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Research Article

Fabrication of Shell and Tube Heat Exchanger using Helical Baffles based on Kern's Principle

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Abstract

Shell and tube heat exchanger is a class of heat exchanger. Heat exchanger is a device used to transfer heat between a solid and a fluid or between two or more fluids. This paper is concerned with the study of shell and tube 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 heat exchangers are given from which kern's method for design is described in detail with step inside the paper. Also other research papers are studied and the review from those papers is also describes in this paper with some of the review work in detail

Keywords: *Helical baffles, Kern's method, square pitch, triangular pitch.*

1. Introduction

Heat exchangers are always been important part to the lifecycle and operations of many systems. Over the past quarter century, the importance of heat exchangers has increased from the viewpoint of energy conversion and performance recovery. Much more attention is paid to heat exchangers because of environmental concerns such as thermal, air and water pollution, as well as waste heat recoveries. It can be considered as key equipment in the chemical process industry. Heat exchanger is a device of finite volume used to transfer heat between a solid and a fluid or between two or more fluids. These two fluids are separated by solid wall to prevent mixing and also to prevent direct contact between them. Typically one system is been cooled while the other is heated. More than 30-40% of heat exchangers used in various industries are of this type due to their robust geometry construction, (Master, B. I., Chunangad, *et al*, 2003) easy maintenance and possible upgrades. One common example of heat exchanger is the radiation in the car, in which it transfers heat from the water (hot engine-cooling fluid) in the radiator to the air passing through the radiator. There are two main types of heat exchangers (Bell, K. J *et al* 1981)

- Direct contact heat exchanger, where both media between which heat is exchanged are in direct contact with each other.
- Indirect contact heat exchanger, where both the media are separated by a wall through which heat is transferred so that they never mix.

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- Heat exchangers are also classified based on different parameters like flow direction, compactness of the body, transfer type and construction.
- Parallel flow heat exchangers: Parallel flow heat exchangers are the one in which two fluids flow in parallel to each other.
- Counter flow heat exchangers: In counter flow heat exchangers the fluid flows in opposite direction.
- Cross flow heat exchangers: It is a combination of both parallel and counter flow.

Heat exchangers are globally assumed to be operating under adiabatic conditions. It therefore means that heat losses or gains between the heat exchangers and the environment can be assumed. The thermal inertia for heat exchangers is negligible and therefore mostly assumed therefore the general balance equation of energy is reduced to where the total energy ht is a value that can be approximated by enthalpy and stands for the difference between the output and the input. A primary objective in the heat exchanger Design is the estimation of the minimum heat transfer area required for a given heavy duty (Schlünder, *et al* 1983)

2. Methods and material

2.1 Shell and Tube Heat Exchanger

This type of heat exchanger is said to have originated from the jacketed coil distiller. Shell and tube heat exchanger is an indirect contact type heat exchanger. In this we make use of both parallel and counter flow. Shell and tube heat exchangers in various sizes are widely used in industrial operations and energy conversion systems. As the name suggests this type of heat exchangers consists of a shell (a large pressure vessel) with a bundle of pipes inside it. The shell is a container for the shell fluid. Usually, it is cylindrical in shape with a circular cross section, although shells of different shapes are used in specific applications. For this particular study E shell is considered, which is generally a one pass shell. E shell is the most commonly used due to its low cost and simplicity, and has the highest long-mean temperature-difference (LMTD) correction factor. One fluid runs through the tube and the other fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called tube bundle pipes composed in it can be plain, longitudinally finned etc. Although the tubes may have single or multiple passes, there is one pass on the shell side, while the other fluid flows within the shell over the tubes to be heated or cooled. Tubular Exchanger Manufacturers Association (TEMA) regularly publishes standards and design recommendations. Shell and tube heat exchangers are designed normally by using Kern's method o Bell-Delware method .Kern's method is mostly used for the preliminary design and provide 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.

2.2. Basic components of a shell and tube heat exchanger

The major components of a shell and tube heat exchangers are tubes (tube bundles), tube sheets, shell, impingement plates, channel covers, baffles.

2.2.1. Tubes

The tubes are the basic components 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 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.

2.2.2. Tube Sheets

The tubes are held in place by being inserted into holes in the tubes 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 metallurgic ally bounded to one side (Stehlik, *et al* , 1994)

2.3.3. 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 the economy, though other alloys can be and are used when corrosion or to high temperature strength demand must be made.

