids. By improving the cross-flow regions the design could be improved instead of the parallel flow.

D. Dr. T. Mothilal: Determining the double pipe exchanger performance, the hot fluid has made to cold fluid through annulus and flow through inner tubes. Analysis of the six various fin inclinations. Total coefficient of heat transfer using those helical fins and best increment of the rate of heat transfer. Dr T. Mothilal, et al. (2017) for a gasoline engine the turbocharger usage will increase the vehicle performance in power terms as high pressure obtained is most high which in turn enhances the performance.

III. DOUBLE PIPE HEAT EXCHANGER DESIGN

The double pipe exchanger as a valued resource in many industries for a range of purposes, it is the simplest design and capability to operate below large pressures made, from processing of material to preparation of food. This is one type of heat exchanger, a pipe is arranged inside another pipe, along cold fluid flows through the inner tube and flowing through the space among the outer and inner tube. They can run in counter flow or those fluid can flow travel parallel to one another. while travelling through the system, heat from the hot fluid is transferred through the inner tube to the cold fluid.

The following factors are considered to design the heat Exchanger

1. Resistance to heat transfer should be minimized.

2. Cost and material requirements should be kept low.

3. Resistance to the Corrosion.

The 3D double pipe heat exchanger model is designed in SolidWorks modelling software.

A. Design Specifications of Double Pipe Heat Exchanger

Outer diameter of Inner Pipe: DOI =130 mm

Inner diameter of Outer Pipe: D_{IO}= 90 mm

Inner diameter of Inner Pipe: D_{II}=40 mm

Thickness of the Pipes= 3 mm

B. Modelling of heat exchanger using solid works software:

The 3D double pipe heat exchanger model is designed in SolidWorks modelling software. The model is as shown in the adjacent picture.

Fig.1 Double Pipe Heat Exchanger

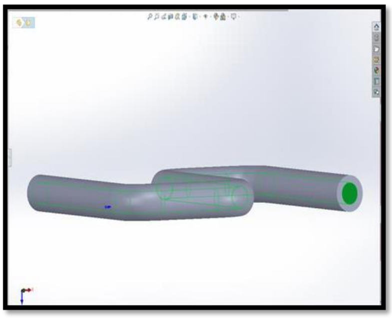


Fig.2 Double Pipe Heat Exchanger

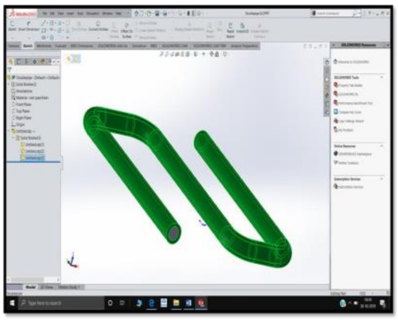


Fig.3 SolidWorks 2019

IV. CFDANALYSIS OF DOUBLE PIPE HEAT EXCHANGER

Computational fluid dynamics (CFD) is a term used to describe a way of modelling fluids using numerical methods and algorithms. Without the aid of computers presently those are solved using computers but early methods were completed manually. Computational fluid dynamics is a most important tool to model type fluids, what would occur in reality they are only an approximation of technological advances and but even with the most state of art super computers.

A. Design Specifications of Double Pipe Heat Exchanger:

The double pipe is a type of heat exchanger is usage in company like a process of cooling fluid and condenser for Chemical process. This type of heat exchanger is designed in a big size for important application in industries. in order to make this little double pipe type heat exchanger become practicality, for this little double pipe the better design choose.

Heat transfer is the transfer of heat energy from one substance another substance. Heat transfer is one of the important functions to be measured as the efficiency and the concentric tube heat exchanger performance. By usage of CFD simulation software, it can minimize the operation cost and time compared by Analytical calculations in order to measure the optimum parameter and the behaviour of this type of heat exchanger.

B. Meshing:

The meshing is performed in ANSYS Mechanical to discretize the elements of the 3d model i.e. heat exchanger. The relative finer mesh is obtained on the model of Double Pipe heat exchanger. The 3D type of meshing is used for this model. The mesh size of 5 mm is taken for the accurate results. The inlet and outlet portions of the heat exchanger is fixed in the ANSYS Mechanical.

