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Fluent Analysis of U Tube Heat Exchanger with RIB Variations

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ABSTRACT:

Heat transfer is the most imperative phenomena in numerous industries which prompts design of heat recovery systems and in addition design of sub systems. The devices which are utilized for heat exchange is called as heat exchangers. Heat exchanger is a device used to exchange heat from a fluid on one side of a barrier to a fluid on the opposite side without bringing the fluid into direct contact. Typically, these tubes are produced using metal which has great thermal conductivity keeping in mind the end goal to exchange heat adequately starting with one fluid then onto the next fluid.

The aim of this study is to assess the influence of U tube heat exchanger to get best heat transfer by using U tube heat exchanger. The purpose of this study is to use CFD software and Experimental setup to analyze the Temperature drop, Pressure drop and Friction factors by varying under different Reynolds number such as 4870,8760,11432 and 15130 and changing heat exchanger tube material properties like copper and aluminium. The experiment is carried out by different rib thicknesses such as 1mm, 2mm, 3mm, 4mm and also by varying cross section such as 1-4mm, 2-5mm, 3-6mm and performed in turbulent flow to get better heat transfer rate.

The study of heat transfer coefficient of U tube heat exchanger under various rib thicknesses with different materials, it is predicted that 1-4 mm rib thickness exhibits better heat transfer than the remaining.

Key words:
U tube heat exchangers, cfd, catia, Ribs.

1. INTRODUCTION:

1.1 Classification of Heat Exchanger:

The heat exchangers can be classified in a few ways as per the transfer procedure, number of fluids and heat exchange mechanism. Conventional heat exchangers are classified on the premise of construction type and stream arrangement. The other criteria utilized for the classification of heat exchangers are the kind of process functions and fluids included (gas-gas, gas fluid, fluid, two phase gas etc.).The arrangement as indicated by the surface compactness manages one of the essential class of heat exchangers named as compact heat exchangers. There is a wide assortment of heat exchangers for different sorts of uses, hence the development also would vary broadly. Be that as it may, despite the variety, most heat exchangers can be classified into some basic types in light of some major design concept.

1.2 Tubular Heat Exchangers:

Tubular heat exchangers are by and large worked of round, curved and rectangular tubes. Flat twisted tubes have additionally been utilized as a part of a few applications. There is impressive adaptability in design because the core geometry can be varied easily by changing the tube diameter, length, and arrangement. Tubular heat exchangers can be intended for high pressures with respect to condition and high-pressure contrasts between the fluids. Tubular exchangers are utilized principally for liquid to-fluid and fluid to phase change (condensing or evaporating) heat exchange applications

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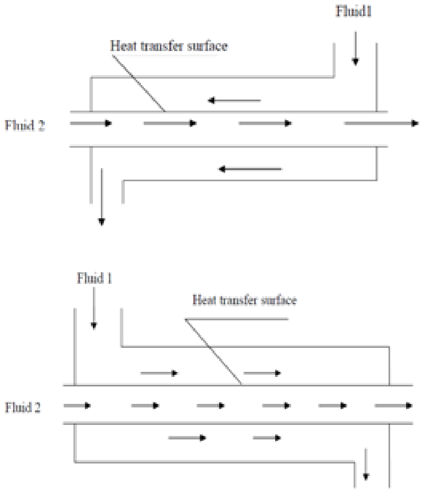

Fig 1.1: Double pipe heat exchanger

1.3 Heat Transfer Considerations:

The energy flow between hot and cold streams, with hot stream in the bigger diameter tube, is as shown in Figure 2.10. Heat transfer mode is by convection on the inside as well as outside of the inner tube and by conduction across the tube. Since the heat transfer occurs across the smaller tube, it is this internal surface which controls the heat transfer process. By convention, it is the outer surface, termed Ao, of this central tube which is referred to in describing heat exchanger area. Applying the principles of thermal resistance,

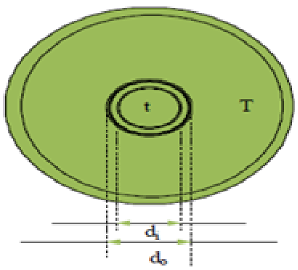

Fig 1.2: End view of a tubular heat exchanger

$$R = \frac{1}{h_o A_o} + \frac{\ln\left(r_o/r_i\right)}{2\pi \cdot kl} + \frac{1}{h_i A_i}$$

