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Analysis and Best Insulating Material to Reduce the Heat Losses in Heat Exchangers

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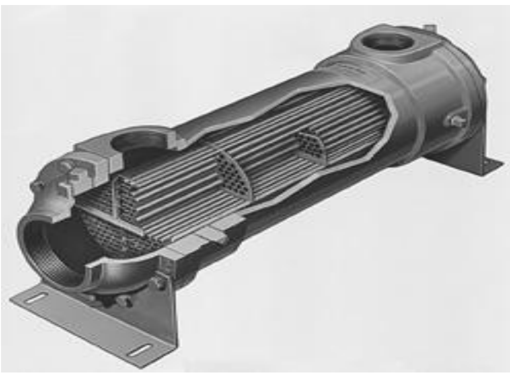
ABSTRACT: The main objective of this work is to analyze the best insulation material for shell and tube Heat exchanger and airflow pattern using results obtained from computational fluid dynamics Module FLUENT. This deals with the computational fluid dynamics analysis of flow in heat Exchanger. This involves with the three dimensional analysis of flow through a heat exchanger having inlet and outlet. The software used for this purpose is CATIA v5 and ANSYS 18.0. The three dimensional model of the heat exchanger are made by CATIA v5 and analysis are to be carried out by module FLUENT. The models are first generated using the data and then meshed after that various velocity and pressure contours are to be drawn and graphed in this work to analyze the flow. Various graphs indicating the variation of velocity, pressure and temperature of the fluid flow heat exchanger are given. This work strongly focused on optimum insulation material and lowest cost insulation material which
give best results and to reduce weight of heat exchanger.

I. INTRODUCTION

A shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure and higher-temperature applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed by several types of tubes: plain, longitudinally finned, etc.



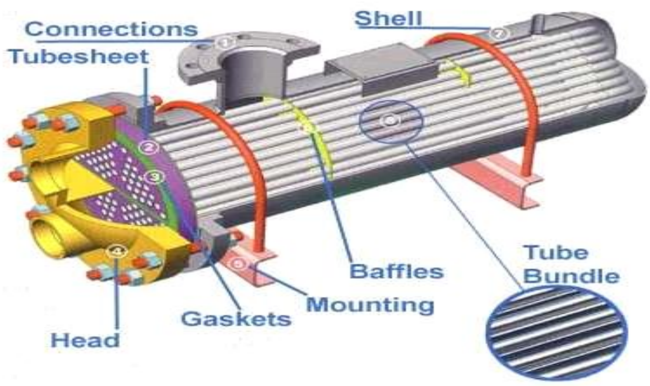


Fig 1.1: shell and tube heat exchanger.

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A heat exchanger is a device for transferring heat from one fluid to another, where a solid wall separates the fluids so that they never mix. They are widely used in refrigeration, air conditioning, space heating, power production, and chemical processing. One common example of a heat exchanger is the radiator in a car, in which the hot radiator fluid is cooled by the flow of air over the radiator surface.

Two fluids, of different starting temperatures, flow through the heat exchanger. One flows through the tubes (the tube side) and the other flows outside the tubes but inside the shell (the shell side). Heat is transferred from one fluid to the other through the tube walls, either from tube side to shell side or vice versa. The fluids can be either liquids or gases on either the shell or the tube side. In order to transfer heat efficiently, a large heat transfer area should be used, leading to the use of many tubes. In this way, waste heat can be put to use. This is an efficient way to conserve energy.

Heat exchangers with only one phase (liquid or gas) on each side can be called one-phase or single-phase heat exchangers. Two-phase heat exchangers can be used to heat a liquid to boil it into a gas (vapor), sometimes called boilers, or cool a vapor to condense it into a liquid (called condensers), with the phase change usually occurring on the shell side. Boilers in steam engine locomotives are typically large, usually cylindrically-shaped shell-and-tube heat exchangers. In large power plants with steam-driven turbines, shell-and-tube surface condensers are used to condense the exhaust steam exiting the turbine into condensate water which is recycled back to be turned into steam in the steam generator.

