ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Thermal Analysis of Shell and Tube Heat Exchanger by Using Fluent Tool

K.Maheswari Devi
Post Graduate Student,
Department of Mechanical Engineering,
Global College of Engineering & Technology,
Kadapa, A.P.

G.V. Nagamani, M.Tech, MISTE, AMIE
Associate Professor,
Department of Mechanical Engineering,
Global College of Engineering & Technology,
Kadapa, A.P.

ABSTRACT:

Heat exchangers are devices in which heat is transferred from one fluid to another. Heat exchangers are widely used equipment in various industries such as process, power generation, and transportation, refrigeration industry and chemical process industries. The process in solving simulation consists of modeling and meshing the basic geometry of shell and tube heat exchanger using FLUENT package ANSYS 14.5. In this project, modeling of shell and tube heat exchanger with baffles tubes and supports created by using CATIA V5R20 software. Then, the boundary condition will be set before been simulate in FLUENT based on the industrial data.The scope of this paper is to study the temperature distribution inside the shell and baffles using ANSYS FLUENT 14.5 software tool. Calculating the heat transfer capacity of the heat exchanger by mathematical modeling equations. The flow and temperature fields inside the shell and tube are resolved using a commercial FLUENT package. Our heat exchanger consists of two fluids (water) of different starting temperatures flow through the heat exchanger. Here, we are varied tubes with different materials copper and brass. Finally analysis has been done by varying the tube materials and hence it is observed that copper material gives the better heat transfer rates than the brass material.

1.INTRODUCTION:

The purpose of a heat exchanger is just that to exchange heat. Most processes require the heating or cooling of streams to produce a desired temperature before the stream can be fed to operations.

In any heat exchanger there must be a fluid that requires a change in energy (heating or cooling) and a fluid that can provide that energy change. One fluid is sent through a pipe on the inside of the heat exchanger while the other fluid is sent through a pipe on the outside. In this configuration, no mixing of the hot and cold fluids needs to take place. This is very convenient for many processes, especially when product purity needs to be ensured. This arrangement also allows for large quantities of heat to be transferred quickly, and it is relatively easy to maintain consistent operating conditions.There are three principle means of achieving heat transfer, conduction, convection, and radiation. Heat exchangers run on the principles of convective and conductive heat transfer. Radiation does occur in any process. However, in most heat exchangers the amount of contribution from radiation is miniscule in comparison to that of convection and conduction. Conduction occurs as the heat from the hot fluid passes through the inner pipe wall. To maximize the heat transfer, the inner-pipe wall should be thin and very conductive. However, the biggest contribution to heat transfer is made through convection.

There are two forms of convection; these are natural and forced convection. Natural convection is based on the driving force of density, which is a slight function of temperature. As the temperature of most fluids is increased, the density decreases slightly. Hot fluids therefore have a tendency to rise, displacing the colder fluid surrounding it. This creates the natural “convection currents” which drive everything from the weather to boiling water on the stove. Forced convection uses a driving force based on an outside source such as gravity, pumps, or fans. Forced convection is much more efficient, as forced convection flows are often turbulent.

Turbulent flows undergo a great deal of mixing which allow the heat to be transferred more quickly. In this particular apparatus, water is used as both the hot and cold fluid. The purpose of this heat exchanger is to cool a hot stream. Cooling water flows through the outer pipe (the shell), and hot water flows through the inner pipe on the inside. Heat transfer occurs in both directions; the hot water is cooled, and the cooling water is heated. This arrangement is called a "shell-and-tube" heat exchanger. There are many other forms of heat exchangers; most notably, the double-pipe heat exchanger. In this arrangement a cold fluid flows through a pipe in the center of the apparatus and is heated by a hot fluid on the outside of that pipe. The hot water used in the shell-and-tube heat exchanger is produced by means of a double-pipe heat exchanger. The discharge from the shell of the shell-and-tube heat exchanger is circulated through the inner pipe of the double pipe heat exchanger. Low-pressure steam condenses on the outside of the pipe, heating the water before it enters the tubes of the shell-and-tube heat exchanger.

