Numerical Analysis of Shell and Tube Heat Exchanger using HTRI

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Abstract— Shell and tube heat exchanger are widely used in chemical industry power plant, petroleum refining, air-conditioning and power generation systems. The objective of this paper is to present an overview of literature dealing with the study of thermal performance of shell and tube heat exchanger. Influence of various parameters such as baffle geometry, baffle type, tube length, number of tube, shell diameter, pitch ratio on performance of shell and tube heat exchanger.

Key words: shell and tube heat exchanger, performance analysis, heat transfer coefficient, pressure drop

I. INTRODUCTION

Heat exchangers are one of the most important devices of mechanical systems in modern society. Most industrial processes involve the transfer of heat and more often, it is required that the heat transfer process be controlled. There are different types of heat exchangers; but the type widely used in industrial application is the shell and tube. As its name implies, this type of heat exchanger consists of shell with a bundle of tubes inside it. One fluid runs through the tubes, and another flows over the tubes to transfer heat between the two fluids. The tube bundle may consist of several types of tubes: plain, longitudinally finned, etc.

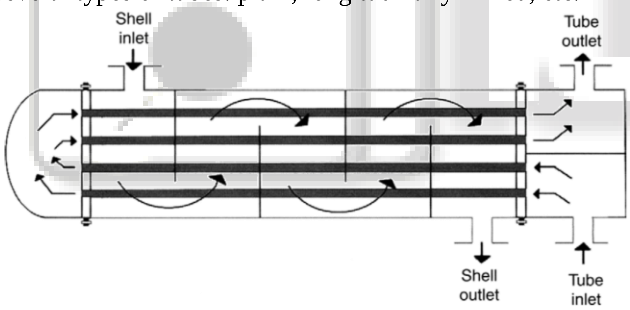

Fig. 1: A typical Shell and Tube Heat Exchanger with one shell pass and two tubes passes

To ensure that the shell side fluid will flow across the tubes and thus induce higher heat transfer, baffles are installed in the shell to force the shell-side fluid to flow across the tube to enhance heat transfer and to maintain uniform spacing between the tubes; schematically, this is shown in Fig.1.

Shell-and-tube heat exchangers in various sizes are widely used in industrial operations and energy conversion systems. Shell-and-tube heat exchangers have been very successfully designed according to TEMA standards and using recommended correlation based analytical approaches. These approaches have constantly improved since the early days due to accumulating industrial experience and operational data, and improving instrumentation. The correlation based approaches can be used for sizing and can also be used iteratively to obtain general performance parameters (rating) of a heat exchanger. At a given iteration, if the performance of the considered design is calculated to be unsatisfactory, a better performing design can be obtained by changing the design parameters in the right direction. There are design charts such as •∈-NTU (Effectiveness- Number of Transfer Unit) curves and LMTD (Logarithm Mean Temperature Difference) correction factor curves for the analysis of simple types of exchangers. Similar design charts do not exist for the analysis of complex heat exchangers with multiple entries on the shell side and complex flow arrangements.

The need to understand the transfer of heat between various systems in industrial as well as residential application is an important process which motivates the researcher to improve design and performance of heat exchanger. A vast amount of material is published regarding shell and tube heat exchanger which depicts various factors affecting the performance of shell and tube heat exchanger.

Rajiv Mukherjee [1] explained the basics of exchanger thermal design, covering such topics as: STHE components; classification of STHEs according to construction and according to service; data needed for thermal design; tube side design; shell side design, including tube layout, baffling, and shell side pressure drop; and mean temperature difference which gave the overall idea to design optimal shell and tube heat exchanger.

Dogan Eryener [2] studied that the optimum ratio of baffle spacing to shell diameter is determined by applying the thermo economic analysis method. The results of these methods were then used to demonstrate how the optimum baffle spacing ratio is affected by the varying values of the heat exchanger geometrical parameters. The optimum baffle spacing ratio corresponding to the minimum annual total cost decreases as the pitch ratio increases. It was observed that the optimum ratio corresponding to the triangular layout was greater than that of the square tube layout. The optimum ratios increase as the heat exchanger area increases.