If we define overall the heat transfer coefficient, Uc, as:

$$U_c = \frac{1}{RA_o}$$

Substituting the value of the thermal resistance R yields:

$$\frac{1}{U_c} = \frac{1}{h_o} + \frac{r_o \ln\left(r_o/r_i\right)}{k} + \frac{A_o}{h_i A_i}$$

Standard convective correlations are available in text books and handbooks for the convective coefficients, ho and hi. The thermal conductivity, k, corresponds to that for the material of the internal tube. To evaluate the thermal resistances, geometrical quantities (areas and radii) are determined from the internal tube dimensions available.

1.4 Log Mean Temperature Differences:

Heat flows between the hot and cold streams due to the temperature difference across the tube acting as a driving force. As seen in the Figure 7.3, the temperature difference will vary along the length of the HX, and this must be taken into account in the analysis.

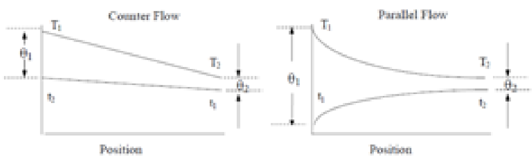

Fig.1.11:Log Mean Temperature Differences

1.5: Temperature Differences between Hot and Cold Process Streams

From the heat exchanger equations shown earlier, it can be shown that the integrated average temperature difference for either parallel or counter flow may be written as:

$$\Delta\theta = LMTD = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)}$$

The effective temperature difference calculated from this equation is known as the log mean temperature difference, frequently abbreviated as LMTD, based on the type of mathematical average that it describes.

While the equation applies to either parallel or counter flow, it can be shown that $\Delta\theta$ will always be greater in the counter flow arrangement. Another interesting observation from the above Figure is that counter flow is more appropriate for maximum energy recovery.

2. LITERATURE REVIEW:

In their paper they described the study of design of Shell and tube heat exchangers the tube sheets are very heavy. The reason is attributed to the over simplified mechanical model for the calculation of the tube sheet thickness especially the insufficient consideration of the tube support to the tube sheet. In their paper a 3-D finite element model was established for a U-tube heat exchanger consisting of tube sheet, tube channel, part of shell and tubes. [1] In his research paper he described the study of U-tube type of ground coupled heat exchanger, which is used in air-conditioning applications to improve the COP as external heat exchanger. This technique is wildly used in the last decades, and it is attracting the increasing research interest for such application. [2]

In their study they simulated the heat transfer performance of the U-tube heat exchangers with backfill materials of shape-stabilized phase change materials (PCMs) and crushed stone concrete in this paper. The shape-stabilized PCMs refer to a mixture of decanoic acid and lauric acid that the mass concentration of decanoic acid is 60% with10% silica and 6% expanded graphite. It makes the shape-stabilized PCM has the coefficient of thermal conductivity of 1.528 W/(m•K) and the latent heat of 109.2 kJ/kg. [3] In his research paper he described the study of triple tube heat exchanger. The heat exchanger consist of triple tube in various diameter. Triple tubes are located to concentric method with U tube arrangement. Hot fluid enters to one end and leave the cold fluids another end. The coolant fluid flow to middle of the tube. The hot fluid flow to remaining two tube with laminar flow of inside of the tubes. This flow is increase the effectiveness of heat transfer rating with U shape. [4]

In their paper they described the study of Combined heat exchanger with the ground source heat pump engineering in Hefei, a 100-meterdeep vertical u-shaped buried pipe was analyzed, and the experimental study on the heat transfer performance of different operating mode, the unit energy efficiency and the change of soil temperature field was taken under a typical climate condition in the summer of Hefei. The change of soil temperature field around the heat exchanger after running for a long time was simulated and analyzed. [5] In their research paper they described the study of analysis results wherein Naphtha fluid was maintained at a desired temperature in a stacked u-tube heat exchanger The main objective of work was finite element analysis of pressure vessel at different boundary condition. The stresses developed in pressure vessel were analyzed by using ANSYS. [6]

Used Catia Tools:

Circle, Rectangular Pattern, Circular Pattern, Pad, Pocket and Plane.

