Design and Analysis of a Heat Exchanger with Helical Baffles by using CFD

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ABSTRACT
Heat exchangers are used extensively in engineering applications. In present day shell and tube heat exchanger are the most common type heat exchanger widely used used in cars, in planes, in boilers, in ships, in refrigeration systems, in air conditioning systems, in power stations, in oil refineries, in space applications, in renewable energy applications because it suits high pressure applications. The performance of heat exchangers has always been an important part to the lifecycle and operation. Whether developing a new heat exchanger or optimizing the design of an existing one, understanding the coupled fluid flow and heat transfer physics, or the “conjugate heat transfer” process, associated with heat exchanger operation, is essential to provide better cooling performance. The process in solving simulation consists of modeling and meshing the basic geometry of shell and tube heat exchanger using CFD package ANSYS 15.0v.The most important goal of the conjugate heat transfer analysis is to identify the heat transfer characteristics.The objective of the paper is design of shell and tube heat exchanger with helical baffle and study the flow and temperature field inside the shell using ANSYS software tools. The heat exchanger contains 7 tubes and 600 mm length shell and diameter of 90 mm. The helix angle of helical baffle will be varied from 0 to 200mm. In simulation will show how the pressures vary in shell due to different helix angle and flow rate. The flow pattern in the shell side of the heat exchanger with continuous helical baffles was forced to be rotational and helical due to the geometry of the continuous helical baffles, which results in a significant increase in heat transfer coefficient per unit pressure drop in the heat exchanger. Based on these results, design iterations can be easily implemented which can predict the influence of design parameters such as tube diameter, number of loops, loop distribution, etc. Ultimately, an optimal fluid flow.

Key words: Heat exchangers, helical baffles, heat exchanger feasibilities.

1.0 Introduction

In the cross flow exchanger the fluids flow normal to each other. Thermodynamically, the effectiveness of the cross flow exchanger falls between the parallel and counter flow exchangers. This is one of the most common flow arrangements used for extended surface heat exchanger, because it greatly simplifies the header design at the exit of each fluid.

The entrance and exit ports for the shell fluid and tube fluid are referred to as “Nozzles”. These nozzles are pipes of constant cross section welded to the shell and channels. They are used to distribute or collect the fluid uniformly on shell and tube sides.

1.1BAFFLES

It is apparent that higher heat transfer coefficient results when the liquid is maintained in the state of turbulence. To induce turbulence outside the tube it is customary to employ baffles, which cause the liquid to flow through the shell at right angles to the exit of the tubes. Baffles are used to support tubes, enable a desirable velocity to be maintained for the shell side fluid, and prevent failure of tubes due to flow-induced vibration.

2.0 DESIGN PARAMETERS WITH CATIA

CATIA started as an in-house development in 1977 by French aircraft manufacturer Anions Marcel Dassault, at that time customer of the CADAM software to develop Dassault's Mirage fighter jet. It was later adopted in the aerospace, automotive, shipbuilding, and other industries. Computer Aided Three dimensional Interactive Application (CATIA) is well known software for 3-D designing and modelling for complex shapes. Commonly referred to as 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development (CAX), including conceptualization, design (CAD), engineering (CAE) and manufacturing (CAM).

In the present context, the components of heat exchanger are modeled using part drawing features and then assembly modules used, further the assembly of the heat exchanger is model generated. The part drawing is a versatile module where in the whole heat exchanger can be modeled as a single unit as opposed to the assembly module where each part is modeled separately and finally assembled to get the required component using the various options available. The geometric model of heat exchanger is shown below.

