Parametric Investigation to Evaluate the Effect of Baffle Configuration on the Heat Transfer Rate of a Shell and Tube Heat Exchanger

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Abstract - *In this study, attempts were made to evaluate the effect of various baffle configuration on the fluid flow and heat transfer rate characteristics of a shell and tube heat exchangers. Baffle spacing is one of the most important factors in designing of shell and tube heat exchangers, and there are no fixed criteria for the determination of baffle spacing in the literature. The heat exchanger contains triangular pitch with 7 tubes, 6 baffles, 600 mm length, and shell diameter of 90 mm. The baffle spacing considered for the study are 66mm, 76mm and 86mm. The mass flow rate and baffle spacing were varied and performances were investigated for a baffle cut of 30%. The flow and temperature field inside the shell were studied using computational fluid dynamics software tool using the finite elements method. From the computational fluid dynamics simulation results, the shell side outlet temperature, flow near baffle, optimal mass flow rate and optimal baffle spacing for the heat exchanger geometry were determined and finally, the results were compared to those obtained by numerical calculations.*

Key Words: **Baffle configuration, Computational fluid dynamics (CFD), Heat transfer rate, Mass flow rate, Shell and tube heat exchanger**

1. INTRODUCTION

Increasing demand in using renewable energy has led to vast investigation on extraction and utilizing the waste heat energy. The term waste heat energy refers to some amount of heat left in the system even after heat extraction of the system as to make the extraction as efficient as possible. One of the techniques that proposes using renewable energy is effective usage of energy extraction and conversion systems. The gap between demand and supply in almost all sorts of renewable energy may be handled utilizing appropriate energy extraction systems. Heat exchangers provide a suitable option for recovering the waste heat and converting into useful work.

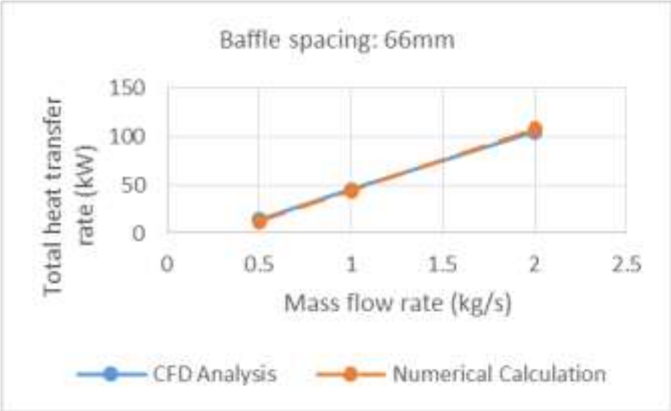
Shell and tube heat exchangers are used in the industries for high pressure applications. The shell and tube heat exchanger consists of a shell, bundle of tubes and baffles. One of the two fluids passes through the tubes, and the other flows over the tubes so as to exchange heat between the two fluids, in heating or cooling applications. Baffles are flow-directing panels which are placed within the shell of the heat exchanger. They provide support to the tubes, prevent tube vibration and sagging, and direct the flow to have higher heat transfer coefficient. The distance between two baffles is baffle spacing. From the literature survey we can say that as compared to tube side flow the shell side flow has a complicated structure due to the existence of baffles. Baffles are used for navigating the flow inside the shell from the inlet to the outlet while retaining effective circulation of the shell side fluid, hence, providing effective use of the heat transfer area. Hence, it acts as a key parameter to be studied as there are no hard and fast rule for their selection and configuration. The drawback is that, increasing the number of baffles also increases pressure drop. This study is conducted with the Computational fluid dynamics tool to study the effect of baffle configuration on the heat transfer and outlet temperature on the shell side of the shell and tube heat exchanger as the focus is on extraction of as much heat as possible.

2. RESULTS AND DISCUSSION

For different mass flow rates of shell side fluid (0.5 kg/s, 1 kg/s, and 2 kg/s) simulation results were obtained. The simulated results for variety of fluid flow rates for model with varying baffle spacing were validated with the data obtained by numerical calculations. It is found that the exit temperature at the shell outlet is in co-relation with the simulated and calculated results.

Table -1: Outlet temperature and Heat Transfer for 66mm Baffle spacing

Baffle spacing: 66mm			
Mass flow rate (kg/s)	Outlet temperature [K]	Total heat transfer rate (kW)	
		CFD Analysis	Numerical Calculation
0.5	306.6	13.82	12.41
1	310.94	45.38	43.66
2	312.44	104.24	107.57

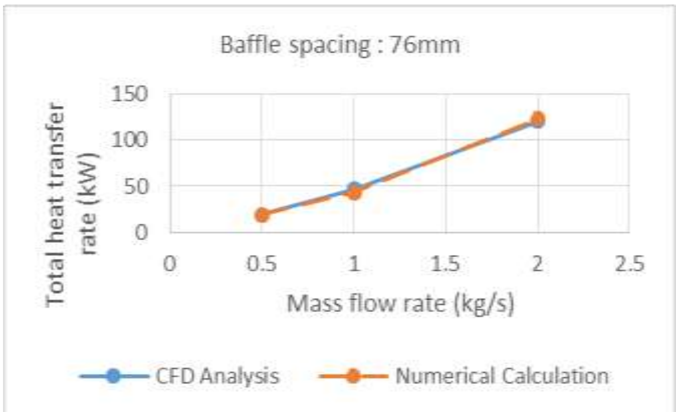


Graph -1: Variation of Total Heat Transfer at 66mm Baffle Spacing

For the baffle spacing of 66mm outlet temperature is seen to be 306.60K, 310.94K and 312.44K for the mass flow rates of 0.5Kg/s, 1Kg/s and 2Kg/s. The outlet temperature increased as the baffle spacing increases. The maximum outlet temperature for 0.5Kg/s is 322.13K at 86mm baffle spacing which is approximately 5% increase in heat transfer compared to 66mm baffle spacing and approximately 4% increase compared to 76mm baffle spacing.

