An Overview of Shell & Tube Type Heat Exchanger Design by Kern’s Method

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ABSTRACT:
This paper is concerned with the study of shell & tube type heat exchanger. Also the main components of shell and tube type heat exchanger are shown in drawing and its detail discussion is given. Moreover the constructional details and design methods of shell and tube type heat exchangers has been given from which of that the Kern method for design is described in detail with step inside the paper. Also some of research paper is studied and the review from those papers is also described in the paper with some of review work in detail.

Keywords: shell & tube type heat exchanger; kern’s method; design methods; STHE.

I. INTRODUCTION
A device whose primary purpose is the transfer of heat energy between two fluids at different temperature is named a heat exchanger. A heat exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs. There are various types of heat exchangers available in the industry, however the Shell and Tube Type heat exchanger is probably the most used and widespread type of the heat exchanger’s classification. It is used most widely in various fields such as oil refineries, thermal power plants, chemical industries and many more. This high degree of acceptance is due to the comparatively large ratio of heat transfer area to volume and weight, easy cleaning methods, easily replaceable parts etc. Shell and tube type heat exchanger consists of a number of tubes through which one fluid flows. Another fluid flows through the shell which encloses the tubes and other supporting items like baffles, tube header sheets, gaskets etc. The heat exchange between the two fluids takes through the wall of the tubes.

II. BASIC COMPONENTS OF SHELL AND TUBE TYPE HEAT EXCHANGER
Some of the basic components of a shell and tube type heat exchangers are as given below:

2.1 Tubes:
The tubes are the basic component of the shell and tube heat exchanger, providing the heat transfer surface between one fluid flowing inside the tube and the other fluid flowing across the outside of the tubes. It is therefore recommended that the tubes material should be highly thermal conductive otherwise proper heat transfer will not occur. The tubes may be seamless or welded and most commonly made of copper or steel alloys.

2.2 Tube sheets:
The tubes are held in place by being inserted into holes in the tube sheets and there either expanded into grooves cut into the holes or welded to the tube sheet. The tube sheet is usually a single round plate of metal that has been suitably drilled and grooved to take the tubes however where the mixing between two fluids must be avoided, a double tube sheet may be provided. The space between the tube sheets is open to the atmosphere so any leakage of either fluid should be quickly detected. The tube sheet must withstand to corrosion. The tube sheets are made from low carbon steel with a thin layer of corrosion resisting alloy metallurgically bounded to one side.

2.3 Shell:
The shell is simply the container for the shell side fluid, and the nozzles are the inlet and exit ports. The shell normally has a circular cross section and is commonly made by rolling the metal plate of appropriate dimensions in to cylinder and welding the longitudinal joint. In large heat exchanger, the shell is made out of low carbon steel wherever possible for the reason of economy, though other alloys can be and are used when corrosion or to high temperature strength demand must be made.
2.4 Impingement plates:
When the fluid under high pressure enters the shell there are high chances that if the fluid will directly impinge over the tubes then their breakage or deformation may occur. To avoid the same the impingement plates are installed to waste the kinetic energy of fluid upto some extent so that the fluid may impact the tubes with lower velocity.

2.5 Channel covers:
The channel covers are round plates that bolt to the channel flanges and can be removed for the tube inspection without disturbing the tube side piping. In smaller heat exchangers, bonnets with flanged nozzles or threaded connections for the tube side piping are often used instead of channel and channel covers.

2.6 Baffles:
Baffles serve two functions; Most importantly, they support the tubes in the proper position during assembly and operation and prevent vibration of the tubes caused by flow induced eddies, and secondly, they guide the shell side flow back and forth across the tube field, increasing the velocity and heat transfer coefficient.