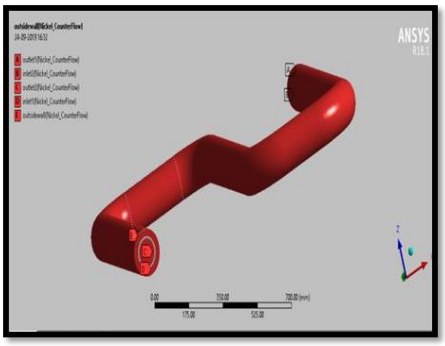


Fig. 4 Named Sections

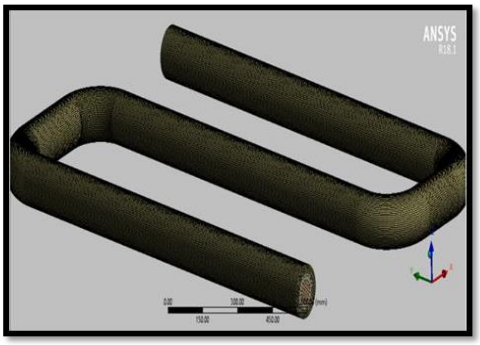


Fig. 5 Mesh

Quality	
Inflation	
Assembly Meshing	
Advanced	
Statistics	
Nodes	516836
Elements	421222

Fig. 6 Mesh Statistics

Details of "Body Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	5. mm
Advanced	
Defeature Size	Default (0.551 mm)
Size Function	Uniform
Behavior	Soft
Growth Rate	Default (1.20)

Fig. 7 Mesh Sizing

C. ANSYS Fluent:

Fluent is a CFD code used for flow modelling applications. Fluent needs some input data and domain drawn from various softwares like SOLIDWORKS, GAMBIT, CATIA,PRO-E and other design software. Now fluent can analyse the given domain with boundary conditions and solve the governing equations for the flow giving the different flow parameters.

D. Problem Setup:

The mesh is checked and quality is obtained. The analysis type is changed to Pressure Based type. The velocity formulation is changed to absolute and time to steady state.

E. Material:

The material properties were derived from tables based on the temperature which was being calculated in the model. The material was defined in FLUENT using its material browser. For the different flow arrangement problem model certain properties were defined by the user prior to computing the model, these properties were: thermal conductivity, density, heat capacity at constant pressure, ratio of specific heats, and dynamic viscosity.

- Nickel: Nickel is used for the design of Double Pipe Heat exchanger. The properties of Nickel are as follows:

  Thermal conductivity - 91 w/m-k

  Specific heat (Cp) - 460 KJ/K

  Density -8900 Kg/m^3

- Titanium: Titanium is used for the design of Double Pipe Heat exchanger. The properties of Nickel are as follows:

  Thermal conductivity - 7.44 w/m-k

  Specific heat (Cp) - 544 KJ/K

  Density - 4850 Kg/m^3

- Water: Water is the cold fluid used in the double pipe heat exchanger. The properties of the water are as follows

  Thermal conductivity - 0.6 w/m-k

  specific heat (Cp) - 4.18 KJ/K

  Density - 998 Kg/m^3

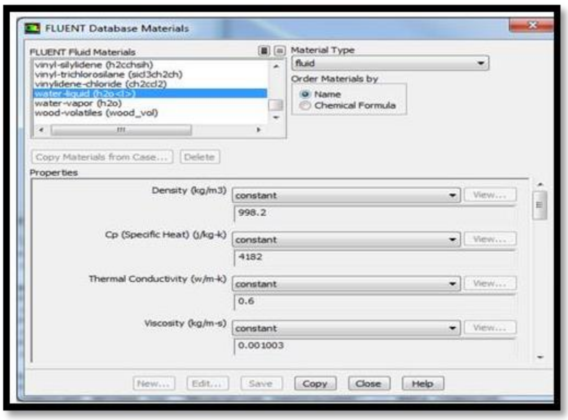


Fig. 8 ANSYS Fluent

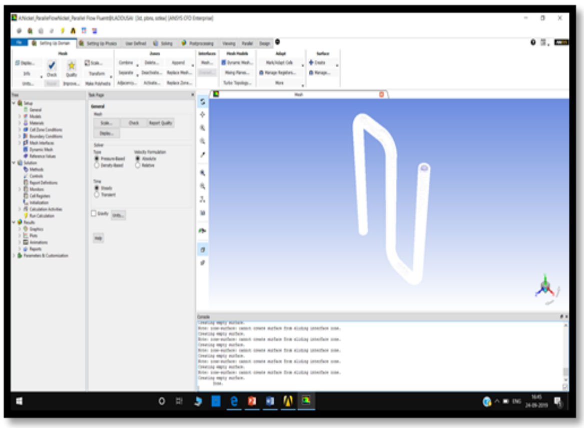


Fig. 9 ANSYS Fluent Materials

F. Cell zone conditions:

Cell Zone Conditions defines the state of the fluids used in the solver. In the ANSYS Fluent the inner and annular regions are filled with fluid and assigned as Liquid state where as for the Double Pipe Titanium and Nickel materials are applied as Solid.