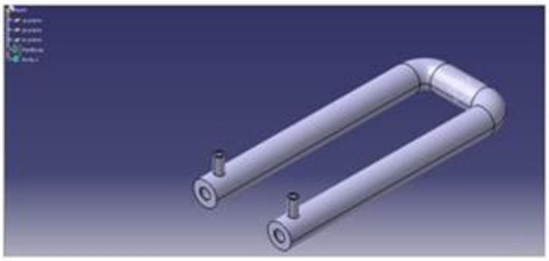

Fig.3.1 Designed Catia model of U Tube

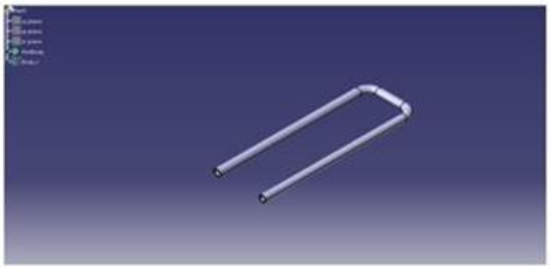

Fig 3.2 Designed Catia model of inner tube

Used Catia Tools:

Plane, Project 3D Elements, Pad, Pocket and Rectangular Pattern.

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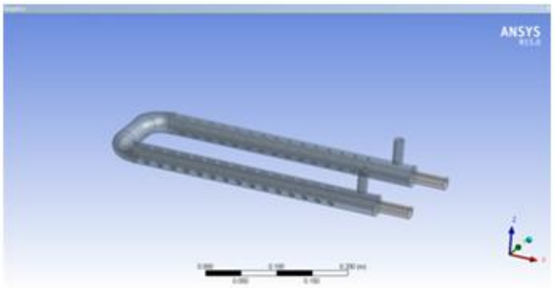

Fig 3.3 Designed Catia model of U tube without rib

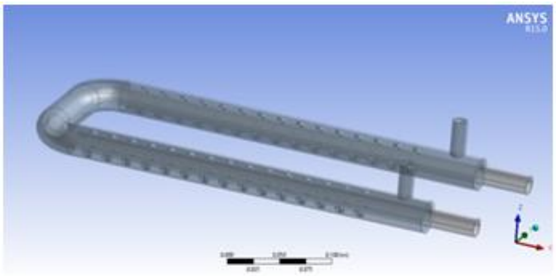

Fig 3.4 Designed Catia model of U tube with rib

1) Rib Thickness
Dimensions:
Rib thickness = 1mm,2mm,3mm,4mm.

Used Catia Tools:
Helix, Point, Line, Rectangle and Pad.

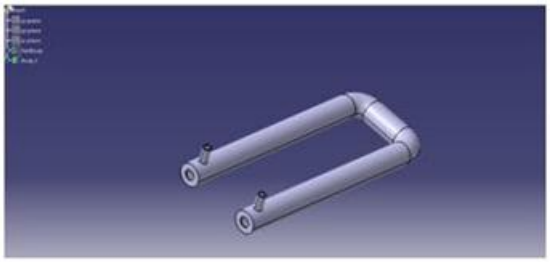

Fig 3.5 Designed Catia model with 1mm rib

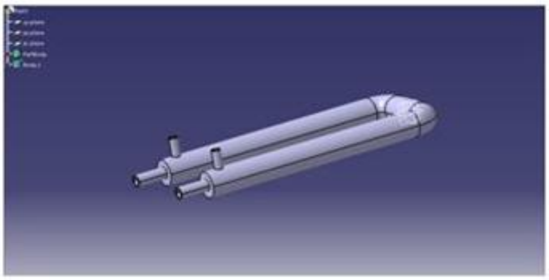

Fig 3.6 Designed Catia model with 2mm rib

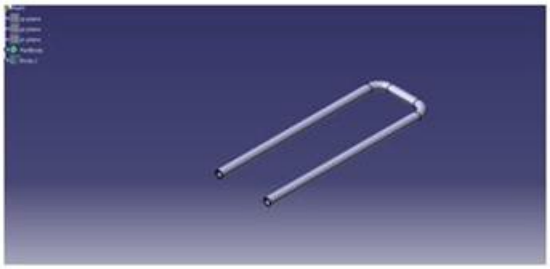

Fig 3.7 Designed Catia model with 1-4 convergent

PROBLEM DESCRIPTION:

Here we had calculated the effectiveness of heat exchanger by varying the velocities of fluids by considering the same mass flow rates. The experimental analysis is carried out by taking the combination of different fluids. The experimental is done on U-tube heat exchanger. Two reservoirs or tanks were constructed for storage of two fluids (i.e..,hot and cold fluids) The analysis is done for laminar flow of both fluids. The laminar flow is obtained by keeping constant mass flow rate.