A. shell and tube heat exchanger types

There can be many variations on the shell and tube design. Typically, the ends of each tube are connected to plenums (sometimes called water boxes) through holes in tubesheets. The tubes may be straight or bent in the shape of a u, called u-tubes.

A.1.u-tubes

The shell and tube (u-tube) is the most common type of heat exchanger used in the process, petroleum, chemical and hvac industries, it contains a number of parallel u-tubes inside a shell. Shell tube heat exchangers are used when a process requires large amounts of fluid to be heated or cooled. Due to their design, shell tube heat exchangers offer a large heat transfer area and provide high heat transfer efficiency.

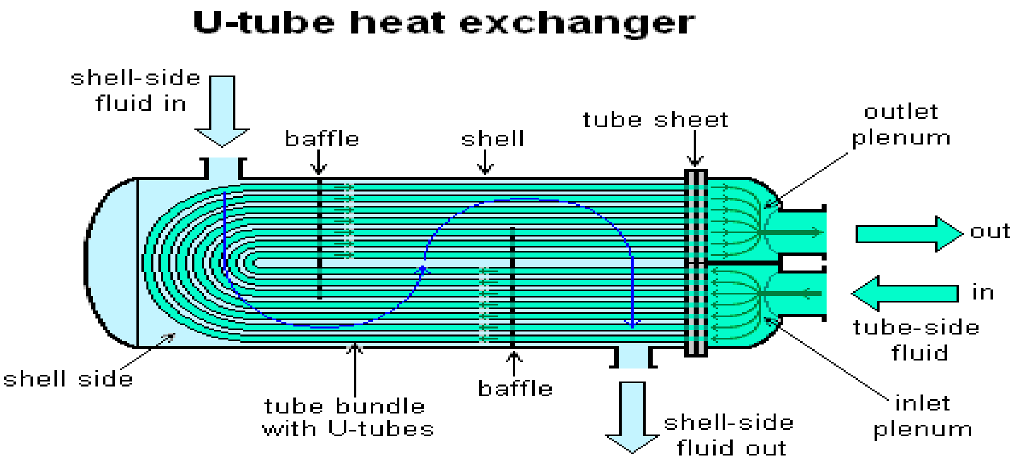

fig 1.2: u-tube heat exchanger.

In nuclear power plants called pressurized water reactors, large heat exchangers called steam generators are two-phase, shell-and-tube heat exchangers which typically have u-tubes. They are used to boil water recycled from a surface condenser into steam to drive the turbine to produce power. Most shell-and-tube heat exchangers are either 1, 2, or 4 pass designs on the tube side. This refers to the number of times the fluid in the tubes passes through the fluid in the shell. In a single pass heat exchanger, the fluid goes in one end of each tube and out the other.surface condensers in

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power plants are often 1-pass straight-tube heat exchangers. Two and four pass designs are common because the fluid can enter and exit on the same side. This makes construction much simpler.

A.2 straight-tube 1-pass

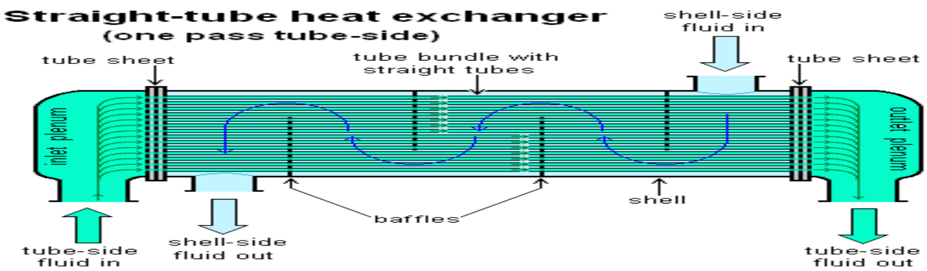

fig 1.3: straight tube heat exchanger(onepass tube-side)

One pass means that the fluid enter on one side and exit on the other side of the heat exchanger

