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CFD Analysis for Flow and Temperature Distribution in Shell and Tube Heat Exchanger with Baffles

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Abstract: **Shell-and-tube heat exchanger is one of the most widely used heat exchange apparatus in various industrial processes and in research fronts. Baffle selection is critical to control and improve the thermo-hydraulic performance of this type of heat exchanger. three-dimensional computational fluid dynamics (CFD) Analysis, using the commercial software, have been performed to study and compare the Temperature, heat transfer coefficient Velocity pressure distribution between the segmental baffles and helical baffles at low shell side flow rates. In this comparison, the whole heat exchangers consisting of the shell, tubes, and baffles are modelled. The model predicts the thermo-hydraulic performance with a considerably good accuracy, by comparing with Segmental baffle and helical baffle with 5 turns and 6 turns. The model is created using the commercial software and the heat transfer analysis is carried out using the fluent therefore the obtained results is then compared using the nanofluid Al_2O_3 in shell side.**

Keywords: **Shell and Tube Heat Exchanger; Nanofluid Al_2O_3; Segmental Baffle; Helical Baffles; CFD Analysis;**

I. INTRODUCTION

One of the most important processes in engineering is the heat exchange between flowing fluids, and many types of heat exchangers are employed in various types of installations, as petro-chemical plants, process industries, pressurized water reactor power plants, nuclear power stations, building heating, ventilating, and air-conditioning and refrigeration systems. As far as construction design is concerned, the tubular or shell and tube type heat exchangers are widely in use.

The shell-and-tube heat exchangers are still the most common type in use. They have larger heat transfer surface area-to-volume ratios than the most of common types of heat exchangers, and they are manufactured easily for a large variety of sizes and flow configurations. They can operate at high pressures, and their construction facilitates disassembly for periodic maintenance and cleaning. The shell-and-tube heat exchangers consist of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and a second fluid flows within the space between the tubes and the shell. Typical Shell-and-Tube heat exchanger is shown in Figure 1.

Heat exchangers in general and tubular heat exchangers in particular undergo deterioration in performance due to Temperature Distribution. The common idealization in the basic tubular heat exchanger design theory is that the fluid is distributed uniformly at the inlet of the exchanger on each fluid side throughout the core. However, in practice, Temperature Distribution is more common and significantly reduces the idealized heat exchanger performance. Temperature Distribution can be induced by the heat exchanger geometry, operating conditions (such as viscosity or density-induced Distribution), multiphase flow, fouling phenomena, etc. Geometry-induced Temperature Distribution can be classified into gross Temperature Distribution, passage-to-passage Temperature Distribution and manifold-induced Temperature Distribution.

The flows in shell-and-tube heat exchangers have only been investigated analytically [1,2, and 3] due to their complexity. Ranjit Kumar Sahoo [3], Wilfried Roetzel [2] and Chakkrit Na Ranong[1] carried out an analysis of the effect of Distribution on the thermal performance and the temperature distribution in shell and tube heat exchanger using a finite difference method.

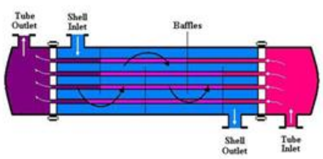

Figure 1: Shell-and-tube heat exchanger

Working of shell and tube heat exchanger:

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 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 of several types of tubes: plain, longitudinally finned, etc.

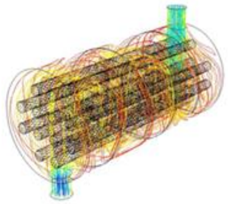

Figure 2: Shell and Tube Heat Exchanger Design

II. METHODOLOGY

CFD Model:

The CFD model of a Shell and Tube Heat Exchanger, to simplify CFD analysis, some basic characteristics of the process following assumption are made:

•The shell side fluid is constant thermal properties

•The fluid flow and heat transfer processes are turbulent and in steady state

•The leak flows between tube and baffle and that between baffles and shell are neglected

•The natural convection induced by the fluid density variation is neglected

•The tube wall temperature K constant in the whole shell side

III. MESHING

Figure 3: Discretized Geometry using Tetrahedron elements

Initially a relatively coarser mesh is generated with 1.8 Million cells. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured cells (Tetrahedral) as much as possible, for this reason the geometry is divided into several parts for using automatic methods available in the ANSYS meshing client. 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, for the mesh independent model, a fine mesh is generated with amount given in the table below. For this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed.

IV. RESULTS

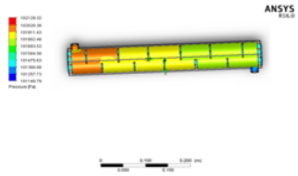

Figure 4: Pressure distribution of the fluid inside the shell and tube heat exchanger

The above Figure represents the pressure distribution of the fluid inside the shell and tube heat exchanger the left end bar with Color range is called as legend it ranges from blue to red whereas value closer to blue is a minimum value and value closer to the red is higher value , in this case low pressure and high pressure . We can observe from the figure the areas near baffle regions have higher pressures.