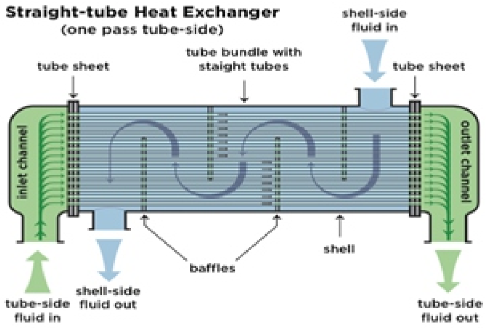

Fig 1.1 Tube Exchanger

1.1 Advantages and Disadvantages of Shell and Tube Heat Exchanger Advantages:

1.Less expensive as compared to Plate type coolers
2.Can be used in systems with higher operating temperatures and pressures
3.Pressure drop across a tube cooler is less
4.Tube leaks are easily located and plugged since pressure test is comparatively easy
5.Tubular coolers in refrigeration system can act as receiver also.
6.Using sacrificial anodes protects the whole cooling system against corrosion
7.Tube coolers may be preferred for lubricating oil cooling because of the pressure differential

Disadvantages:

1.Heat transfer efficiency is less compared to plate type cooler.
2.Cleaning and maintenance is difficult since a tube cooler requires enough clearance at one end to remove the tube nest.
3.Capacity of tube cooler cannot be increased.
4.Requires more space in comparison to plate coolers.

Limitations:

- Both shell side and tube side exposed to packing. Volatile and/or toxic fluids should be avoided.
- Packing limits design pressure and temperature for both shell and tube sides.

1.2 APPLICATIONS:

Industrial applications:

- Chemical process.
- Petrochemical & Refining.
- Food & dairy (Non sanitary only).
- Power generation.
- Nuclear.
- Water plants.

Sanitary Applications:

- Brewery process.
- Juice, sauce, soup, syrup & oils.
- Sugar.
- Portable water and clean in place solutions.
- Chocolate & peanut butter.
- Cheese, dairy, whey products.
- Blood, plasma and meat.

Pharmaceutical applications:

- Ultra pure water.
- Pure steam.
- Blood, plasma and growth media.
- Formulated pharmaceutical.

1.3 INTRODUCTION OF FLUENT:

One of the biggest challenges in the engineering industry is being able to come up with efficient and optimal designs for new products.

One of the strongest tools offered is FLUENT. FLUENT is a very useful program recently acquired by ANSYS. It has the capability to model fluid flow past objects with the ability to design, test, and analyze results all under one program. Although it is a strong tool for engineering, it is also very difficult to use. For this reason, tutorials have been created to teach FLUENT with the hope that these tutorials will serve as a fundamental tool in teaching and as references for future senior design projects. The way the tutorials are set up are by creating and analyzing basic flow fields and then to ensure the accuracy of each test case it is then validated against a scholarly reference.The structure of the tutorials is to first reproduce the fundamentals learned in a Fluid Mechanics and Thermo Dynamics courses. One of the first scenarios learned in fluid mechanics is the flow through a cylindrical pipe. The tutorials created follow very closely to how a fluid mechanics course would be taught. For this reason, the first tutorial is the laminar flow of fluid through a cylindrical pipe. The next tutorial is turbulent flow of fluid through a cylindrical pipe. By doing the turbulent case, it will allow the user to see the difference between laminar and turbulent flows and to gain some insight as to why different methods of analyzing structures in FLUENT are necessary. The next created learning module is to analyze flow over a flat plate. Analyzing the flow over a flat plate is very important because it will give the user a more in-depth look as to what happens when flow passes over an object. In addition, other tutorials such as a turbulent flow past a nozzle, turbulent jet flow, turbulent compressible and incompressible flow past an airfoil, turbulent incompressible flow past a periodic airfoil, and a discrete phase modeling tutorials are created to be able to serve as fundamental tutorials so that the user may then use them as precursors to analyzing more complicated problems.In addition, one of the most important parts in creating the tutorials is the need for validation. Validation is extremely important when analyzing solutions, because it is the only way to ensure the accuracy of the results obtained in FLUENT. Validation is made by comparing results from FLUENT to theoretical and experimental data from scholarly sources.

2. RESULTS AND DISCUSSIONS

2.1 DESIGN OF SHELL AND TUBE HEAT EXCHANGER:

In this project work has taken steel 1008 material for shell, copper and brass material for tube. Hence these materials have good working properties compared to the other materials such as Silver, Cast Iron, Aluminum etc.