2.3.4 Channel Covers

The channel covers are round plates to 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.

2.3.5. 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 field, increasing the velocity and heat transfer coefficient.

2.3 Kern's Method

Kern provided a simple method for calculating shell-side pressure drop and heat transfer coefficient. However, this method is restricted to a fixed baffle cut (25%) and cannot adequately account for baffle-to-shell and tube-to-baffle leakage. Kern method is not applicable in laminar flow region where shell-side Reynolds number is less than 2000. Although the Kern equation is not particularly accurate, it does allow a very simple and rapid calculation of shell-side heat transfer coefficient and pressure drop to be carried out.

2.4 Helical Baffles

The Helical Baffle heat Exchanger is otherwise known as a Helix changer solution that removes many of the deficiencies of Segmental Baffle Heat Exchanger. It is very effective where heat exchanger are predicted to be faced with vibration condition Quadrant shaped baffle segment are arranged right angle to the tube axis in a sequential pattern that guide the shell side flow in a helical path over the tube bundle. The Helical flow provides the necessary characteristics to reduce flow dispersion and generate near plug flow conditions. The shell side flow configuration offers a very high conversion of pressure drop to heat transfer. Advantages over segmental STHE are increased heat transfer rate, reduced bypass effects, reduced Shell Fouling Factor, Prevention of flow induced vibration & Reduces Pumping cost. For the convenience of manufacturing, up to now all helical baffles actually used in Shell and tube heat exchangers arenon-continuous approximate helicoids. The non-continuous helical baffles are usually made by four elliptical sector-shaped plates joined in succession. The elliptical sector shaped plates are arranged in a pseudo helical (non continuous) manner, with each baffle occupying one-quarter of the cross section of the heat exchanger and being angled to the axis of the heat exchanger. The two adjacent baffles may be joined end to end at the perimeter of each sector, forming a continuous helix at the outer periphery (Fig. 1(a)); this structure of connecting baffles together is called a single helix manner. Another connection between two adjacent sectors is the middle-over lapped connection, as shown in Fig. 1(a) where the helix angle, designated by, helical pitch, B, and baffle thickness, sp, are presented. As shown in Fig. 1(c), the helix angle is referred to as the angle between the normal line of the elliptical sector-shaped plates and the heat ex-changer axis. The research results of experimental measurements and numerical simulations provide the bases of engineering design method, for which the primary objects are to determine the required heat transfer surfaces and the fluid pressure drops of shell-and-tube sides. In the design method, the input data are flow rates and at least three of the inlet and outlet temperatures of both sides in heat exchanger. After primary guessing for the heat exchanger structure, the over-all heat transfer coefficient and the pressure drop can be determined by adopting correlations obtained from tests or simulations. If the calculated heat transfer rate and pressure drops cannot satisfy the design requirements, the heat exchanger is re-constructed, and the calculation is repeated again until the calculated heat transfer rate and the pressure drops can satisfy the pre-conditions. It can be seen that the heat transfer and pressure drop correlations are the basis for the design method (J.P. Holman, *et al*, 2003)

2.5 Tube Layout

- Tube layout is characterized by the included angle between tubes.
- Two standard types of tube layouts are the **square** and the **equilateral triangle**.
- Triangular pitch (30^o layout) is better for heat transfer and surface area per unit length (greatest tube density.)
- Square pitch (45 & 90 layouts) is needed for mechanical cleaning.
- Note that the 30°,45° and 60° are staggered, and 90° is in line.
- For the identical tube pitch and flow rates, the tube layouts in decreasing order of shell-side heat transfer coefficient and pressure drop are: 30°,45°,60°, 90°.
- **The 90° layout** will have the lowest heat transfer coefficient and the lowest pressure drop.
- **The square pitch:**(90° or 45°) is used when jet or mechanical cleaning is necessary on the shell side.In that case, a minimum cleaning lane of ¼ in. (6.35 mm) is provided. The square pitch is generally not used in the fixed header sheet design because cleaning is not feasible.
- **The triangular pitch:** provides a more compact arrangement, usually resulting in smaller shell, and the strongest header sheet for a specified shell-side flow area. It is preferred when the operating pressure difference between the two fluids is large.
- **The selection of tube pitch** is a compromise between a
- **Close pitch** (small values of P_T/d_o) for increased shell-side heat transfer and surface compactness, and an
- **Open pitch** (large values of P_T/ d_o) for decreased shell-side plugging and ease in shell-side cleaning.

