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Performance Analysis of Shell and Tube Heat Exchanger Having Different Baffle Cut At Various Inclination Angles

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Abstract: This paper provides the information regarding visualization of the flow and the temperature field on the shell side with the help of using computational fluid dynamics. in the present work attempt were made to determine the effect of varying baffle cut size at constant mass flow rate and different baffle inclination angles on performance of shell and tube heat exchanger. the shell and tube heat exchanger with segmented baffle is designed to study the flow and temperature inside the shell and tube heat exchanger using ANSYS software tool for different baffle assemblies and orientation. Also overall heat transfer coefficient, heat transfer rate and pressure drop on shell side fluid is calculated for each design. This project totally contains 12 designs, six designs with 25% baffle cut value and other six for the heat exchanger having value of 35% baffle cut. The simulation process consists of modeling and meshing the basic geometry of shell and tube heat exchanger using CFD package ANSYS R18.2. The heat exchanger contains 7 tubes and 1200 mm length and 140 mm shell diameter. In simulation we will show how the temperature and pressure varies in shell due to different baffles orientation and baffle cut percentage. from the result obtained it can be concluded that heat exchanger having lesser baffle cut percentage gives better performance as compared to that other one. The value of overall heat transfer rate and heat transfer coefficient is greater and decrease in pressure drop is less for shell and tube heat exchanger having less percentage of baffle cut.

Keywords: baffle, baffle orientation, Overall performance, segmented baffle, Shell and tube heat exchanger.

I. INTRODUCTION

A ‘heat exchanger’ may be defined as an equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs. In heat exchanger the temperature of each fluid changes as it passes through the exchangers, and hence the temperature of the dividing wall between the fluids also changes along the length of the exchanger. One of the important processes in engineering is the heat exchanger 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 and refrigeration systems.

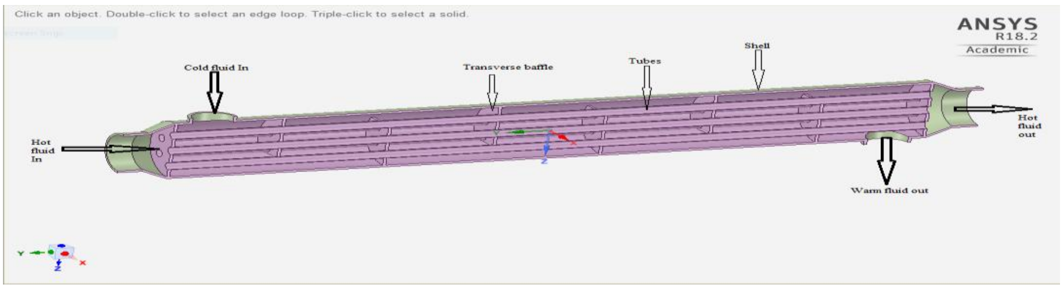

Figure: 1 Different Parts of Shell and Tube Heat Exchanger

The problem faced in performance is of lower heat transfer coefficient value as well as higher pressure drop at shell side of shell and tube heat exchanger to eliminate these problem attempts are going to made here. previously attempts have been made to increase the performance of the shell and tube heat exchanger by calculating the required parameters for a fixed baffle cut percentage at various inclination angle of baffle. Now further work is going to do by comparing the performance of previously designed heat exchanger with that new one having baffle cut value different from that used in first design with same changes in inclination angle and fixed mass flow rate. this work is going to analyze the temperature and pressure variation of shell side fluid of shell and tube heat exchanger by comparing two different designs of shell and tube heat exchanger

II. PROBLEM IDENTIFICATION

In present work, geometric modeling and simulation of single pass, counter flow shell and tube heat exchanger containing segmental baffles having different baffle cut percentages at different orientations angles has been conducted to calculate some parameters (heat transfer rate, overall heat transfer coefficient and pressure drop). A geometric model of segmented baffled shell and tube type heat exchanger has been designed to carry out the analysis. Water at two different temperature is taken as the working fluid used in both shell and tubes. The arrangement of flow used in analysis is counter flow which is more efficient compared to that parallel flow arrangement. Baffles with different orientation angles results in producing more turbulence compared with baffle plate having straight position i.e.- zero degree orientation with respect to its vertical axis. To take the advantage of this particular condition baffles used in single pass counter flow shell and tube heat exchanger are inclined at different angles. As the turbulence value is proportional to heat transfer coefficient therefore the larger the turbulence, the greater will be heat transfer coefficient and as a result the value of heat transfer rate will increase as the value of heat transfer rate depends upon value of heat transfer coefficient. So by increasing turbulence value of fluid within heat exchanger, heat transfer rate, heat transfer coefficient and logarithmic mean temperature difference value will also increase accordingly.