4. CFD ANALYSIS:

Computational fluid dynamics (CFD) study of the system starts with the construction.

4.1 GEOMETRY:

Heat exchanger is built in the ANSYS workbench design module. It is a counter-flow heat exchanger. First, the fluid flow (fluent) module from the workbench is selected. The design modeller opens as a new window as the geometry is double clicked.

Fig. 4.1 Imported model in geometry

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Fig. 4.4 Fine Meshed model of U tube

Table.4.1 geometry type and model

PART NUMBER	PART OF THE MODEL	STATE TYPE
1.	INNER FLUID	FLUID
2.	OUTER FLUID	FLUID
3.	INNER TUBE	SOLID
4.	OUTER TUBE	SOLID

4.1 The Main Solver:

The solver is the heart of CFD software. It sets up the equation set according to the options chosen by the user and meshes points generated by the pre-processor, and solves them to compute the flow field.

4.2 MESHING:

Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the wall region. Later on, a fine mesh is generated. For this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed. Save project again at this point and close the window.

4.3 SETUP:

The mesh is checked and quality is obtained.

Table 4.2 cell zone conditions

Different material properties	Density (ρ) kg/m^3	Thermal conductivity(K) W/mk	Specific heat C_p j/kgK
Copper	8978	387.6	381
Aluminium	2719	203.2	871

4.3.1 BOUNDARY CONDITIONS:

Boundary conditions are used according to the need of the model. The inlet and outlet conditions are defined as velocity inlet and pressure outlet. As this is a counter-flow with two tubes so there are two inlets and two outlets. The walls are separately specified with respective boundary conditions. No slip condition is considered for each wall. Except the tube walls each wall is set to zero heat flux condition. The details about all boundary conditions can be seen in the table as given below.

Table 4.3 boundary conditions

	BOUNDARY CONDITION TYPE	MASS FLOW RATE (kg/s)	TEMPERATURE (k)
INNER INLET	Mass flow inlet	0.444	298
INNER OUTLET	Pressure outlet	-	-
OUTER INLET	Mass flow inlet	1.7377	348
OUTER OUTLET	Pressure outlet	-	-

4.4 SOLUTION:

RUN CALCULATION:

After giving the boundary conditions to the inner and outer fluid, finally we have to run the calculations. The number of iteration is set to 500 and the solution is calculated and various contours, vectors and plots are obtained.

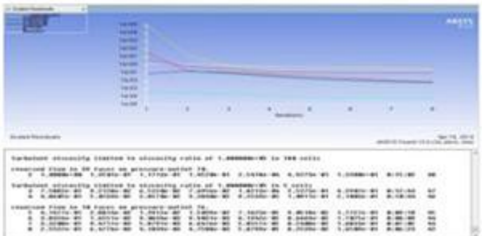

Fig 4.5 Calculations was running

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4.5The Post-processor:

The post-processor is the last part of CFD software. It helps the user to examine the results and extract useful data.

4.6 OVERVIEW OF FLUENT PACKAGE:

FLUENT is a state-of-the-art computer program for modelling fluid flow and heat transfer in complex geometries. FLUENT provides complete mesh flexibility, solving your flow problems with unstructured meshes that can be generated about complex geometries with relative ease. Supported mesh types include 2D triangular/quadrilateral, 3D FLUENT also allows user to refine or coarsen grid based on the flow solution.

5. RESULTS AND DISCUSSIONS:

The objective of this project is to predict that at which condition the maximum heat transfer rate is obtaining in U tube Heat Exchanger by introducing water and by changing parameters like inlet flow conditions, flow arrangements i.e. counter flow & parallel flow which are further divided into laminar flow & turbulent flow by maintaining constant temperature at inner inlet and outer inlet. Different materials like copper & aluminium were used by introduced.