G. Boundary conditions:

This paper deals with turbulent flow of water through a double pipe. It also contains heat transfer and single-phase flow.

TABLE I: Boundary Conditions

S.NO	PARAMETER	VALUE	UNITS
1	Mass flow rate of hot fluid	1.3	Kg/s
2	Mass flow rate of cold fluid	0.99	Kg/s
3	Inlet temperature of hot fluid	343	K
4	Inlet temperature of cold fluid	293	K
5	Heat flux around the surface	0	W/m2

V. RESUILTS & DISCUSSIONS

The results obtained from the simulation are validated using the NTU method to know the accuracy of the results. The results are classified as Parallel Flow and Counter flow for the both the materials.

A. Case 1: Parallel Flow:

The results for both the materials in parallel flow conditions are obtained and temperature contours are obtained. The boundary conditions are set up in Ansys Mechanical and Fluent.

Titanium:

The solution is converged after the 250 iterations in the Ansys Fluent. The following are the results obtained from the Ansys Fluent Solver

Outlet temperature of hot fluid - $T_{hot\ Out}$ = 443K

Outlet temperature of cold fluid - $T_{Cold\ Out}$ = 304 K

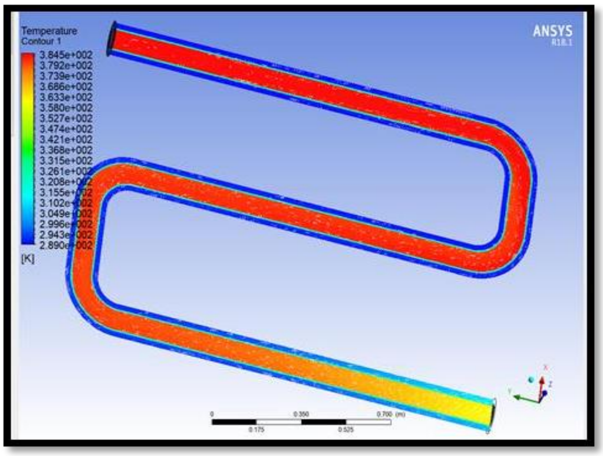


Fig. 10 Contours of static temperature for Titanium Parallel flow

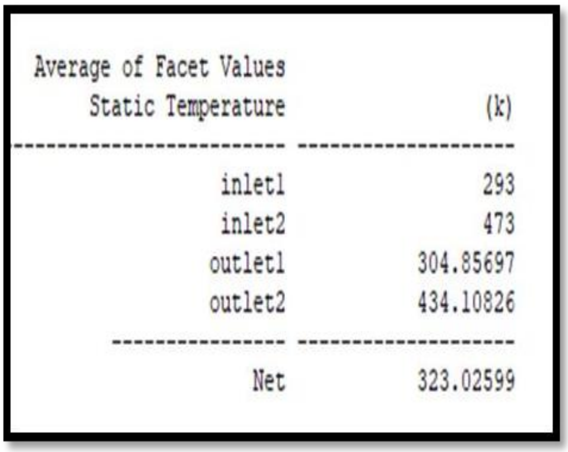


Fig. 11 Facet Values of static temperature for Titanium Parallel flow

Nickel:

The solution is converged after the 250 iterations in the Ansys Fluent. The following are the results obtained from the Ansys Fluent Solver

Outlet temperature of hot fluid - $T_{hot\ Out}$ = 443 K

Outlet temperature of cold fluid - $T_{Cold\ Out}$ = 304 K

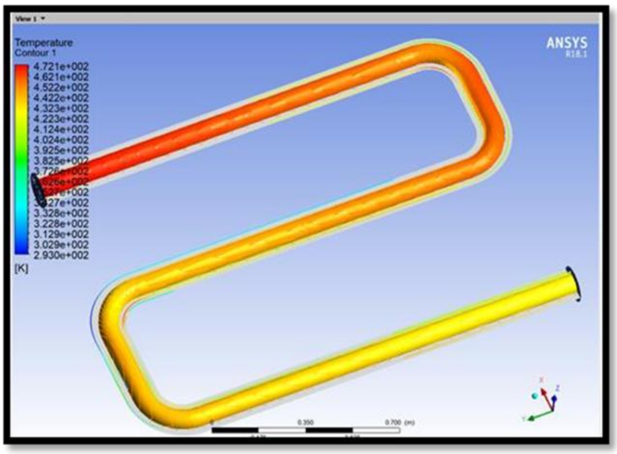


Fig. 12 Contours of static temperature for Nickel Parallel flow

Average of Facet Values Static Temperature	(k)
inlet1_fluid_flow_fluent_	293
inlet2_fluid_flow_fluent_	343
outlet1_fluid_flow_fluent_	295.63148
outlet2_fluid_flow_fluent_	325.74533
Net	300.55838