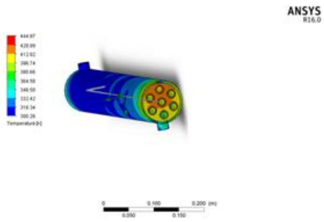

Figure 5: Temperature distribution of the fluid inside the shell and tube heat exchanger

The above Figure represents the Temperature distribution of the fluid inside the shell and tube heat exchanger the left end bar with Color range is called as legend it ranges from blue to red whereas value closer to blue is a minimum value and value closer to the red is higher value , in this case low Temperature and high Temperature . We can observe from the figure that the temperature is decreasing at the outlet region because of heat transfer we can see that the slight Color difference at the end of the outlet that represents the decrease in temperature.

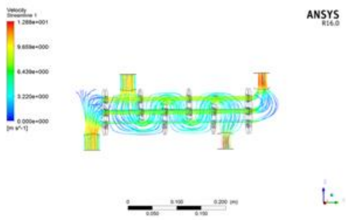

Figure 6: Stream line velocity of the fluid pattern inside the shell and tube heat exchanger

The above figure represents the stream line velocity of the fluid pattern inside the shell and tube heat exchanger this type of figures are important in predicting flow patterns in the considered system.

Case I: Segmental Baffles

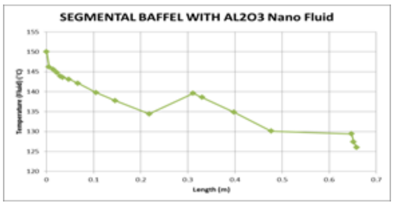

Figure 7: Length vs Temperature

The above graph represents the Length Vs Temperature in the shell and tube heat exchanger in the plot the x-axis represents the Length of the shell and tube heat exchanger in meters and the y axis represents Temperature of the fluid in kelvin from the plot we can say that the temperature of the fluid is decreases due to conduction and convection process takes place in the segmental baffle due to non-uniform distribution the plot is represented as above.

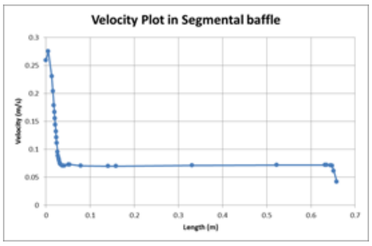

Figure 8: Length vs Velocity

The above graph represents the Velocity with Length in the segmental baffle shell and tube heat exchanger, in the plot the x-axis represents the length of the heat exchanger and the y-axis represents the velocity in m/s the constant velocity represents the linear path inside the tube therefore there is no change in velocity.

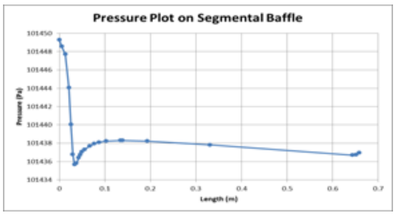

Figure 9: Length vs Pressure

The above graph represents the Pressure with Length in the segmental baffle shell and tube heat exchanger, in the plot the x-axis represents the length of the heat exchanger and the y-axis represents the pressure in Pascal the constant velocity represents the linear path inside the tube therefore there is no change in pressure.

Case II: Helical Baffles with 5 turns

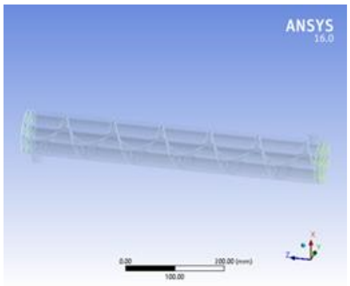

Figure 10: Analysis of the Shell and tube heat exchanger with helical baffle Filled with 5 turns

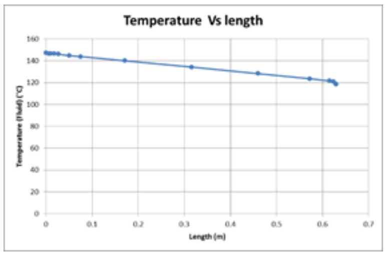

Figure 11: Temperature vs Length using Helical 5 turns

The above graph represents the Length Vs Temperature in the shell and tube heat exchanger in the plot the x-axis represents the Length of the shell and tube heat exchanger in meters and the y-axis represents Temperature of the fluid in kelvin from the plot we can say that the temperature of the fluid is decreases due to conduction and convection process takes place in the Helical baffle with 5 turns the uniform distribution of fluid above the tube results in the plot is represented as above.

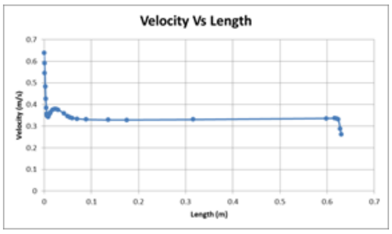

Figure 12: Velocity vs Length using Helical 5 turns

The above graph represents the Velocity with Length in the Helical 5 turn baffle shell and tube heat exchanger, in the plot the x-axis represents the length of the heat exchanger and the y-axis represents the velocity in m/s the constant velocity represents the linear path inside the tube therefore there is no change in velocity.

