Shell & Tube Type Heat Exchangers

Aditya Anand, Ashish Aggarwal, Jatin Kumar
Mechanical Engineering, Dronacharya College of Engineering, Khentawas, Gurgaon, INDIA

Abstract- **This paper is concerned with the study of shell & tube type heat exchangers along with its applications and also refers to several scholars who have given the contribution in this regard. Moreover the constructional details, design methods and the reasons for the wide acceptance of shell and tube type heat exchangers has been described in details inside the paper.**

Index Terms- **shell & tube type heat exchangers; constructional details; design methods and the reasons for the wide acceptance.**

I. INTRODUCTION

Heat exchanger is a mechanical device which is used for the purpose of exchange of heats between two fluids at different temperatures. 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.

II. COMPONENTS DETAILS

Some of the very basic components of a shell and tube type heat exchangers are as given below:

2.1. Tubes

The tubes are the basic components of a shell and tube type heat exchanger. The outer surfaces of the tubes are the boundary along which heat transfer takes place. It is therefore recommended that the tubes materials should be highly thermal conductive otherwise proper heat transfer will not occur. The tubes of Copper, Aluminium and other thermally conductive materials are commonly used in practice.

2.2. Tube sheets

The tubes are held in place by being inserted into holes in the tube sheet and there either expanded into grooves cut into the holes or welded to the tube sheet where the tube protrudes from the surface. The tube sheet is usually a single round plate of metal that has been suitably drilled and grooved to take the tubes (in the desired pattern), the gaskets, the spacer rods and the bolt circle where it is fastened to the shell. However, where mixing between the two fluids (in the event of leaks where the tube is sealed into the tube sheet) must be avoided, a double tube sheet may be provided.

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 a metal plate of the appropriate dimensions into a cylinder and welding the longitudinal joint ("rolled shells").

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.

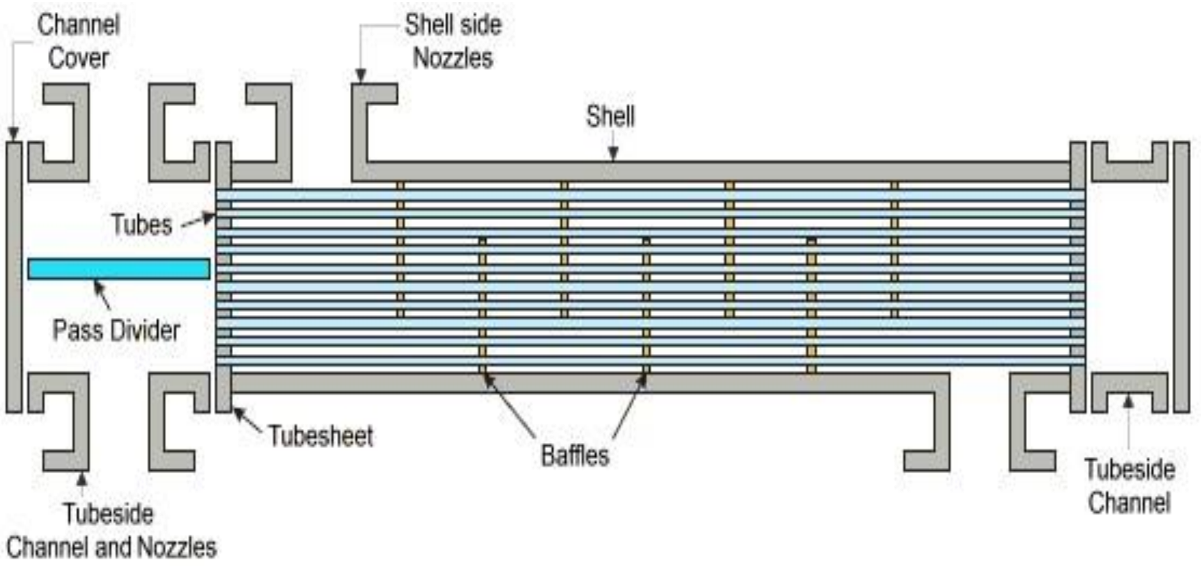

Figure1. Components Schematic of Shell and Tube Type Heat Exchanger

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 BellDelaware 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:

i. First we consider the energy balance to find out the values of some unknown temperature values. Certainly 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 energy balance equation may be given as:

$$Q = m_h c_{ph}(t_{h1} - t_{h2}) = m_c C_{pc}(t_{c2} - t_{c1}) \quad (1)$$

ii. Then we consider the LMTD expression to find its value:

$$LMTD = \frac{(\Delta T1 - \Delta T2)}{ln(\frac{\Delta T1}{\Delta T2})} \quad (2)$$