Su Thet Mon Than et al [3] numerically analyzed the heat transfer area and pressure drop and checking whether the assumed design satisfies all requirements or not. In design calculation, the MATLAB and AUTOCAD software were used. A computer program had been written in MATLAB for shell and tube heat exchanger design. The primary aim of this design was to obtain a high heat transfer rate without exceeding the allowable pressure drop. It can be conclude that the Re and ho are gradually decreased corresponding to as high as number of tube. Because of mass flow rate are constant, velocity are increase and Re, ho are also decrease. Also Re and h gradually decreases corresponding as high as tube effective length. Gradual decrease in Reynolds Number means there is significant decrease in pressure drop respectively.

Ali Falavand Jozaei et al [4] analysed numerically the shell and tube heat exchanger using EES and Aspen B-JAC software. The effects of baffle spacing from 4 inches to 24 inches were considered. The effects of baffle spacing are considered from 4 to 24 inches over overall heat transfer coefficient (OHTC) to pressure drop ratio ($U/\Delta p$ ratio). The results show that U/ Δ p ratio is low when baffle spacing are minimum (4 inches) because pressure drop is high; however, heat transfer coefficient is very significant. Then with the increase of baffle spacing, pressure drop rapidly decreases and OHTC also decreases, but the decrease of OHTC is lower than pressure drop, so (U/ Δ p) ratio increases. After increasing baffles more than 12 inches, variation in pressure drop is gradual and approximately constant and OHTC decreases; Consequently, U/ Δ p ratio decreases again. If baffle spacing reaches to 24 inches, STHX will have minimum pressure drop, but OHTC decreases, so required heat transfer surface increases and U/ Δ p ratio decreases. After baffle spacing more than 12 inches, variation of both estimated price and shell side pressure drop is negligible. Optimum baffle spacing was suggested between 8 to 12 inches (43 to 63% of inside shell diameter) for sufficient heat duty, low cost and low pressure drop.

Shreya Sahajpala et al [5] discussed the thermal design of a desuperheater- condenser manually as well as using HTRI software. The manual calculations were based on standard co-relations available in various literatures. The results have been compared with HTRI and concluded that for good and optimized design, manual and software based calculations should be carried out simultaneously and verified with each other.

Yusuf Ali Kara et al [6] prepared a computer based design model for preliminary design of shell and tube heat exchangers with single phase fluid flow both on shell and tube side. The program determined the overall dimensions of the shell, the tube bundle, and optimum heat transfer surface area required to meet the specified heat transfer duty by calculating minimum or allowable shell side pressure drop. The program was restricted to single-segmental baffle having 25% baffle cut that is most frequently used, triangular-pitch layout that results in greatest tube density. The conclusion was that the allowable shell side pressure drop can be considered as a design constraint for optimum performance of shell and tube heat exchanger.

Zahid H. Ayub [7] investigated a new chart method which is simple and accurate method to calculate single-phase shell side heat transfer coefficient in a single segmental shell and tube heat exchanger. A case study of rating water-to-water exchanger had been shown to indicate the result from this method with the more established procedures and software available in the market. However, it was easy to incorporate it as a simple but accurate design tool that can be beneficial for the design engineers in the field. Also ccorrelation for shell side heat transfer coefficient was developed.

R.Hosseini et al [8] experimented the heat transfer coefficient and pressure drop on the shell side of a shell-and-tube heat exchanger for three different types of copper tubes (smooth, corrugated and with micro-fins). Also, experimental data had been compared with theoretical data available. Correlations had been suggested for both pressure drop and Nusselt number for the three tube types. A shell-and-tube heat exchanger of an oil cooler used in a power transformer had been modeled and built for this experimental work and investigated the effect of surface configuration on the shell side heat transfer as well as the pressure drop of the three types of tube bundles. Corrugated and micro-fin tubes have shown degradation of performance at a Reynolds number below a certain value (Re < 400). At a higher Reynolds number the performance of the heat exchanger greatly improved for micro-finned tubes.

B.T.Lebele-Alawa et al [9] carried out the Numerical analysis of heat transfer in heat exchangers. The parameter analyzed included: the outlet temperature, heat transfer coefficient and heat exchanger effectiveness. The numerical analysis had shown that the calculated outlet temperatures of both shell and tube heat exchanger and overall heat transfer coefficients obtained for the three cases considered agree reasonably with the stated values in the Indorama -Eleme Petrochemicals. Performance was improved with a corresponding high efficient transfer of thermal energy.