In the design copper is used as tube material and carbon steel as shell material with condition of perfect insulation so that no heat is going outside to atmosphere also no short circuit flow condition is assumed. Water is taken as both hot and cold fluid. Hot water with temperature value 56°C enters through tube and cold fluid with input temperature of 23 °C, that is at Room temperature, passes through the place in between tubes and between shell and tube. Six number of baffles are arranged within the shell having equal spacing value which supports the 7 tubes which are used to carry the hot fluid and to prevent vibration problems within the shell. The reason for using counter flow heat exchanger is that it is most efficient heat exchanger among the others and allows proper transfer of fluid between the hot and cold fluid. The outside temperature and pressure value are taken as normal atmospheric condition which is 1 bar and 23°C

Table: 1 Heat Exchanger specification and its dimensions

SPECIFICATION	DIMENSIONS
Length of heat exchanger, L	1200 mm
Shell inner diameter, D_s	140 mm
Shell thickness, t_s	5 mm
Tube length, l	1200 mm
Tube outer diameter, d_o	20 mm
No. of tubes, N_t	7
Baffle inclination, □	0°, 25°, 30°, 35°, 40°, 45°
Baffle cut	25% , 35%
Baffle spacing, ΔB_t	170 mm
Baffle thickness, t	5 mm
No of baffles, N_b	6

These design parameters are chosen based on previous analysis and studies of different models.

III. SIMULATION METHODOLOGY

In the present work, simulation is done by using Finite Volume method tool (ANSYS-AIM R18.2) for this geometric modeling is done using Ansys Space Clime. for generating symmetric structure mid plane were created. Using this plane three body regions (i.e.- copper structure and two fluid volume) are splitted into six parts from which three part were analyzed by using symmetry properties and rest of three bodies were deleted. Uniform mesh setting are applied at all regions. In flow section all interface boundary are automatically detected in Ansys AIM. At last contour plots of temperature and pressure were created.

A. Geometric Modeling

Geometric modeling is done by using space clime under Ansys R18.2. Symmetry property of the model is used to analyze it. Given below are the geometric model of those two design at 0° inclination with tow different baffle cut percentage.

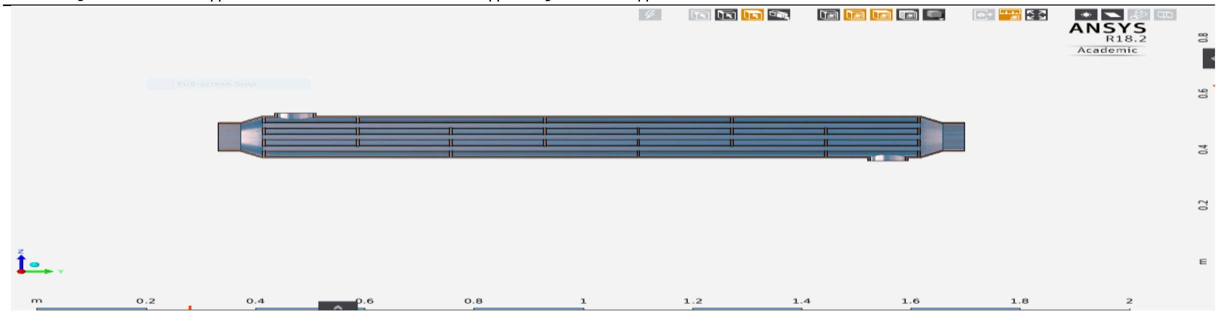

Figure-02: geometric model of STHE with 25% baffle cut

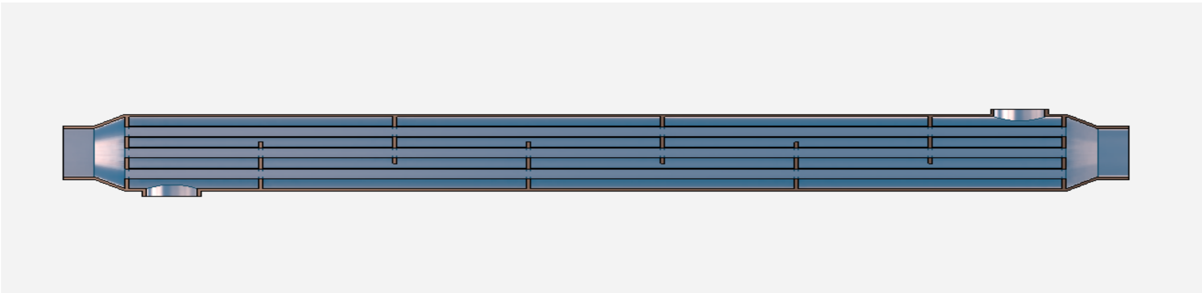

Figure-03: geometric model of STHE with 35% baffle cut

B. Meshing

Model consists of both tetrahedral and hexahedral cells having triangular and quadrilateral faces at the boundaries. At later stage, a fine mesh is generated using edge sizing. In this, the edges and regions of high pressure and temperature gradients are finely meshed.