The thickness of ribs are changed as 1mm,2mm,3mm,4mm. Simultaneously the inner rib thickness was also changed as 1-4mm and 2-5mm and 3-6mm thicknesses forming a convergent inside the tube. 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.

5.1 REPORTS:

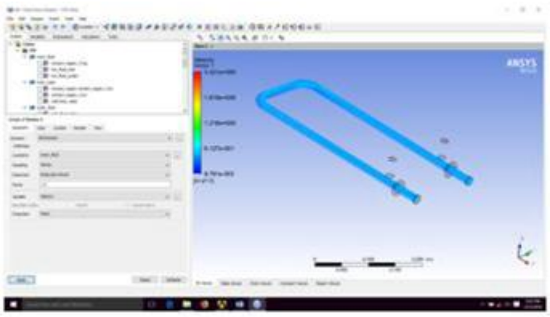

Fig 5.1 Velocity variation in Hot fluid at 1mm

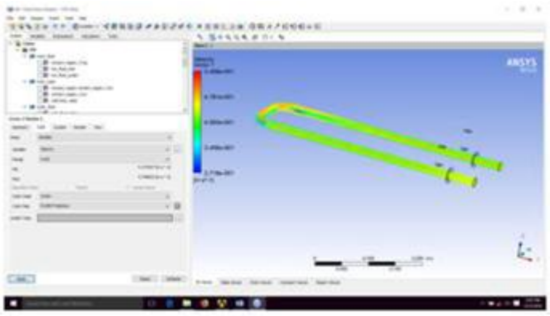

Fig 5.2 Velocity variation in Cold fluid 2mm

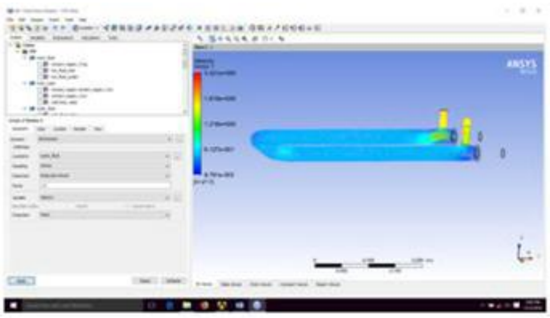

Fig 5.3 Velocity variation in cold fluid at 2 mm

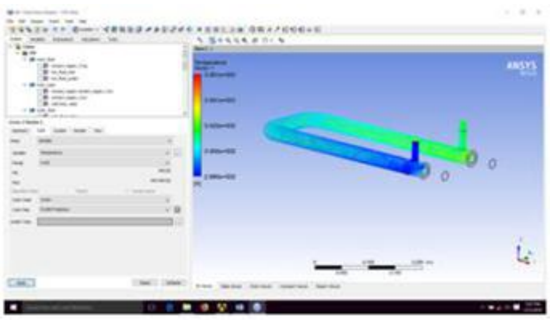

Fig 5.4 Temperature variation in cold fluid at 3 mm

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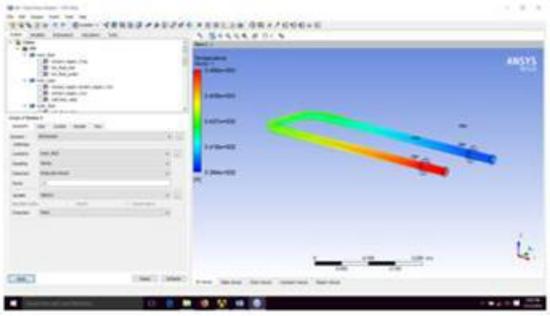