M. Thirumarimurugan et al [10] carried out the performance Analysis of Shell and Tube Heat Exchanger Using Miscible System. A mathematical model was developed for the outlet temperatures of both the Shell and Tube side fluids and was simulated using MATLAB program and compared the predicted result with experimented result. It was found that cold fluid outlet temperature decreased and overall heat transfer coefficient increased with increase in flow rates of cold fluid. Finally a correlation for the calculation of film heat transfer coefficient is developed using dimensional analysis for tube side.

Ebieto et al [11] carried out the performance analysis of shell and tube heat exchanger. For this numerical method was used to develop correlation for performance analysis. A program was written in MATLAB to check for the thermal and hydraulic suitability of the heat exchangers. The program was tested with data of five different industrial heat exchangers from Port Harcourt Refinery. And conclude that program was reliable and can be applied in the performance analysis of shell and tube heat exchanger.

Sunil S. Shinde et al [12] summarized the numerical & experimental analysis and investigated that the performance of tubular heat exchanger can be improved by helical baffles instead of conventional segmental baffles. For the helical baffle heat exchangers, the ratios of heat transfer coefficient to pressure drop are higher than those of a conventional segmental heat exchanger. This means that the heat exchangers with helical baffles will have a higher heat transfer coefficient when consuming the same pumping power. It can be concluded that proper baffle inclination angle will provide an optimal performance of heat exchangers.

Amarjit Singh et al [13] performed an experimental analysis on the shell-and-tube type heat exchanger containing segmental baffles at different orientations respectively 0º, 30º, and 60º. The baffles were analyzed for laminar flow having the Reynolds number range 303–1516.The conclusion was; (i) the heat transfer coefficient increases with increase in Reynolds number in shell-and-tube heat exchanger for both hot fluid inlet and cold fluid inlet.(ii) The Nusselt number increases with increase in Reynolds number in shell-and-tube heat exchanger for both hot fluid inlet and cold fluid inlet.(iii) The value of LMTD increases with increase in Reynolds number from 303 to 1516.(iv) The value of temperature constants ξ and ω decreased with increase in Reynolds number.(v) The value of pressure drop gradually increases with increase in Reynolds number.

Sirous Zeyninejad Movassag et al [14] experimented to the STHEs in shell side tube bundle replacement with segmental and helical baffle. Also comparison of shell side flow behavior for both tube bundles by using CFD technique had been carried out. By comparison of running times, helical baffles resulted in better performance which indicates lower fouling tendency compared to segmental baffles. Helical baffles provide smooth behaviour of the fluid flow in the shell side which leads to lower pressure drop. Helical baffles indicate higher heat transfer for the same pressure drop.

II. Conclusion

Most industrial processes involve the transfer of heat and more often, it is required that the heat transfer process be controlled. In order to achieve maximum efficiency of heat exchanger many researcher have put their effort to maximize the performance along with reduced cost. From the literature review it can be conclude that,

(1) Reynold number and heat transfer coefficient are gradually decreased corresponding to increase in number of tube at constant mass flow rate because of increased velocity.
(2) Reynold number and heat transfer coefficient also decreased with increased in tube effective length. Also Re and h increased with increased in number of baffle.
(3) Heat load increased with increased in shell diameter and number of baffle.
(4) Shell side convective heat transfer coefficient and overall heat transfer coefficient have inverse relationship with baffle spacing.
(5) Performance of heat exchanger depends on ratio of baffle spacing to shell diameter which depends on tube length, pitch ratio, tube outer diameter, heat transfer area and number of tube. Also the optimum ratio of baffle spacing to shell diameter corresponding to the triangular layout is greater than that of the square layout.
(6) It was found that fluid outlet temperature decreased and the overall heat transfer coefficient increased with increased in flow rate of cold fluid.
(7) The performance of tubular heat exchanger can be improved by helical baffle instead of conventional segmental baffle. There was a significant impact of Reynold number on different parameters of shell and tube type heat exchanger such as heat transfer coefficient increase with increase in Reynold number in shell and tube type heat exchanger for both hot fluid inlet and cold fluid inlet. Also the value of pressure drop gradually increases with increase in Reynold number.
(8) It reveals that tube pitch ratio, tube length, tube layout as well as baffle spacing ratio was found to be important design parameters which has a direct effect on pressure drop and cause conflict between the effectiveness and total cost.

In brief, it is necessary to evaluate optimal performance for shell and tube heat exchanger to run at minimal cost in industries.

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