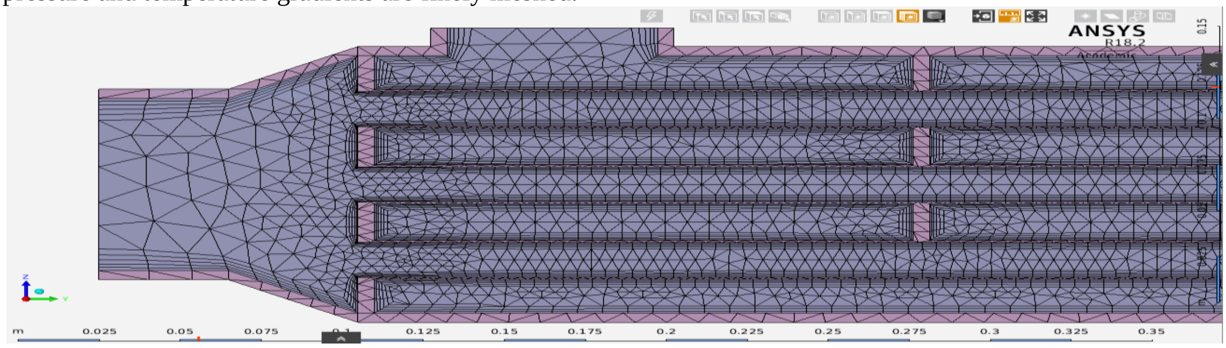

Figure-04: meshing of model having 25% baffle cut

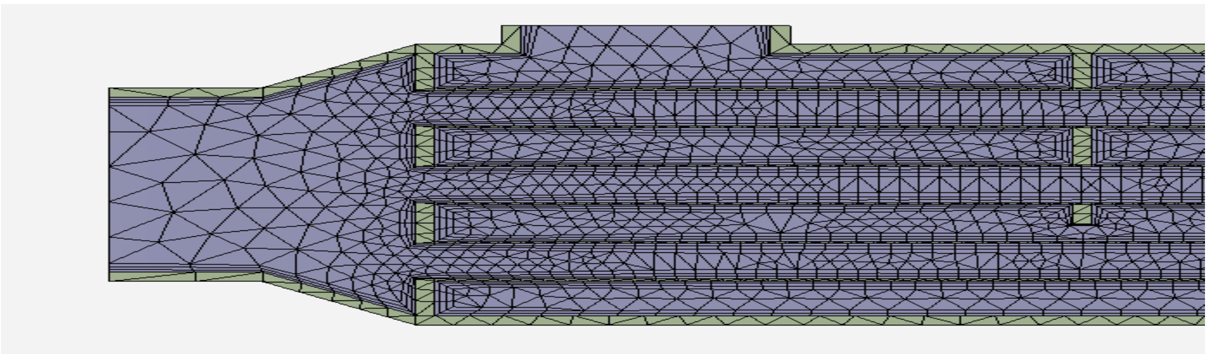

Figure-05: meshing of model having 35% baffle cut

C. Boundary Conditions

Different boundary conditions were applied for different zones. Since it is a shell-and-tube heat exchanger, there are two inlets and two outlets. The inlets were defined as velocity inlets and outlets were defined as pressure outlets. The inlet velocity of the cold fluid was kept constant i.e. 0.5 m/s, whereas velocity of hot fluid was also kept constant. The outlet pressures were kept default i.e. atmospheric pressure. The hot fluid temperature at inlet was 329 k and cold fluid inlet temperature was kept 296 k. The other wall conditions were defined accordingly. The surrounding air temperature was kept 296 k. Under the Above boundary condition and solution initialize condition simulation was set for 600 iteration.