A.3 straight-tube 2-pass

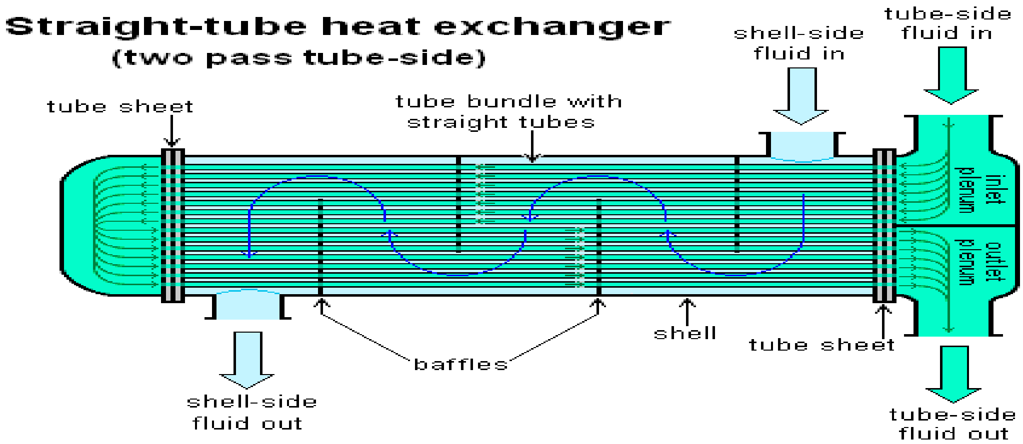

Fig 1.4:straight tube heat exchanger(two pass tube-side).

Two pass heat exchanger means that the fluid enters and exit on the same side of the heat exchanger. There are many different types or designs of shell and tube heat exchangers to meet various process requirements. Shell and tube heat exchangers can provide steady heat transfer by utilizing multiple passes of one or both fluids. Sec shell and tube heat exchangers come in two (2) and four (4) pass models standard, and multi-pass custom models

Shell and tube heat exchangers use baffles on the shell-side fluid to accomplished mixing or turbulence. Without the use of baffles, the fluid can become stagnant in certain parts of the shell.

B INTRODUCTION TO CAD

Throughout the history of our industrial society, many inventions have been patented and whole new technologies have evolved. Perhaps the single development that has impacted manufacturing more quickly and

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significantly than any previous technology is the digital computer. Computers are being used increasingly for both design and detailing of engineering components in the drawing office.

Computer-aided design(cad) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. Cad is most commonly associated with the use of an interactive computer graphics system, referred to as a cad system. Computer-aided design systems are powerful tools and in the mechanical design and geometric modeling of products and components. There are several good reasons for using a cad system to support the engineering design

Function:

- To increase the productivity
- To improve the quality of the design
- To uniform design standards
- To create a manufacturing data base
- To eliminate inaccuracies caused by hand-copying of drawings and inconsistency between
- Drawings

Initially, catia name is an abbreviation for computer aided three-dimensional interactive application the french dassault systems is the parent company and ibm participates in the softwares and marketing, and catia is invades broad industrial sectors, and has been explained in the previous post position of catia between 3d modelling software programs.. A window will be opened and there are types of design.

II. LITERATURE REVIEW

Muhammad mahmood aslam bhutta et al.[1] focuses on the applications of computational fluid dynamics (cfd) in the field of heat exchangers. It has been found that cfd employed for the fluid flow mal-distribution, fouling, pressure drop and thermal analysis in the design and optimization phase. Different turbulence models such as standard, realizable and rng, k – ε, rsm, and sst k - ε with velocity-pressure coupling schemes such as simple, simplec, piso and etc. Have been adopted to carry out the simulations. Conventional methods used for the design and development of heat exchangers are expensive. Cfd provides cost effective alternative, speedy solution and eliminate the need of prototype, it is limited to plate, shell and tube, vertical mantle, compact and printed circuit board exchangers but also flexible enough to predict the fluid flow behavior to complete heat exchanger design and optimization involving a wide range of turbulence models and integrating schemes the k - ε turbulence model is most widely employed design and optimization .the simulations results ranging from 2% to 10% with the experimental studies. In some exceptional cases, it varies to 36%.