Fig. 13 Facet values of static temperature for Nickel Parallel flow

Case 2: Counter Flow:

The results for both the materials in Counter flow conditions are obtained and temperature contours are obtained. The boundary conditions are set up in Ansys Mechanical and Fluent.

Titanium:

The solution is converged after the 250 iterations in the Ansys Fluent. The following are the results obtained from the Ansys Fluent Solver

Outlet temperature of hot fluid - Thot Out = 435 K

Outlet temperature of cold fluid - TCold Out = 296 K

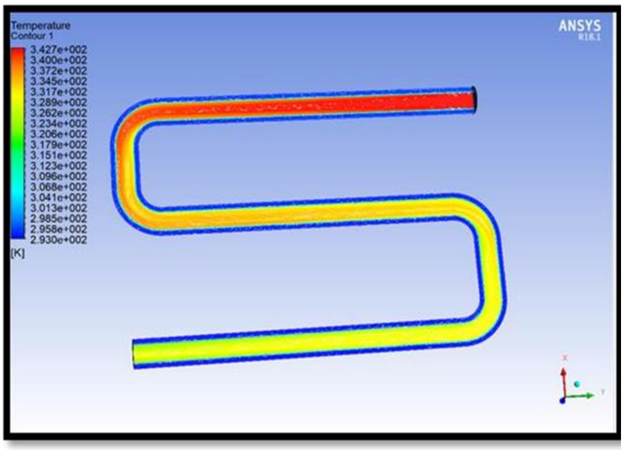


Fig. 14 Contours of static temperature for Titanium Counter flow

Average of Facet Values Static Temperature	(k)
inlet1	385
inlet2	289
outlet1	352.67945
outlet2	306.87434
Net	310.35945

Fig. 15 Facet values of static temperature for Titanium Counter flow

Nickel:

The solution is converged after the 250 iterations in the Ansys Fluent. The following are the results obtained from the Ansys Fluent Solver

Outlet temperature of hot fluid - Thot Out = 435 K

Outlet temperature of cold fluid - TCold Out = 296 K

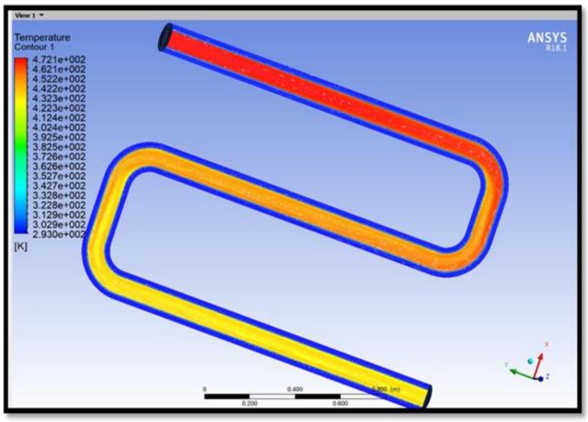
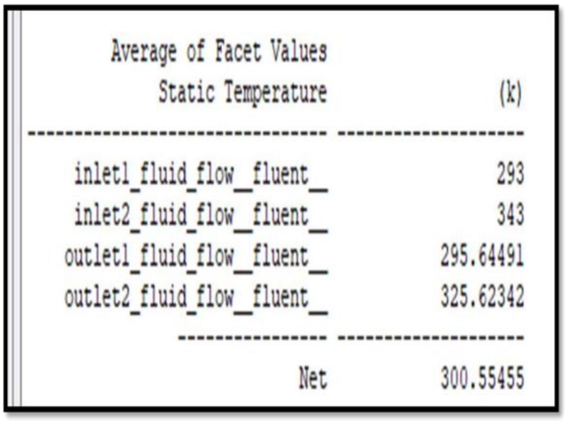


Fig. 16 Contours of static temperature for Nickel Counter flow



Average of Facet Values
Static Temperature (k)

inlet1_fluid_flow_fluent_	293
inlet2_fluid_flow_fluent_	343
outlet1_fluid_flow_fluent_	295.64491
outlet2_fluid_flow_fluent_	325.62342
Net	300.55455