IV. RESULT & DISCUSSION

The computational fluid dynamics analysis was done for the twelve designs of STHXs with each six design having different baffle cut percentage i.e.- different baffle diameter, in which cold water flow through the shell side and hot water flow through the tube side of the STHXs. Performance of two STHXs are compared. Simulation results are obtained for 0.5m/s velocity and 1.65 kg/s fluid flow rate for the two model with 25% and 35% baffle cut respectively having 0° baffle inclination angle. The simulation results for 1.65 kg/s mass flow rate for models with 25% baffle cut (having 0°, 25°,30°,35°,40° and 45° baffle inclination) and 35% baffle cut (having 0°, 25°,30°,35°,40° and 45° baffle inclination) are obtained. The maximum velocity is equal to 0.5m/s for all twelve models at the inlet and exit surface and the velocity magnitude reduces to zero at the baffles surface. It is seen that the maximum value of heat transfer rate for heat exchanger with 25% baffle cut is 21559.820 watt at 45° inclination angle and that of heat exchanger with 35% baffle cut having maximum heat transfer value of 18551.80 at 35° baffle inclination angle which is less as compared to previous one. Also the overall heat transfer coefficient for both designs are 9826.32 w/m^{2}k and 8337.68 w/m^{2}k respectively. the value of pressure drop in heat exchange with less percentage of baffle cut is also lower (pressure drop value decreased by 8.11% to that pressure drop at 0° inclination angle) compared to the model with greater percentage of baffle cut (which pressure drop value decreased by 7.82 % to that pressure drop at 0° inclination angle).the value of overall heat transfer coefficient for both type of model with 25% and 35% baffle cut percentage at their best inclination angle value i.e.- 45° and 35° are increased by 5.68% and 1.5% as compared to their value at 0° inclination angle. Here we observe that the increase in overall heat transfer coefficient value is also greater for heat exchanger with 25% baffle cut percentage.

A. Temperature Variation

The temperature distribution at different points of the counter flow shell and tube heat exchanger are shown in figure below. Here all the twelve models temperature variation are shown through the geometry which indicates that the region having red area are at higher temperature as compared to the region with cold area. This temperature distribution is the indication of thermal behavior of both hot and cold fluid which are flowing through tubes and shell respectively.

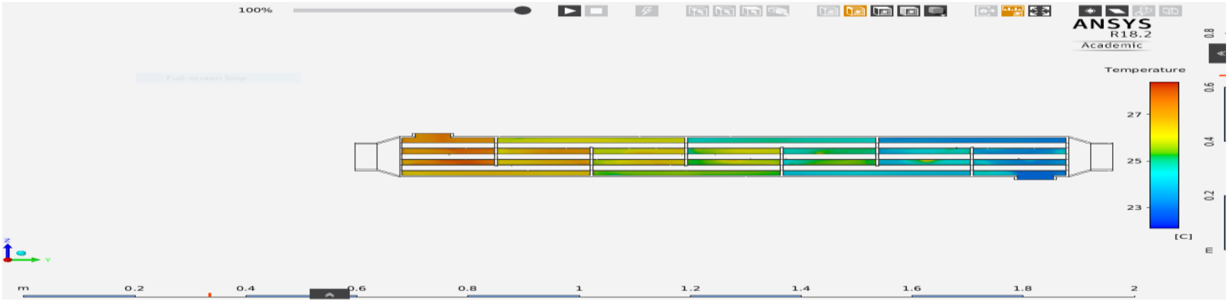

Fig-06: Temperature Distribution for 0° baffle inclination at 25% baffle cut percentage

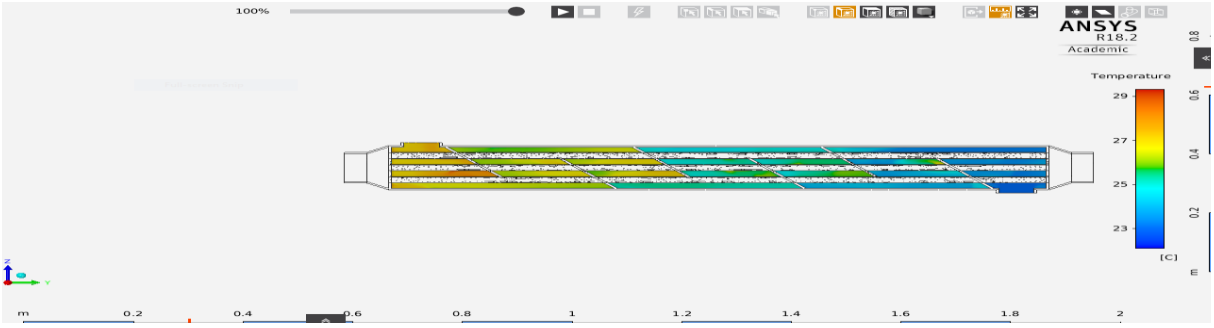

FIG-07: 9 Temperature Distribution for 45° baffle inclination at 25 % baffle cut percentage