III. THEORETICAL CALCULATION OF HEAT EXCHANGER

In this present work different types of analysis are performed. Here double tube in shell with insulating material model is selected. Water is sending with 0.001 m/s velocity in shell as well as tubes. Out put and inlet temperature are noted as below. And further calculation is performed using thermal calculations.

Tube inlet temp = 30°c = 303 k
Shell inlet temp = 50°c = 323 k
Velocity in tube = 0.001 m/sec
Velocity in shell = 0.001 m/sec

Water:

T_{c1}= shell inlet temp = 303 k
T_{c2}= shell outlet temp = 304.25 k
T_{h1}= tube inlet temp = 323 k
T_{h2}= tube outlet temp = 313.92 k

Properties of water:

Thermal conductivity k= 0.6 w/mk
Specific heat cp = 4182 j/kgk
Density = 998.2 kg/m^3

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Viscosity μ= 0.001033 pa-s
Heat carried by hot water $q_h = m_h \times c_p \times \delta t_h$ = j/sec
Δt_h = temp difference in hot water = 323-313.92 = 9.08k
Q_h = 0.01 x 4182 x 9.08
= 379.7j/sec
Heat carried by cold water qc = $m_c \times c_p \times \delta t_c$
Δt_c = temp difference in cold water = 304.25-303 = 1.25 k
Q_c = 0.1 x 4182 x 1.25
= 522 w
The average of two readings $q_{avg} = (q_h + q_c)/2$
Q_{avg} = (379+522)/2
= 450 w
$Q_{max} = m_{min} \times c_p \times (t_{h1} - t_{c1})$
= 0.01 x 4182 x (343-303)
= 1672 w
Heat exchanger effectiveness:
Effectiveness (ϵ) = (q_{avg} / q_{max})
€ = 450/1672
= 0.26
Log mean temperature difference (lmtd):

$$LMTD = \frac{\delta t1 - \delta t2}{\ln(\frac{\delta t1}{\delta t2})}$$

$\Delta t_1 = t_{h1} - t_{c2}$
= 18.75k
$\Delta t_2 = t_{h2} - t_{c1}$
= 10.92k
Lmtd = 14.4 k
Overall heat transfer coefficient (uo):
The outer surface area of heat exchanger
$A_o = \pi d_o$ l
D_o= outer dia of tube
= 25.4mm
L = heat exchanger length
= 0.2 meter
Area $a_o = \pi \times 12.7 \times 10^{-3} \times 0.5$
= 0.01632 m^2

IV. MODELLING OF INLINE FLAT TUBES

To create the heat exchanger catia v5-6r 2016 software is used.here the heat exchanger mainly consists of four parts, they are, one is tubes, second one is water in tube, third one is air and final one is fins. All these are individual components. X-y plane is selected to draw sketch which is circular tube of dia is 25.4 mm and 100 mm,all are spaced at 30 mm vertical pitch using circular command(for inline arrangement) as shown in fig.4.1.

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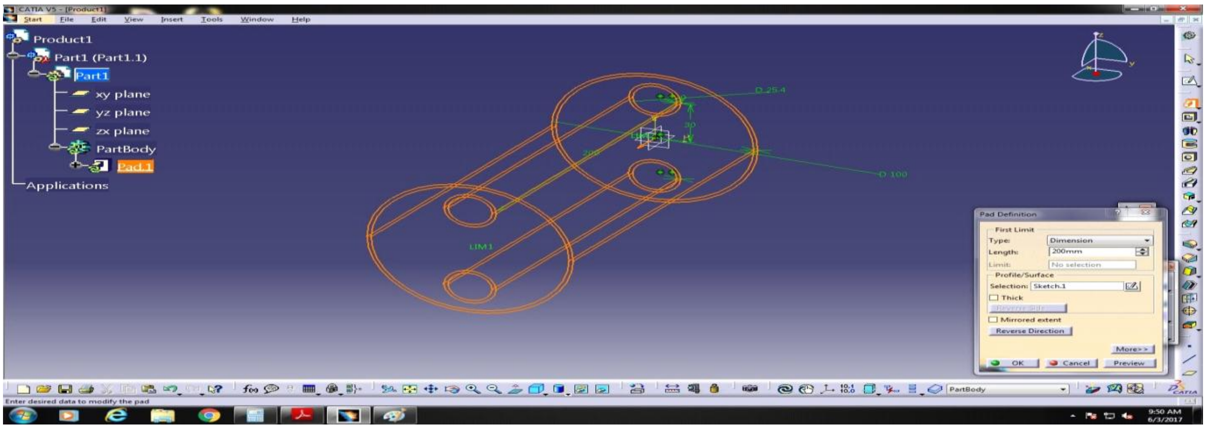