Fig 5.5 Temperature variation in hot fluid at 3 mm

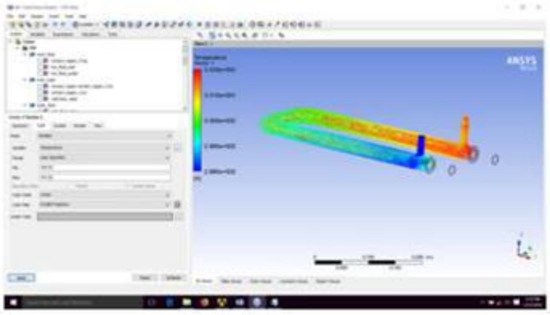

Fig 5.6 Temperature variation in cold fluid at 4 mm

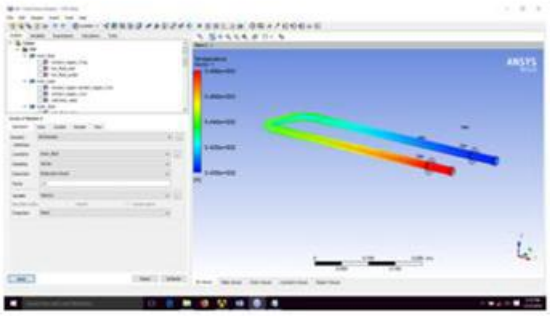

Fig 5.7 Temperature variation in cold fluid at 4 Mm

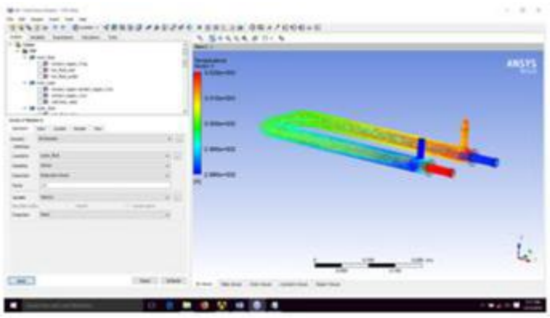

Fig 5.8 Temperature variation in heat exchanger at 4 mm

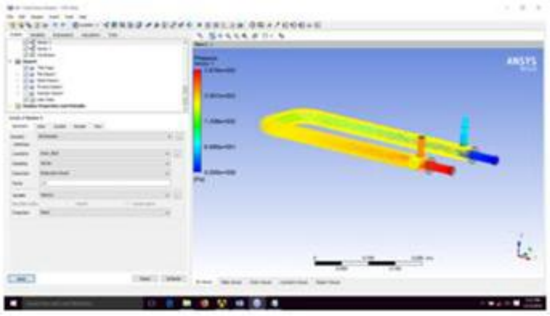

Fig 5.9 Pressure variation in heat exchanger at 4 Mm

By comparing the above results we got best results in 2mm rib thickness and further the simulation was carried out to the convergent thicknesses and varying cross section. Due to decrement shape of the ribs it reduces the dead zones in between inner tube and outer tube.

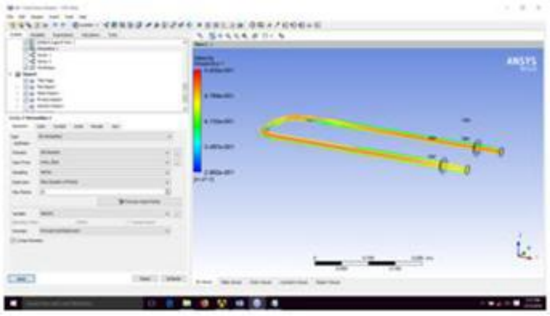

Fig 5.10 Velocity variation in hot fluid at 1- 4 mm

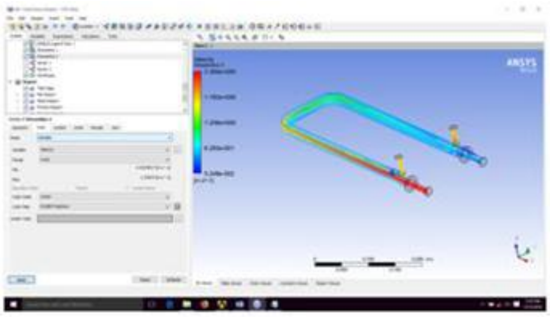

Fig 5.11 Velocity variation in heat exchanger at 1- 4 mm

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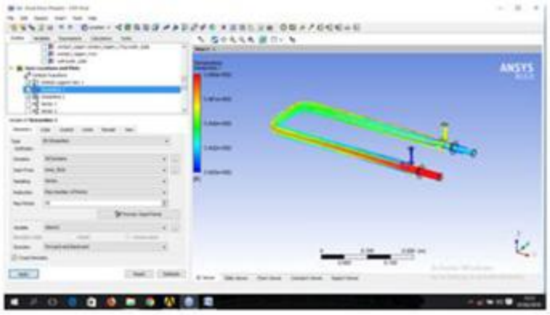