2.2 DIMENSIONS OF MODELLING:

Dimensions of shell and tube heat exchangers:

No of tubes = 07
Length of the tubes = 300mm
Tube diameter = 15mm
Shell length = 500mm
Shell diameter = 100mm
Thickness = 3mm

Table 1: THERMAL PROPERTIES OF STEEL 1008

Thermal Conductivity	45 W m^-1 C^-1
Density	7872 kg m^-3
Specific Heat	481 J kg^-1 C^-1

Table 2: THERMAL PROPERTIES OF FRESH WATER

Thermal Conductivity	0.604 W m^-1 C^-1
Density	997.4 kg m^-3
Specific Heat	4179 J kg^-1 C^-1

Table 3: THERMAL PROPERTIES OF BRASS

Thermal Conductivity	111 W m^-1 C^-1
Density	8600 kg m^-3
Specific Heat	162 J kg^-1 C^-1

Table 4: THERMAL PROPERTIES OF COPPER

Thermal Conductivity	400 W m^-1 C^-1
Density	8933 kg m^-3
Specific Heat	385 J kg^-1 C^-1

2.3 Modeling of Shell and Tube Heat Exchanger in CATIAv5

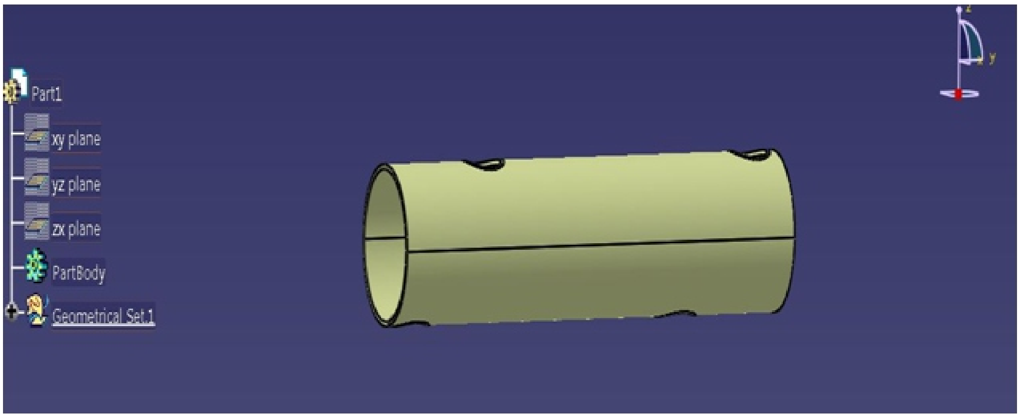

Fig 2: Design of shell

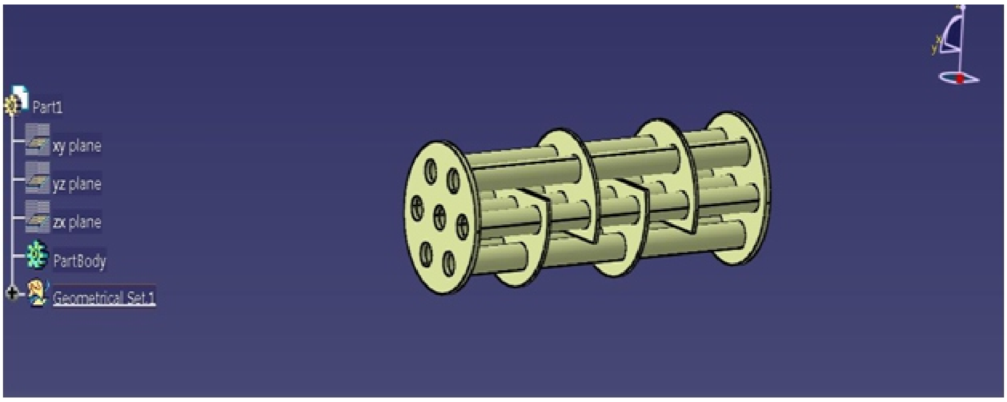

Fig 3: Design of tubes and baffles

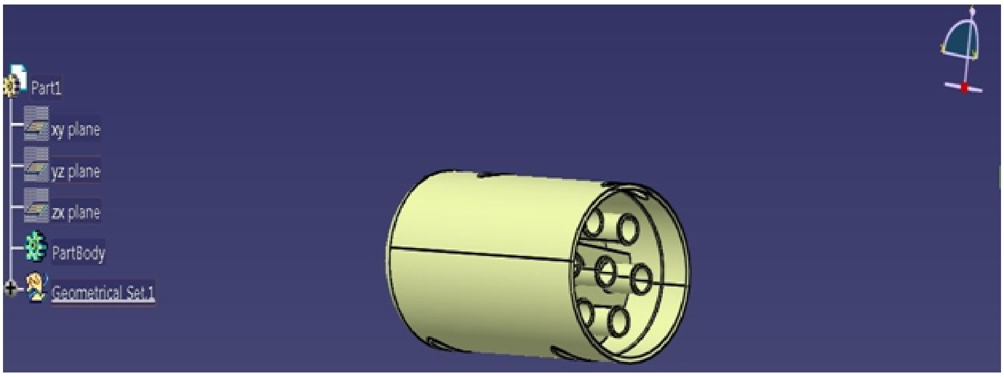

Fig 4: Assembled part

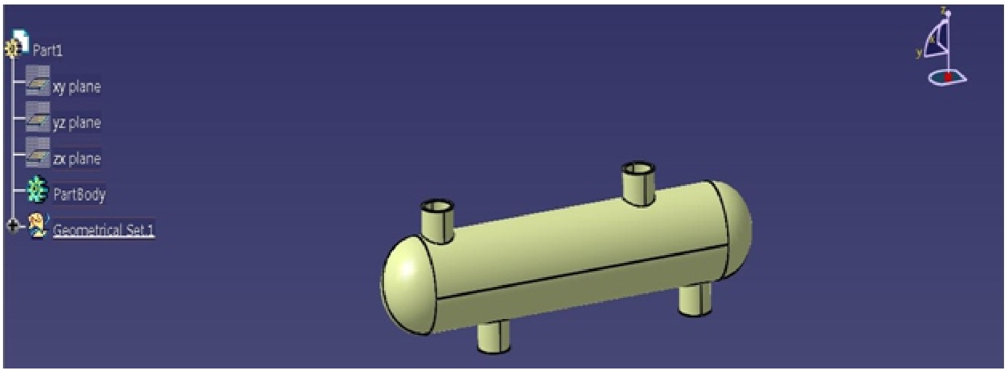

Fig 5: Shell and tube heat exchanger

2.4 FLUENT analysis of shell & tube heat exchanger:

1.First, Prepared shell and tube heat exchanger model in CATIA V5 and Save as this part as IGES for Exporting into Annoys Workbench 14.5 Environment. Import .IGES Model in ANSYS Workbench Simulation Module.

2.Apply material for shell and tube heat exchanger model. The material properties of shell and tubes are show in table 1, 2, 3 and 4.

3.Mesh the shell and tube heat exchanger model. The meshing model of shell and tube heat exchanger model as show in figures