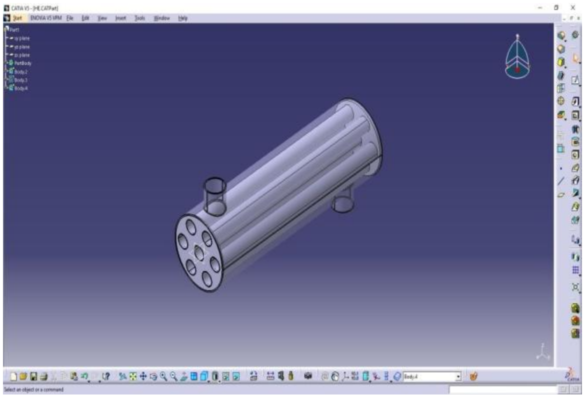

Figure 2.1 Design of heat exchanger in CATIA

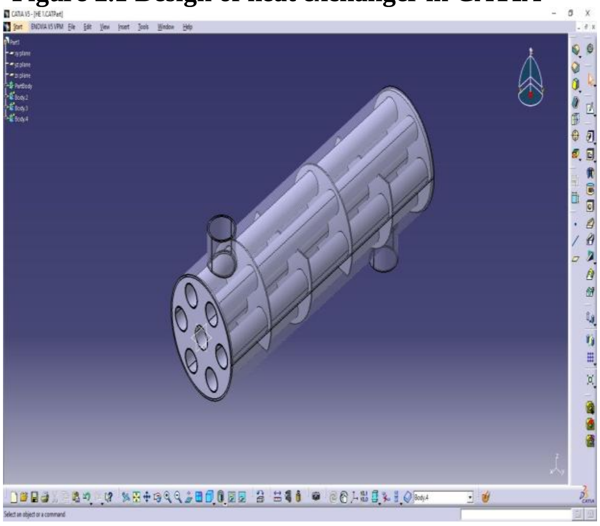

Figure 2,2 shows Assembly of heat exchanger by using CATIA.

3.0 BOUNDARY CONDITIONS AND MESHING: MESH GENERATION:-

In finite element analysis the basic concept is to analyze the structure, which is an assemblage of direct pieces called element, which are connected together at a finite number of points called nodes loading boundaries condition are then applied to this elements and a network of this elements is known as mesh. The finite element model is carried out in Ansys and the following thermal boundary conditions are imposed.

Convective film coefficient=0.37225e-3W/mm^2 ^{0}C

Temp inlet =33 .00 ^{0}C

Temp outlet =34.3 0 ^{0}C

The following material properties are given as input

For brass

Thermal conductivity =0.105W/m-K

Coefficient of Thermal expansion=1.9e-5/^{0}C

Young's Modulus =1.05e+5MPa

Poisson's Ratio =0.307

Density=8.75 g/c.c

For steel

Thermal conductivity =0.05 W/m-K

Coefficient of Thermal expansion =6e-006/^{0}C

Young's Modulus (EX)=2e+005MPa

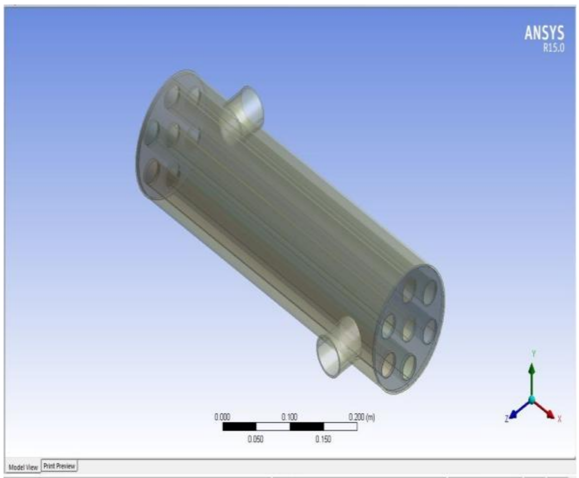

Figure 3.1 shows the simulated diagram of heat exchanger in ANSYS soft ware

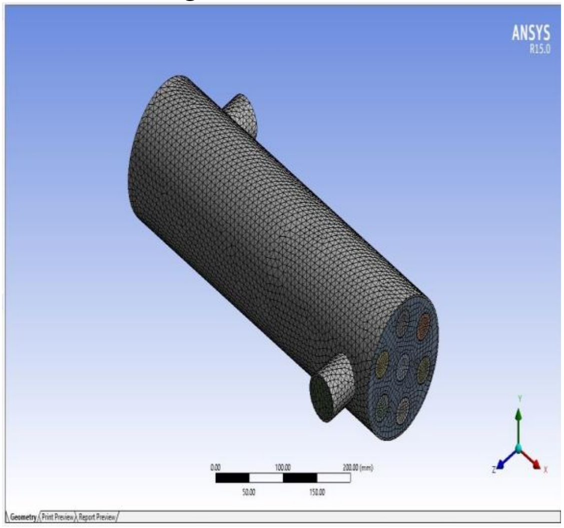

Figure 3.2 shows the simulated diagram of heat exchanger in ANSYS software

4.0 PROCEDURE FOR ANALYSIS

Preferences-structural-thermal: Preprocessor:

Element type-switch element type-structural to thermal-OK

Solution-define load-delete-all load data-all load options-close

Plot-Elements

Preprocessor-element type-close

Material properties-material models

Material model 1(brass)

Linear isotropic properties-

Young's Modulus (EX)=1.05e+5MPa Poisson's Ratio (NUXY)=0.307

Thermal Properties-

Coefficient of Thermal expansion (ALPX)=1.9e-5/^{0}C

Thermal conductivity (KXX)=0.105W/m-K

Material model 2(steel)

Linear isotropic properties-

Young's Modulus (EX)=2e+005MPa

Thermal properties-

Coefficient of Thermal expansion (ALPX)=6e-006/^{0}C

Thermal conductivity (KXX)=0.05 W/m-K

Thermal Analysis

Plot-elements

Select-components/assembly-by component name-OK

Pipe-apply-OK-Common-also select-OK

Plot-elements (select everything below selected elements)

Solution-define loads-apply-thermal-temperature-on nodes-box-OK

Temperature value-33-OK-fit-Temperature-on nodes-box-OK

Temperature value-34.3-OK-fit

Define loads-apply-Thermal-connection-on elements-Uniform-pick all-0.37225e-3W/mm^2 ^{0}C-bulk temperature-49.7 ^{0}C –OK

Select-components-components/assembly-OK

Shell-from full set-OK-Plot-elements

Select-everything below-selected elements-apply-convection-uniform

Pick all-0.37225e-3W/mm^2 ^{0}C-bulk temperature-49.7^{0}C –OK

4.1 30% PROPYLENE GLYCOL AND 70% WATER AT 40^{0}C

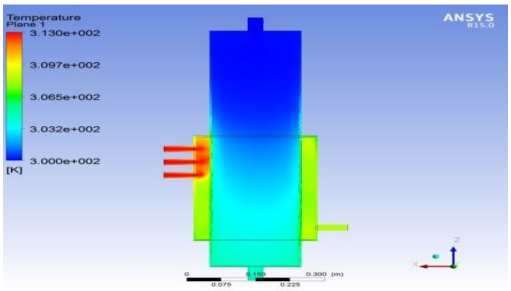

Figure 4.1 shows the temperature flow at an applied conditions in heat exchanger

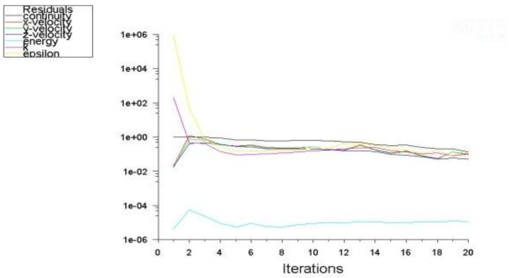

Figure4.2 shows the graph between iterations and velocity and energy etc..

4.2 40 %PROPYLENE GLYCOL 60%WATER AT 65^{0}C

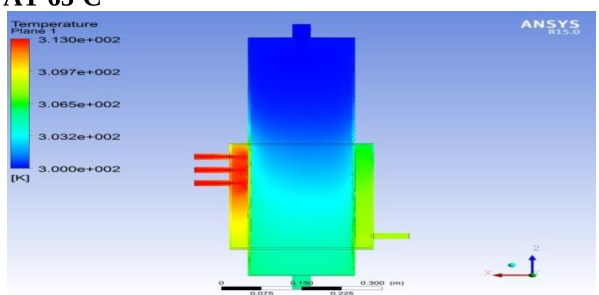

Figure 4.3 shows the Temperature variation inside the heat exchanger at given conditions.