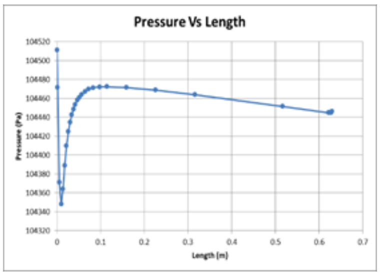

Figure 13: Pressure vs Length using Helical 5 turns

The above graph represents the Pressure with Length in the Helical 5 turns baffle shell and tube heat exchanger, in the plot the x-axis represents the length of the heat exchanger and the y-axis represents the pressure in Pascal the constant velocity represents the linear path inside the tube therefore there is no change in pressure.

Case III: Helical Baffles with 6 turns

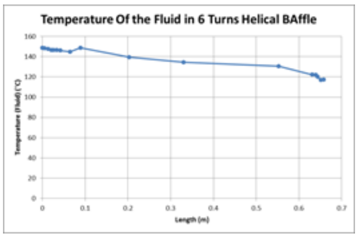

Figure 14: Temperature vs length using Helical 6 turns

The above graph represents the Length Vs Temperature in the shell and tube heat exchanger, in the plot the x-axis represents the Length of the shell and tube heat exchanger in meters and the y-axis represents Temperature of the fluid in kelvin from the plot we can say that the temperature of the fluid is decreases due to conduction and convection process takes place in the Helical baffle with 6 turns the uniform distribution of fluid above the tube results in the plot is represented as above.

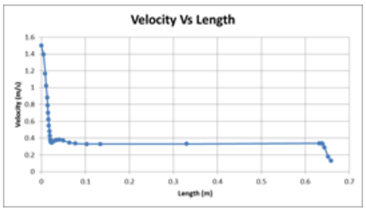

Figure 15: Velocity vs length using Helical 6 turns

The above graph represents the Velocity with Length in the Helical 6 turn baffle shell and tube heat exchanger, in the plot the x-axis represents the length of the heat exchanger and the y-axis represents the velocity in m/s the constant velocity represents the linear path inside the tube there fore there is no change in velocity

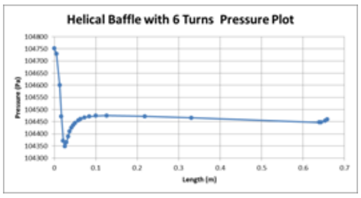

Figure 16: Pressure vs. length using Helical 6 turns

The above graph represents the Pressure with Length in the Helical 6 turn baffle shell and tube heat exchanger, in the plot the x-axis represents the length of the heat exchanger and the y-axis represents the pressure in Pascal the constant velocity represents the linear path inside the tube therefore there is no change in pressure.

COMPARISON

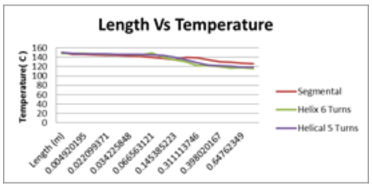

Figure 17: Temperature Comparison

The above Plot represents the Length Vs Temperature plot where the comparison of all 3 models is done in the graph we can observe from the graph that the helix baffle heat exchanger has more heat transfer when compared in both 5 turn baffle heat exchanger and 6 turn baffle heat exchanger there is no much difference but slightly the difference between these two is 6 turns is cooling the hot fluid more rapidly than 5 turns.

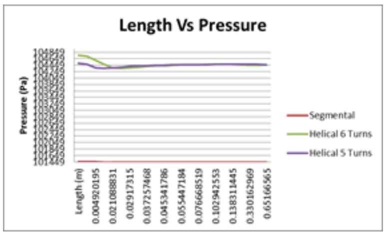

Figure 18: pressure Comparison

The above plot represents the Pressure Vs Length in all the 3 heat exchangers as everyone knows pressure is the most important aspect in the heat exchanger design comparatively the segmental baffle has lower pressure than the other two models.

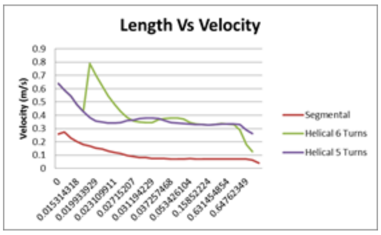

Figure 19: Velocity Comparison

The above graph represents the Length Vs Velocity plot in the all three types of heat exchangers therefore from the plot we can say that due to the uniform fluid distribution in the helical baffle heat exchanger the 6 turns have the higher velocities comparatively.

V. CONCLUSION

The temperature of the hot Fluid outlet in all the three cases is as 127.43C, 118.52C, 116.4945107 C for Segmental baffle, Helical 5 turns baffle and Helical 6 turns baffle although the analysis of the shell and tube heat exchanger is carried out with Al203 nanofluid with volumetric concentration of 4%. Heat transfer between these three models are known to show gradual changes therefore from the comparison and the values obtained from the CFD analysis we can conclude that the Helical baffle with 6 turns possess more heat transfer than the rest of the two designs. Further the work can be extended with different nanofluids.

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