Fig. 17 Contours of static temperature for Nickel Counter flow

TABLE II: Result from ANSYS Fluent

S. No.	Type of analysis	Inlet temperature of hot fluid (K)	Inlet temperature of cold fluid (K)	Outlet temperature of hot fluid (K)	Outlet temperature of cold fluid (K)	Average temperature (K)
1	Titanium Parallel Flow	473	293	434	305	323
2	Titanium Counter Flow	385	289	353	307	310
3	Nickel Parallel flow	343	293	326	296	301
4	Nickel Counter flow	343	293	327	297	301

B. Result validation:

The results obtained from the Ansys fluent is validated by comparing with the theoretical calculations to ensure the accuracy of the solution obtained from the ANSYS Fluent Solver. NTu method is used to validate the results obtained from the ANSYS Fluent. This method is used when only the temperatures of inlet are available. Based on the inlet temperatures the heat transfer and effectiveness of the heat exchanger is calculated

C. NTU Method:

NTU stands for Number of Transfer of Units. This method is very efficient to use to design the heat exchangers when the final temperatures of the hot and cold fluids are not known. We can also find the outlet temperatures and heat flow rates with the help of some charts but it would be time taking as it involves large number of trials and it also least accurate. In this case the Effectiveness –NTU method is used.

The following tables are obtained based on the results obtained from the ANSYS Fluent Solver and NTU method which consists of the comparison between theoretical and experimental values.

For Counter flow:

TABLE III: Result for Titanium Counter Flow

S. No	Parameter	Experiment	Theoretical
1	Outlet Temperature of Cold Fluid	305 K	314 K
2	Outlet Temperature of Hot Fluid	434 K	442 K
3	Heat Transfer	227 KJ/S	169 KJ/S

TABLE IV: Result for Nickel Counter Flow

S. No	Parameter	Experimental	Theoretical
1	Outlet Temperature of Cold Fluid	296 K	304 K
2	Outlet Temperature of Hot Fluid	435 K	420 K
3	Heat Transfer	103.25 KJ/S	144 KJ/S

For Parallel Flow:

TABLE V: Result for Titanium Parallel Flow

S. No	Parameter	Experiment	Theoretical
1	Outlet Temperature of Cold Fluid	307 K	315 K
2	Outlet Temperature of Hot Fluid	353 K	360 K
3	Heat Transfer	132.5 KJ/S	104 KJ/S

TABLE VI: Result for Nickel Parallel Flow

S. No	Parameter	Experimental	Theoretical
1	Outlet Temperature of Cold Fluid	296 K	304 K
2	Outlet Temperature of Hot Fluid	435 K	420 K
3	Heat Transfer	103.25 KJ/S	144 KJ/S

VI. CONCLUSIONS

A CFD package (ANSYS FLUENT 18.1) was used for the numerical study of heat transfer characteristics of a double pipe heat exchanger for parallel flow and counter flow, and the results are then compared. The paper explains that there is not high variation in the of transfer of heat within the error limits performances of the parallel-flow and the counter-flow configuration.

For the given length and design of the heat exchanger transfer of heat increases in a double pipe heat exchanger is possibly achieved by various methods. Those techniques are divided into passive and active techniques. Active methods involve some external input for the increment of transfer of heat like induced vibrations, injection and suction of fluids and jet impingement etc.

The performance, CFD analysis of various fluids and various materials of pipe were investigated on counter and parallel flow in Double Pipe heat exchanger.

❖ The main objective of this project is to study the performance of the Nickel and Titanium Double pipe heat exchanger by using CFD.

❖ The heat transfer of the heat exchanger is calculated by CFD analysis and it is compared with the theoretical results.

❖ Both the results obtained are almost close to each other. Both the materials exhibit good heat transfer characteristics for the given specifications of the heat exchanger and with the certain assumptions.

❖ Both the parallel and counter flow cases are compared for both the materials.

❖ Based on the temperature contours and the theoretical results obtained it can be concluded that Nickel and Titanium Double pipe heat exchanger can be used where the required heat transfer is minimum.

❖ The ANSYS FLUENT results were found to be fairly consistent with hard calculations with most of the values within 5% of each other.

Future Scope of work:

❖ The corrosion effect of the different fluids on the heat exchanger can be analyzed in the ANSYS Fluent in order to take the consideration of the fouling factor.

❖ Further study must be continued to develop commercial heat exchangers made of Titanium and Nickel which is suitable for applications where heat transfer required is minimum.

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