Fig 5.12 Temperature variation in heat exchanger at 2- 5mm

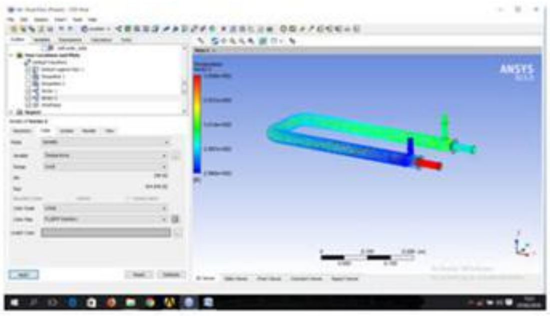

Fig 5.13 Temperature variation in heat exchanger at 3- 6mm

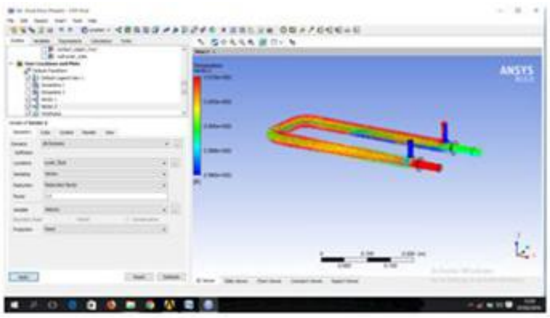

Fig.5.26 Temperature variation in heat exchanger at 3- 6mm

6. CONCLUSION:

At first, the main objective of this project is to create a validation between Experimental & CFD results which was performed using different organic solutions like Kerosene, Water and Transformer oil to check the percentage error, in order to affirm the experimental setup. As the percentage of error is within 4% the experimental setup is validated.

We have done experimental analysis on U-tube heat exchanger by varying different fluid combinations at constant inlet condition like mass flow rates for Turbulent flow. Following are the required results obtained from the experimental investigation. Hence from the above results we have concluded that Kerosene (Hot) – Water (Cold) combination have been proven as the best combination, which gives maximum effectiveness i.e. 35.6%. The experiment is carried out by different rib thicknesses such as 1mm, 2mm, 3mm, 4mm and also by varying cross section such as 1-4mm, 2-5mm, 3- 6mm and performed in turbulent flow to get better heat transfer rate. The study of heat transfer coefficient of U tube heat exchanger under various rib thicknesses with different materials, it is predicted that 1-4 mm rib thickness exhibits better heat transfer than the remaining.

7. REFERENCES:

[1] J.Y.LIU, "Light-weight design of the tube sheet of the U tube heat exchanger based on finite element analysis", Procedia engineering 130(2015) 275-285.

[2] A.F.Elmozughi, Prof. M.A. Muntasser, "Simulation of Vertical U Tube Heat Exchanger", Applied Thermal Engineering 30 (2012) 1331–1341.

[3] Xiangli Li, Cang Tong, Lin Duanmu, Liangkan Liu, "Research on U-tube heat exchanger with shape stabilized phase change backfill material", Procedia Engineering 146 (2016) 640 – 647.

[4] N.R.parthasarathy, S.Yogeswari, "Design and Analysis of Triple U Tube Heat Exchanger", International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) ISSN:0976-1353 Volume 12 Issue 4 –FEBRUARY 2015.

[5] Zhen Gao, Jinwei Ma, Xiaochun Yu, " Experimental and Simulation Study on vertical U Tube Underground Heat Exchanger in Ground-Source Heat Pump", conference paper.

[6] Sonali Gholap, Sushant Pande, Dr. D. R. Panchagade, "Finite Element Analysis of Stacked U Tube Heat Exchanger", Inter national Journal of Engineering Trends and Technology (IJETT) – Volume 39 Number 3- September 2016 ISSN: 2231-5381.

[7] J. Bala Bhaskara Rao and V. Ramachandra Raju, "Numerical and heat transfer analysis of shell and tube heat exchanger with circular and elliptical tubes", International Journal of Mechanical and Materials Engineering (2016) 11:6.

[8] Dhavalkumar Maheshwari1, Kartik Trivedi, " Experimental Investigation of U-tube heat exchanger using Plain tube and Corrugated tube", International Research Journal of Engineering and Technology-Volume: 03 Issue: 05 , May-2016, 2395 -0056.