Where, $\Delta T_1 = t_{h1} - t_{c2}$ and $\Delta T_2 = t_{h2} - t_{c1}$.

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 –

$$A = \frac{Q}{U_0 \Delta T} \quad (3)$$

$$N_t = \frac{A}{\pi d_{t0} l} \quad (4)$$

$$D_b = d_{t0}\left(\frac{N_t}{K_1}\right)^{1/n_1} \quad (5)$$

$$D_i = D_b + \text{additional clearance} \quad (6)$$

$$D_0 = D_i + 2 \times \text{thickness} \quad (7)$$

i. Then we calculate the proper baffle dimension viz. its diameter, thickness and baffle spacing.

ii. Our next step is to find out heat transfer coefficients on the inner and outer surface of the tubes using following correlation:

$$Nu = 0.27(Re)^{0.63}(P_r)^{0.36}(P_r/P_{rw})^{0.25} \quad (8)$$

iii. 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.

III. CONCLUSION

After the above discussion it is easy to say that the shell & tube type heat exchangers has been given a great respect among all the classes of heat exchangers due to their virtues like comparatively large ratios of heat transfer area to volume and weight and many more. Moreover well designed as well as described methods are available for its designing and analysis. The literature survey also shows the importance of this class of heat exchangers. It is also shown by the literature survey that the Computational Fluid Dynamics and other softwares like ANSYS etc. have been successfully used and implemented to secure the economy of time, materials and efforts.

NOMENCLATURE

m- mass flow rate of fluid (kg/second)
- specific heat of fluid (J/kg-)
t - temperature of fluid (°c)
LMTD (or ΔT) - Logarithmic Mean Temperature Difference (°c)
Q - amount of heat transfer taking place (watts)
U - overall heat transfer coefficient (w/ °c)
A- area of heat exchanger (m^2)
L - length of heat exchanger (m)
N - number of tubes
d - diameter of tubes (mm)
D - diameter of shell (mm)
B - baffle spacing (mm)
Nu - Nusselt number
H - heat transfer coefficient (w/ °c)

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

REFERENCES

1. Ahmad Fakheri, "Heat Exchanger Efficiency", J. Heat Transfer 129(9), 1268-1276 (Nov 16, 2006), asme.org.
2. Ahmad Fakheri, "Efficiency and Effectiveness of Heat Exchanger Series", J. Heat Transfer 130(8), 084502 (May 29, 2008), asme.org.
3. Rajeev Mukharji, "Effective design of shell and tube heat exchanger", American Institute of Chemical Engineering, 1988.
4. Jiangfeng Guo, Lin Cheng, Mingtian Xu, "Optimization design of shell and tube heat exchanger
7. V.K. Patel, R.V. Rao, "Design optimization of shell and tube heat exchanger using particle swarm optimization technique", Applied Thermal Engineering 30 (2010) 1417-1425.
8. Hetal Kotwal and D.S PATEL, "CFD Analysis of Shell and Tube Heat Exchanger- A Review", International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 2, March 2013.
9. Shiv Kumar Rathore, Ajeet Bergaley, "Comparative Analysis of Finned Tube and Bared Tube Type Shell and Tube Heat Exchanger", International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 1, July 2012.
10. Hari Haran, Ravindra Reddy and Sreehari, "Thermal Analysis of Shell and Tube Heat ExChanger Using C and Ansys" , International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2013.
11. Donald Q.Kern. 1965. Process Heat transfer (23rd printing 1986). McGraw-Hill companies.ISBN 0-07-Y85353-3.
12. Wolverine Tube Heat Transfer Data Book.