Fig.4.1.1 extruded part of circular tube

The pad command is used to extrude the sketch of the circular tube to a length of 200 mm as shown in fig.4.1.2

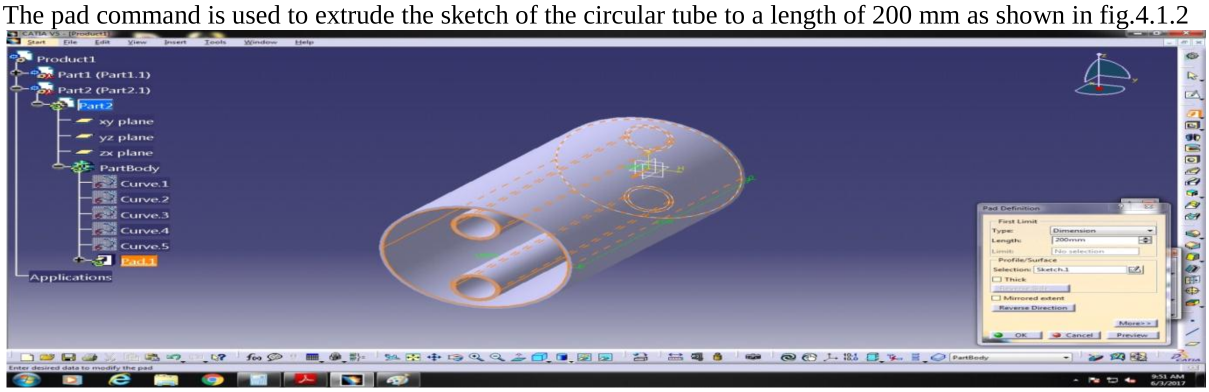

Fig.4.1.2 domain for water flow

Project 3d elements command is used to create the water domain for flow of water as shown in fig.

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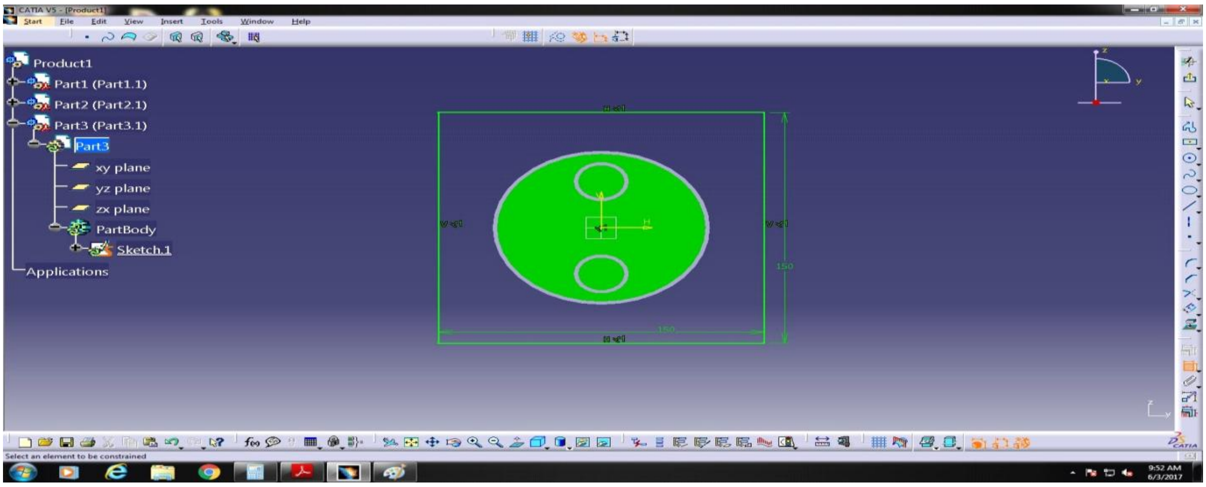