Fig 1: Schematic diagram of component of shell and tube type heat exchanger

III. DESIGN METHODS

Shell and tube heat exchangers are designed normally by using either Kern’s method or Bell-Delaware method. Kern’s method is mostly used for the preliminary design and provides conservative results whereas; the Bell-Delaware method is more accurate method and can provide detailed results. It can predict and estimate pressure drop and heat transfer coefficient with better accuracy. In this paper we have described Kern’s method of designing in detail. The steps of designing are described as follows:

1) To find out the values of some unknown temperature first we consider the energy balance. In this energy balance certain some inputs like hot fluid inlet and outlet temperatures, cold fluid inlet temperature, mass flow rates of the two fluids are needed to serve the purpose. The equation may be given as :

\[ Q = m_h C_{ph} (T_{h1}-T_{h2}) = m_c C_{pc} (T_{c2}-T_{c1}) \]

2) Then we consider the LMTD equation to find its value:

\[ LMTD = \frac{(\Delta T_1 - \Delta T_2)}{\ln \left( \frac{\Delta T_1}{\Delta T_2} \right)} \]

Where, \( \Delta T_1 = T_{h1} - T_{c2} \) and \( \Delta T_2 = T_{h2} - T_{c1} \)

3) Our next step is to calculate the area required of the heat exchanger (on the basis of assumed), number of tubes, tube bundle diameter, diameter of shell and its thickness with the help of following expressions:

\[ A = \frac{Q}{u_0 \Delta T} \]

\[ N_t = \frac{A}{\pi d t o l} \]
\[ D_b = d t 0 \left( \frac{N_t}{K_a} \right)^{1/n_1} \]

\[ D_i = D_b + \text{additional clearance} \]

\[ D_o = D_i \times \text{thickness} \]

4) Then we calculate the proper baffle dimension VIZ. its diameter, thickness and baffle spacing.

5) Our next step is to find out heat transfer coefficients on the inner and outer surface of the tubes using following correction:

\[ N_u = 0.27 \left( R_e \right)^{0.63} \left( P_r \right)^{0.36} \left( \frac{P_t}{P_{rw}} \right)^{0.25} \]

6) Then by the values obtained by the above equation we calculate the actual value of heat transfer coefficient and check whether the actual value is greater than the assumed one or not. If the actual overall heat transfer coefficient is greater than the assumed one then the designing is considered correct. Otherwise the steps need to be repeated guessing more accurately the value of overall heat transfer coefficient.

**IV. REVIEW WORKS**

While reviewing the works of renowned scholars it has been seen that significant amount of works has been done in field of STHE. Some important works have been described in detail as under:

Rajeev Mukherjee [1] explains 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. The basic equations for tube side and shell side heat transfer and pressure drop. Correlations for optimal condition are also focused and explained with some tabulated data. This paper gives overall idea to design optimal shell and tube heat exchanger. The optimized thermal design can be done by sophisticated computer software however a good understanding of the underlying principles of exchanger designs needed to use this software effectively. V.K. Patel and R.V. Rao[2] explore the use of a non-traditional optimization technique; called particle swarm optimization (PSO), for design optimization of shell-and-tube heat exchangers from economic view point. Minimization of total annual cost is considered as an objective function. Three design variables such as shell internal diameter, outer tube diameter and baffle spacing are considered for optimization. Two tube layouts viz. triangle and square are also considered for optimization.

The contents under this headings already accepted by IOSR journal of Mechanical and Civil Engineering for publication of paper titled as “Performance Analysis of Shell & Tube Type Heat Exchanger under the Effect of Varied Operating Conditions” by the Vindhya Vasiny Prasad Dubey, Raj Rahjat Verma, Piyush shanker Verma, A. K. Srivastava in IOSR journals volume 11, Issue 3.