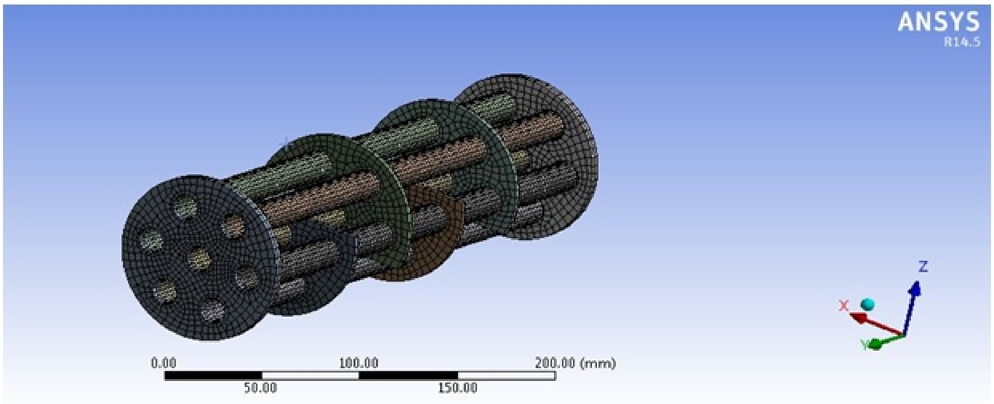

Fig 6: Meshing of tubes with baffles

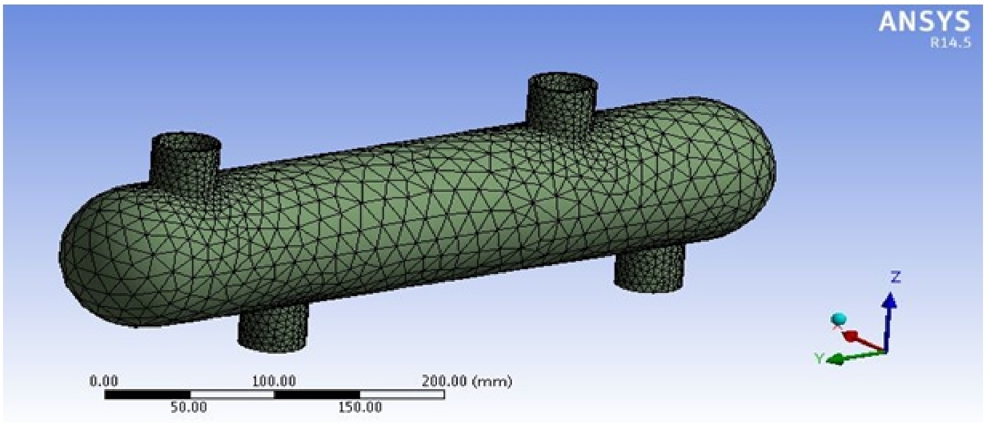

Fig 7: Meshing model of shell & tube heat exchanger arrangement

4.Define type of analysis : FLUENT analysis

5.Define boundary condition for Analysis Boundary conditions play an important role in finite element calculation here; we are giving cold and hot water inlet velocities 0.312m/s and 1.21m/s respectively.

6.Run the analysis

7.Get the results

2.5 Heat exchanged by LMTD method

Analytical analysis

General formula for calculating heat transfer:

The heat release from the shell and tube heat exchangers was obtained by multiplying over all heat transfer co-efficient, Area of tubes and difference of temperatures.

$Q = FUA\ (\Delta T)\ m$

Where,
F = Correction factor
U = overall heat transfer coefficient, W/m²K
A = area, m²
(ΔT) m = LMTD
Inlet velocity of cold water in shell Vc = 0.312m/s
Cold water inlet $T_{ci}=28^0c$
Cold water outlet $T_{co}=35^0c$
Inlet velocity of hot water in shell Vh = 1.2m/s
Hot water inlet $T_{hi}=82^0c$
Hot water outlet $T_{ho}=44^0c$

$$(\Delta T)_m = \frac{(T_{hi}-T_{co})-(T_{ho}-T_{ci})}{\ln\left[\frac{T_{hi}-T_{co}}{T_{ho}-T_{ci}}\right]}$$

$$(\Delta T)_m = \frac{(82-35)-(44-28)}{\ln\left[\frac{82-35}{44-28}\right]}$$

$$=28.78^0\mathrm{C}$$

$$(\Delta T)_m=301.78\mathrm{K}$$

$$A=\frac{\pi}{4}\times d^2\times l$$

$$A=\frac{\pi}{4}\times 0.015^2\times 0.3$$

$$=5.3\times 10^{-5}\mathrm{m}^2$$

For hot water to cold water overall heat transfer coefficient range is 800-1500 w/m²k
We can take U=1150 w/m²k
Calculating correction factor F:

$$R=\frac{T_{hi}-T_{ho}}{T_{co}-T_{ci}}$$

$$R=\frac{82-44}{35-28}=5.42$$

$$P=\frac{T_{co}-T_{ci}}{T_{hi}-T_{ci}}$$

$$P=\frac{35-28}{82-28}=0.129$$

Correction factor F=PR=0.7
Q = FUA (ΔT) m
=0.7 1250 5.3 10-5 301.78
Q =14W
From fluent analysis fig1 and 2 we can observe
(ΔT)m=383K for copper tubes
(ΔT)m=295K for brass tubes
Heat transfer in copper tubes
Q = FUA (ΔT) m
=0.7 1250 5.3 10-5 300=14W
Heat transfer in brass tubes
Q = FUA (ΔT) m
=0.7 1250 5.3 10-5 295=13.6W