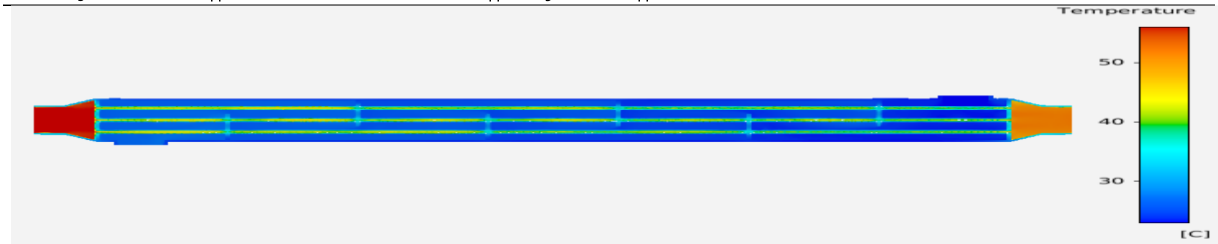

Fig-9 Temperature Distribution for 0° baffle inclination at 35% baffle cut percentage

Fig-10: 9 Temperature Distribution for 35° baffle inclination at 35% baffle cut percentage

B. Pressure Variation

The numerical values of the pressure variations for shell side flowing fluid are shown below in tabular form. With the increase in Baffle inclination angle pressure drop inside the shell is decrease whereas the value of the same increased in tube side with increase in baffle inclination angle. Pressure vary largely from inlet to outlet. The surrounding pressure is taken as atmospheric pressure.

Table: 2 Values of pressure variations

Baffle plate Inclination angle	Pressure drop (hot fluid)		Pressure drop (cold fluid)	
	25%	35%	25%	35%
0°	3674.81	4108.26	3158.34	1447.64
25°	3854.54	3897.99	3068.90	1375.64
30°	3810.40	4112.77	3101.46	1350.36
35°	3851.92	3897.05	2974.35	1333.76
40°	3839.78	4060.49	2930.13	1322.64
45°	3847.72	4082.50	2901.98	1366.47

Similarly all results at different baffle cut percentages and orientation angles are listed below,

Table; 3 Output parameters at different inclination angles

Baffle plate inclination angle	Total Heat Transfer Rate, $Q_{25\%}$ (Watt)	Total Heat Transfer Rate, $Q_{35\%}$ (Watt)	Overall heat transfer co-efficient, $U_{25\%}$ (W/m^2k)	Overall heat transfer co-efficient, $U_{35\%}$ (W/m^2k)	Logarithmic Mean Temp. Difference, $LMTD_{25\%}$ (θ_m)° C	Logarithmic Mean Temp. Difference, $LMTD_{35\%}$ (θ_m)°C
0°	20435.267	18227.541	9297.80	8214.22	29.150	29.432
25°	21339.055	18379.322	9505.86	8272.78	29.173	29.465
30°	21511.534	18006.768	9817.81	8096.30	29.067	29.497
35°	20738.200	18551.800	9452.13	8337.68	29.100	29.510
40°	21049.290	17937.770	9603.53	8050.81	29.070	29.550
45°	21559.820	18406.91	9826.32	8274.53	29.250	29.503

V. CONCLUSION

The heat transfer and flow distribution is discussed in detail. From CFD simulation results, for fixed tube wall and shell inlet temperatures, shell side heat transfer coefficient, pressure drop and heat transfer rate values are obtained. From the previous analysis it is observed that the heat exchanger without any short-circuited flow has the higher heat transfer coefficient than the heat exchanger with leakage, so we have applied the same condition here i.e., no any short circuit flow is taking place. It is found that for 1.65 kg/s mass flow rate there is no much effect on outlet temperature of the tube even though the baffle inclination is increased from 0° to 45°. However the shell-side pressure difference is decreased with increase in baffle inclination angle Baffle cut is reduced in order to provide proper support to the centre row of tubes. It is noticed that for the 25% baffle cut is good estimation to support the tube properly and prevent the condition of vibration to occur. If the baffle inclination angle is beyond 25°, the centre row of tubes is not supported if baffle cut is more. Hence the baffle cut can't be used effectively. Also for the given geometry the mass flow rate must be below 2 kg/s, if it is increased beyond 2 kg/s the pressure drop increases rapidly with little variation in outlet temperature. So, overall we can say that using heat exchanger with 25% baffle cut percentage with 45° inclination angle will give best result compared to all other design models under study. This results in higher heat transfer rate, greater heat transfer coefficient value and lesser pressure drop of that shell side fluid.

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