Table -2: Outlet temperature and Heat Transfer for 76mm Baffle spacing

Baffle spacing: 76mm			
Mass flow rate (kg/s)	Outlet temperature [K]	Total heat transfer rate (kW)	
		CFD Analysis	Numerical Calculation
0.5	309.34	19.56	19.11
1	311.1	46.51	42.98
2	314.3	119.83	122.63

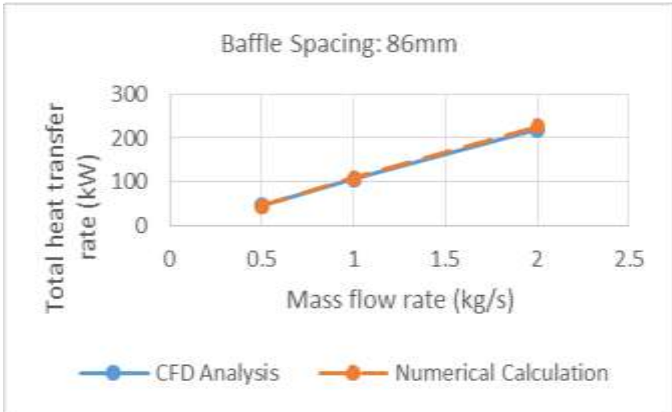


Graph -2: Variation of Total Heat Transfer at 76mm Baffle Spacing

This increase in temperature is due to availability of smooth flow domain for uniform distribution of heat. Baffles also provide increase in turbulence which in turn increases heat transfer. With increase in the mass flow rates the heat transfer rate increases as it is directly proportional to the heat transfer rate. Various graphs have been plotted to show the heat transfer rate of the heat exchangers with variation in the baffle spacing.

Table -3: Outlet temperature and Heat Transfer for 86mm Baffle spacing

Baffle spacing: 86mm			
Mass flow rate (kg/s)	Outlet temperature [K]	Total heat transfer rate (kW)	
		CFD Analysis	Numerical Calculation
0.5	322.13	46.36	44.73
1	325.21	105.62	109.55
2	326.19	219.47	226.41



Graph -3: Variation of Total Heat Transfer at 86mm Baffle Spacing

From the simulation results of the outlet temperatures, heat transfer rates were calculated by using the heat transfer formula for which the specific heat capacity is taken as 4190 J/kg-K. The corresponding graphs are plotted with respect to baffle spacing. The maximum heat transfer rate obtained was 219.47kW for 86mm baffle spacing and 2kg/s mass flow rate. The maximum heat transfer was 52.2% for 86mm when compared to 66mm, and 45.4% when compared to 76mm respectively.

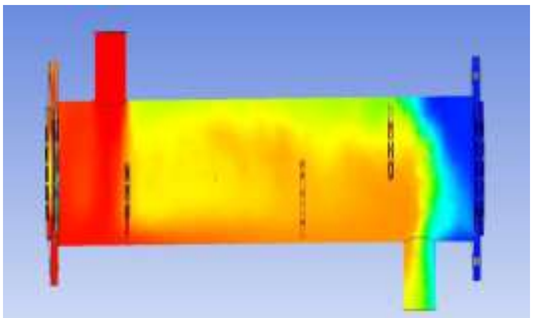


Fig -1: Temperature Contour on Shell Side

The maximum heat transfer rate for models with 66mm, 76mm and 86mm baffle spacing are 104.29 kW, 119.83 kW and 219.47kW respectively. The heat transfer is more for 86 baffle spacing compared to other two models due to smoother guidance of the flow. The maximum velocity is nearly equal to 0.416m/s for all the three models at the inlet and exit surface and the velocity magnitude reduces to zero at the baffles surface. It can be seen that compared to 66mm baffle spacing, 76mm, and 86mm baffles pacing, provide a smoother flow with the rigid baffles guiding the fluid flow.

3. CONCLUSION

The shell side of a shell and tube heat exchanger is modeled with adequate details to resolve the flow and temperature domains. The above study made on heat exchangers by simulating the models in CFD software shows that the values of heat transfer rate and temperatures obtained are in co-relation with values obtained by literature survey and numerical calculations. The overall study states that the heat transfer rate increases with the increase in baffle spacing, the reason the turbulence and flow distribution provided by the baffle spacing on the shell side. It can be said that a heat exchanger with the best possible combination of the above study that is, a heat exchanger with baffle spacing of 86mm and mass flow rate of 2kg/s provided better results in terms of maximum outlet temperature and maximum heat transfer rate. Hence, it can be concluded shell and tube heat exchanger with 86mm baffle spacing results in better performance compared to 76mm and 66mm spacing.

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