Fig.4.1.3 domain for air flow

MERGING

After import the model into ansys from catia, it will show the model as 3 parts . For merge operation, all the 4 parts are selected using control and merged as 1 part. At the end it will show as 1 part and 4 bodies. The 4 bodies within 1 part are shown in table 4.2.1

Part number	Part name	State of part
1	Pipes and insulation	Solid
2	Water in pipes	Fluid
3	Exhaust air	Fluid

Table 4.2.1: naming of various parts of the body with state type.

V. SOLUTION

A 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. Gravity is defined as y = -9.81 m/sec^2

B models

Energy is set to on position. Viscous model is selected as “k-ε model (2 equation). Radiation model is changed to discrete ordinates.

VI. RESULTS OF FLUENT ANALYSIS

It is a cross flow unmixed heat exchanger. Initially the fluid is passing through the tubes with a velocity of 0.001m/s and at a temperature of 50^{o}c. The air is entering with 18 kmph speed at a temperature of 27^{o}c flowing over the tube surface. The heat is transferred from the water to the tube surface by convection and then from the tube the heat is transferred parallely from the parallel pipes by conduction and convection and from tube surface to cold fluid by convection. Now varying the materials of insulating materials and the reynolds number of water flow, the results are obtained as follows.

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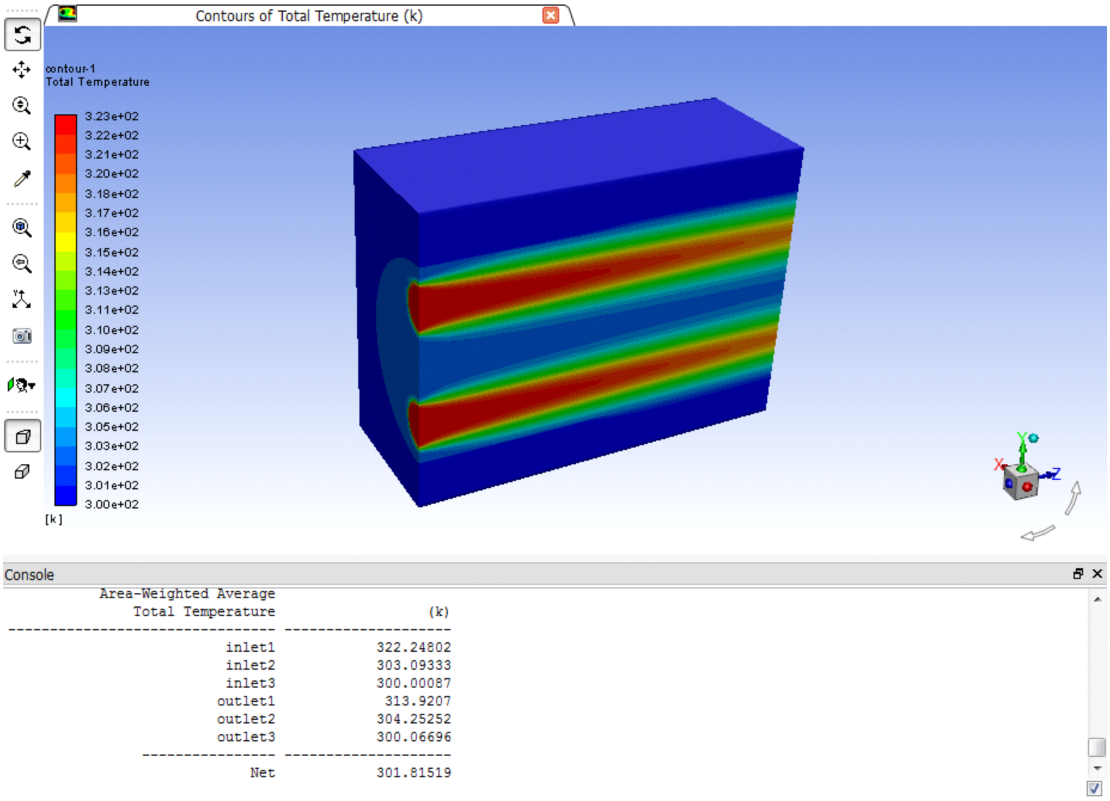

Fig 6.1: temperature distribution in heat exchanger without insulating materials.