The presented PSO technique’s ability is demonstrated using different literature case studies and the performance results are compared with those obtained by the previous researchers. PSO converges to optimum value of the objective function within quite few generations and this feature signifies the importance of PSO for heat exchanger optimization. Hari Haran [3] proposed a simplified model for the study of thermal analysis of shell and tube type heat exchangers of water and oil type is proposed. The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations. This paper shows how to do the thermal analysis by using theoretical formulae and for this they have chosen a practical problem of counter flow shell and tube heat exchanger of water and oil type, by using the data that come from theoretical formulae they designed a model of shell and tube heat exchanger using Pro-E and done the thermal analysis by using ANSYS software and comparing the result that obtained from ANSYS software and theoretical formulae. For simplification of theoretical calculations they have also done a C code which is useful for calculating the thermal analysis of a counter flow of water-oil type shell and tube heat exchanger. Vindhya Vasiny Prasad Dubey[5] proposed a simplified model for the study of thermal
analysis of shell and tube type heat exchangers. This paper shows heat exchanger has been designed using kern’s method to cool the water from 55°C to 45°C by using water at room temperature. Then they carried out thermal analysis on ANSYS14.0 to justify the design. After that they fabricated working model with same dimensions that have been derived from theoretical calculation and then tested under different condition to see its effect on the performance of the heat exchanger. Sandeep k patel[6] proposed a simplified model of shell and tube heat exchanger. This paper shows a simple but accurate method to calculate thermal parameter in a single segment shell and tube heat exchanger. In this paper attempt is made to overcome some theoretical assumptions and serve practical approach as much as possible for shell and tube heat exchanger design and optimization. Number of iteration and their comparisons as well as analysis is performed in HTRI software. The final results are helpful to run the shell and tube heat exchanger water cooler at optimal mass flow rate and baffle spacing.

V. CONCLUSION

After the study and above discussion it is to be said that the shell and tube heat exchanger has been given the great respect among all the classes of heat exchanger due to their virtues like comparatively large ratios of heat transfer area to volume and weight and many more. Moreover well designed methods are available for its designing and analysis. It is also shown by the literature survey that the Computational fluid dynamics and other software like ANSYS HTRI FLOEFD etc. have been successfully used and implemented to secure the economy of time, material and efforts.

Nomenclature:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Temperature of fluid (°C)</td>
</tr>
<tr>
<td>Cp</td>
<td>Specific heat of fluid (J/kg·°C)</td>
</tr>
<tr>
<td>M</td>
<td>mass flow rate of fluid (Kg/s)</td>
</tr>
<tr>
<td>LMTD(or ΔT)</td>
<td>Logarithmic Mean Temperature difference (°C)</td>
</tr>
<tr>
<td>Q</td>
<td>amount of heat transfer taking place (watts)</td>
</tr>
<tr>
<td>U(or U₀)</td>
<td>overall heat transfer coefficient (w/m²°C)</td>
</tr>
<tr>
<td>A</td>
<td>area of heat exchanger (m²)</td>
</tr>
<tr>
<td>l</td>
<td>length of heat exchanger (m)</td>
</tr>
<tr>
<td>D</td>
<td>diameter of shell (mm)</td>
</tr>
<tr>
<td>d</td>
<td>diameter of tubes (mm)</td>
</tr>
<tr>
<td>D₀</td>
<td>tube bundle diameter (mm)</td>
</tr>
<tr>
<td>N</td>
<td>number of tubes</td>
</tr>
<tr>
<td>B</td>
<td>baffle spacing (mm)</td>
</tr>
<tr>
<td>Pr</td>
<td>Prandtl number</td>
</tr>
<tr>
<td>Re</td>
<td>Reynold’s number</td>
</tr>
<tr>
<td>Nu</td>
<td>Nusselt number</td>
</tr>
<tr>
<td>H</td>
<td>heat transfer coefficient (w/m²°C)</td>
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Subscripts:

t = tube side parameter  
s = shell side parameter  
i = inner surface parameter  
o = outer surface parameter  
h = hot fluid parameter  
c = cold fluid parameter  
1, 2 = for inlet and outlet respectively  
max = maximum amount of the quantity

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REFERENCES