2.6 FLUENT ANALYSIS RESULTS

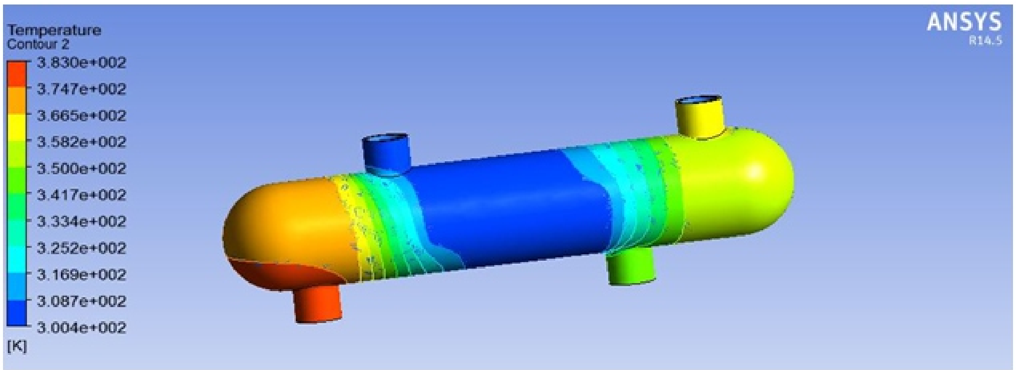

Fig 8: Temperature distribution on steel shell with copper tubes

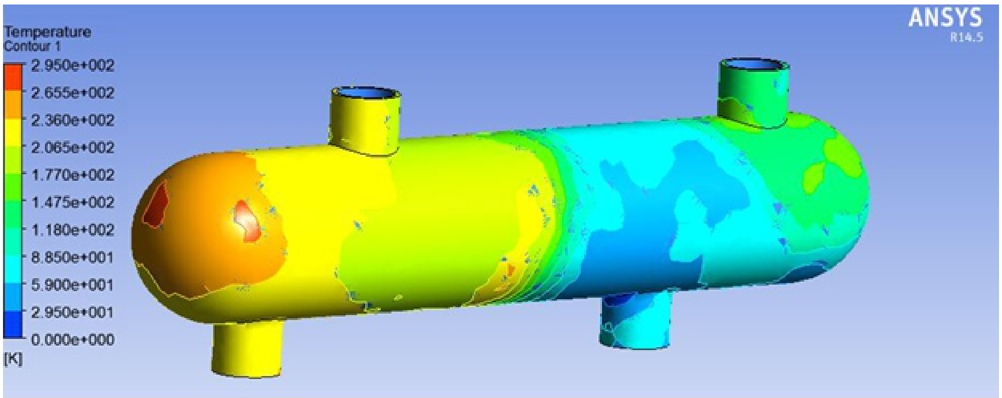

Fig 9: Temperature distribution on steel shell with brass tubes

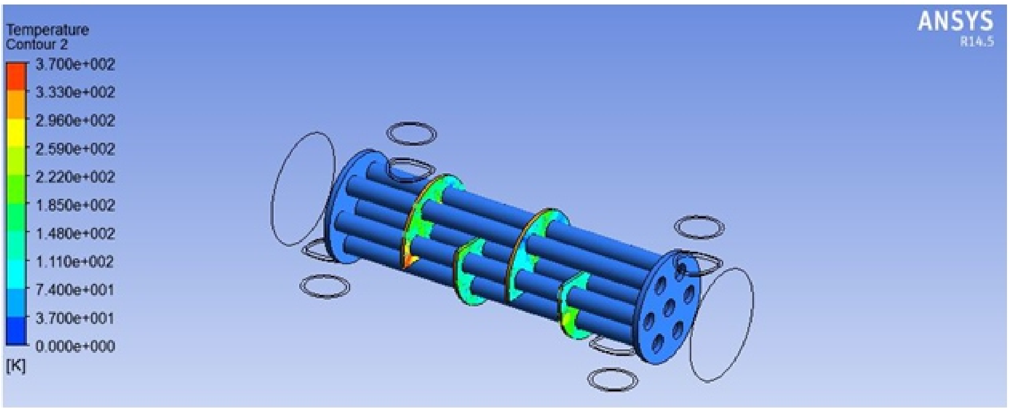

Fig 10: Temperature distribution on baffles with copper tubes

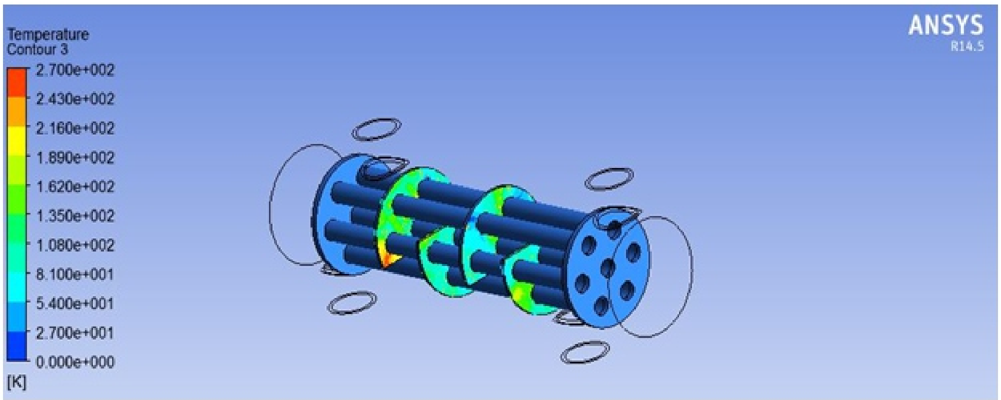

Fig 11: Temperature distribution on baffles with brass tubes

From the fig 28 the maximum temperature appears at hot water inlet side. The minimum temperature appears at cold water inlet. This fluent analysis has done by using only hot water and cold water inlet velocities. The hot water inlet velocity is 1.21m/s and cold water inlet velocity is 0.312m/s. These values are taken from reference journal [1]

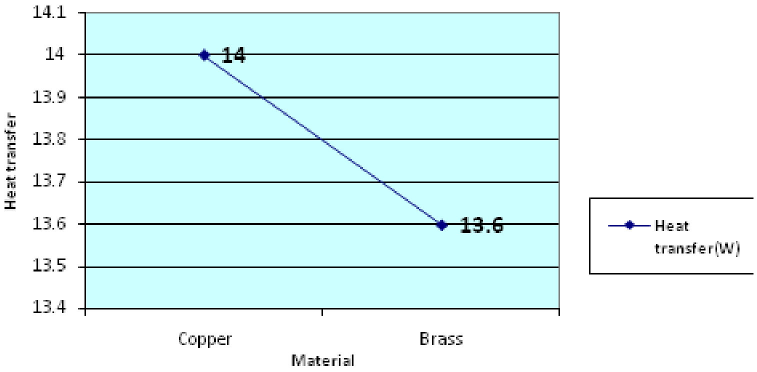

Fig 12: heat transfer for materials

The heat exchanged by copper and brass tubes is calculated by using LMTD method. The ΔT has taken from the fluent analysis fig 1 and 2.

3. CONCLUSION:

After performing all the analysis work for shell & tube heat exchangers the following observation had been done. From the study of results as shown in figures.

1.In this Project, the shell and tube heat exchanger model was created by CATIA V5 R20 software. Then, the model created by CATIA was imported to ANSYS14.5 software.

2.The above result shows the fluent analysis results for shell and tube heat exchanger so we can say that FLUENT is a good tool to reduce time consuming theoretical work.

3.Thus the ANSYS results are calculated for copper and brass materials. The heat released from copper material is 14w and that from brass is 13.6 w which is less when compared with the copper as shown in figure 30 and 31.

4.By changing the tube material from the brass to the copper, temperature difference between output temperature of copper & brass had been varied.

5.The maximum temperature (ΔT)m with copper tubes is obtained 383k and the maximum temperature for brass is obtained 295k as shown in figure 28 and 29. The temperature distribution on baffles as shown in figure

6.By changing the materials of tubes heat transfer rate can be improved in shell and tube heat exchanger.

7.Finally analysis has been done by varying the tube materials and hence it is observed that copper material gives the better heat transfer rates than the brass material.

4. FUTURE WORK:

1.Rate of heat transfer can be improved by varying the tube diameter, length and no of tubes.

2.By changing the fluent heat transfer can be improved.

3.By changing number of baffles heat transfer can be improved.

4.By changing the temperature of tubes and medium rate of heat transfer can be improved.

By changing the materials of tubes heat transfer rate can be improved.