The above fig.6.1 shows the temperature distribution of symmetry model of heat exchanger. Here red color is indicates as max temperature and blue color indicates as minimum temperature. Pipe inlet temperature is 322 k and outlet temperature is 313.9 k. Shell inlet temperature is 303 k and outlet temperature is 304.25k. Air inlet temperature is 300 k and outlet temperature is 300.06 k. We can show all reading from above image.

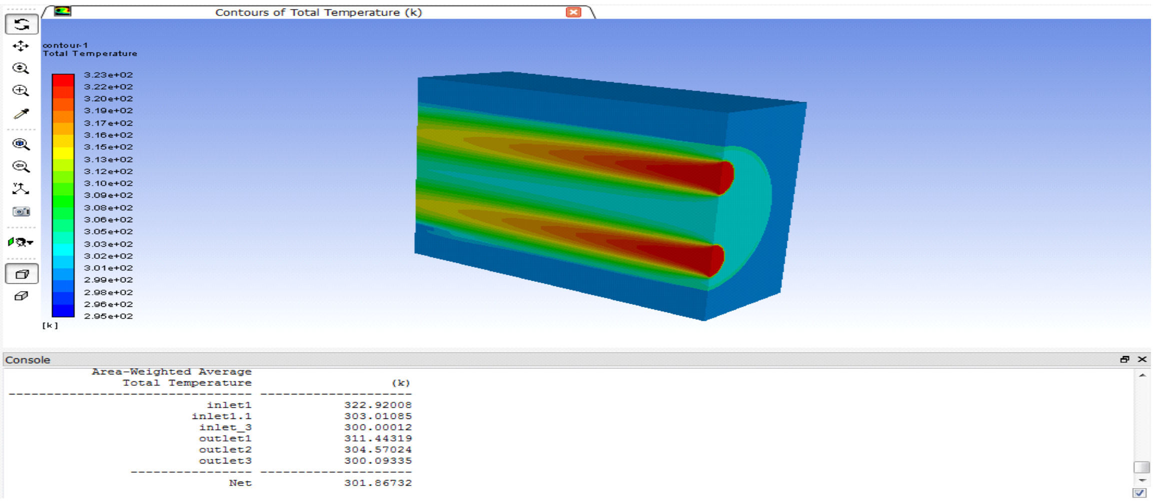

Fig6.2: temperature distribution in heat exchanger with insulating material at velocity 0.001m/s.

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The above fig.6.2 shows the temperature distribution of symmetry model of heat exchanger with pipe inlet 0.001m/s. Here red color is indicates as max temperature and blue color indicates as minimum temperature. Pipe inlet temperature is 322 k and outlet temperature is 311.4 k. Shell inlet temperature is 303 k and outlet temperature is 304.57k. Air inlet temperature is 300 k and outlet temperature is 300.093 k. We can show all reading from above image.

VII.CONCLUSION

In this present work three dimensional fluent analysis is performed on shell tube heat exchanger. Generally when shell is directly contacted to air, heat losses can be observed in heat exchanger. To element of this insulating material is only source to reduce the heat losses.

In this project five types of insulating materials are selected, which is using material are present market. Modeling has done using catia software and analysis is performed in ansys fluent. Initially comparison has done between insulating heat exchanger and without insulating materials. If we increase the flow velocity , the heat exchange rate cannot transfer from high temperature to low temperature properly. After compared the all the results insulation material2 i.e, polystyrene having good thermal properties as compared to remaining materials. If we compare the without insulating material with insulation 2 material, 30% effectiveness has increase with insulating material. Efficiency and overall heat transfer has increased 10% and 50%. Finally if we provide the polystyrene insulation to the shell we can get the more heat transfer to the coolant.

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