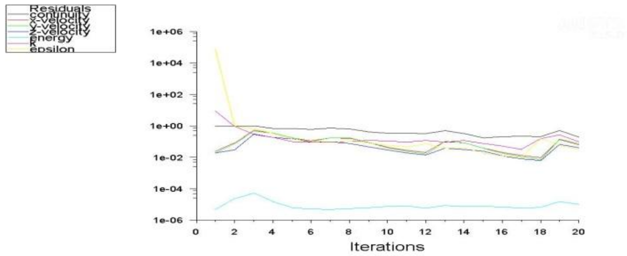

Figure 4.4 shows the graph between and velocity inside the heat exchanger

4.3 40% PROPYLENE GLYCOL 60% WATER AT 90^{0}C

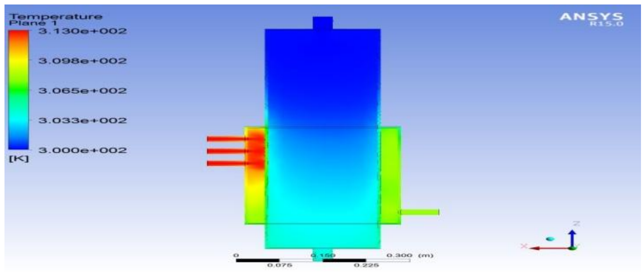

Figure 4.5 shows the Temperature differences inside the heat exchanger

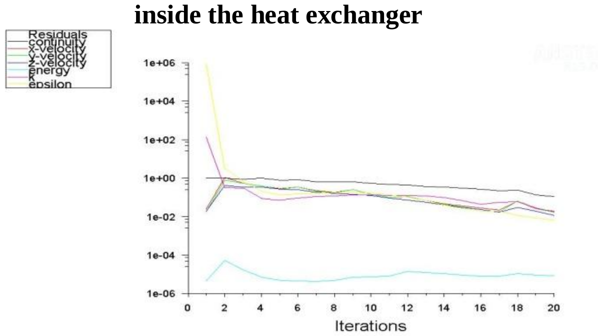

Figure4.6 shows the graph between and iteration velocity inside the heat exchanger

4.4 40% PROPYLENE GLYCOL AND 60 %WATER AT 40^{0}C

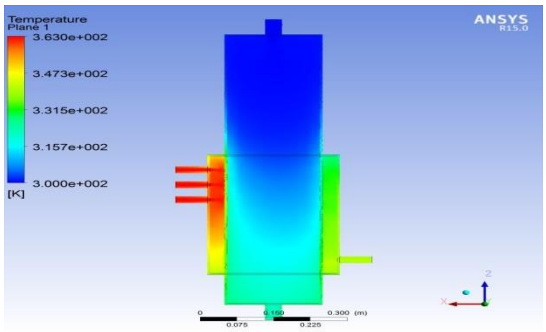

Figure4.7 shows the Temperature analysis inside the heat exchanger at given conditions.

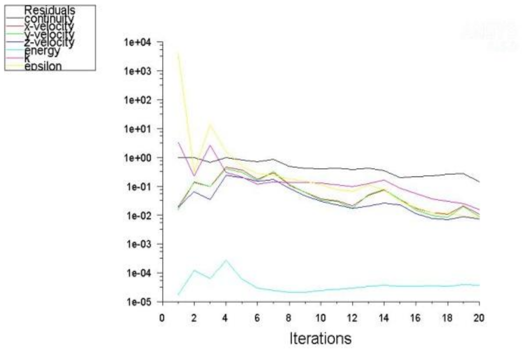

Figure4.8 shows the graph between and velocity inside the heat exchanger

5.0 RESULTS

5.1 40% AT PROPYLENE GLYCOL AND 60% AT WATER

TEMPERATURE - 40^0C (313K):-

Mantel Inlet – 313k

Mantel Outlet – 308.38k

Water Inlet – 300k

Water Outlet – 304.95k

NET – 305.43k

TEMPERATURE – 65^0C (338K):-

Mantel Inlet – 338k

Mantel Outlet – 322.01k

Water Inlet – 300k

Water Outlet – 310.79k

NET – 314.455k

TEMPERATURE – 90^0C (363K):-

Mantel Inlet – 363k

Mantel Outlet – 340.29k

Water Inlet – 300k

Water Outlet – 322.60k

NET – 325.82k

6.0 CONCLUSIONS

However higher specific heat and thermal conductivity of glycol-water mixture results in higher values of mantle side and tank side heat transfer coefficients 52.82 and 41.455 respectively. The disadvantage with the glycol-water mixture is that, glycol should be removed as hazardous waste at regular intervals. The second inlet position 52.82^0C below the top of the mantle tank for the mantle heat exchanger at high inlet temperature of 90°C, high mass flow rates of mantle fluid and the mantle fluid with high thermal properties can improve the performance of the mantle heat.

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