Tube pitch P_t is chosen so that the **pitch ratio** is $1.25 < P_T/d_o < 1.5$.

When the tubes are to close to each other (P_T/d_o less than 1.25), the header plate (tube sheet) becomes to weak for proper rolling of the tubes and cause leaky joints.

Tube layout and tube locations are standardized for industrial heat exchangers.

However, these are general rules of thumb and can be violated for custom heat exchanger designs.

3. Literature Review

A lot has been written about designing heat exchangers, and specifically shell-and-tube heat exchangers. For example, the book by Kern published in 1950 details basic design procedures for a variety of heat exchangers. In the majority of published papers as well as in industrial applications, heat transfer coefficients are estimated, based, generally on literature tables. These values have always a large degree of uncertainty. So, more realistic values can be obtained if these coefficients are not estimated, but calculated during the design task. A few numbers of papers present shell and tube heat exchanger design including overall heat transfer coefficient calculations (Polley *et al*., 1990, Polley and Panjeh Shah, 1991, Jegede and Polley, 1992, and Panjeh Shah, 1992, Ravagnani, 1994, Ravagnani *et al*. (2003), Mizutani *et al*., 2003, Serna and Jimenez, 2004, Ravagnani and Caballero, 2007a, and Ravagnani *et al*., 2009) Gang yong Lei *et al* [1] have showed the effects of baffle inclination angle on flow and heat transfer of a heat exchanger with helical baffles, where the helical baffles are separated into inner and outer parts along the radial direction of the shell. While both the inner and outer helical baffles baffle the flow consistently, smoothly and gently, and direct flow in a helical fashion so as to increase heat transfer rate and decrease pressure drop and impact vibrations, the outer helical baffle becomes easier to manufacture due to its relatively large diameter of inner edge. Lutcha J *et al* have done experiments to the improvement of tubular heat exchangers with helical baffles for investigation of the flow field patterns generated by various helix angles which is expected to decline pressure at shell side and increase heat transfer process significantly (Kuppan, *et al*, 2000).

4. Boundary Conditions

- The working fluid of the shell side is water
- The shell inlet temperature is set to 300k
- The constant wall temperature of 450k is assigned to the tube walls
- Zero gauge pressure is assigned to that outlet nozzle
- The inlet velocity profile is assumed to be uniform
- No slip condition is assigned to all surfaces.

The zero heat flux boundary conditions are assigned to the shell outer wall (excluding the baffle shell interfaces), assuming the shell is perfectly insulated.

5. Formulae used For Designing Shell and Tube Heat Exchanger

Some of the following dimensions are pictured in Figure

L=length of the tube
N_t=No. of tubes
$N_{P=}$ No. of pass
D_s=Shell inside diameter
N_b=No. of baffles
B=Baffle spacing

The baffle spacing is obtained

$$B=\frac{L_t}{N_b+1} \tag{1}$$

5.1 Shell-Side Tube Layout

Figure shows a cross section of both a square and triangular pitch layouts. The tube pitch t P and the clearance t C between adjacent tubes are both defined. Equation of the equivalent diameter is rewritten here for convenience

$$D_e=\frac{4A_c}{P_{heated}} \tag{2}$$

From Figure, the equivalent diameter for the square pitch layout is

$$D_{e=}\frac{4(P_t^2-\pi d_o^2/4)}{\pi d_0} \tag{3}$$

From Figure, the equivalent diameter for the triangular pitch layout is

$$D_e=\frac{4\left(\frac{\sqrt{3P_t^2}}{4}-\frac{\pi d_0^2}{8}\right)}{\frac{\pi d_0}{2}} \tag{4}$$

The cross flow area of the shell c A is defined as

$$A_c=\frac{D_s C_t B}{P_t} \tag{5}$$

The diameter ratio dr is defined by

$$d_r=\frac{d_0}{d_t} \tag{6}$$

Some diameter ratios for nominal pipe sizes are illustrated in Table C.6 in Appendix C. The tube pitch ratio Pr is defined by

$$P_r=\frac{P_t}{d_0} \tag{7}$$

The tube clearance Ct is obtained from Figure

$$C_t=P_t=d_0 \tag{8}$$

The number of tube Nt can be predicted in fair approximation with the shell inside diameter Ds.

$$N_t=(CTP)\frac{\pi D_s^2/4}{\text{Shade area}} \tag{9}$$

where *CTP* is the *tube count constant* that accounts for the incomplete coverage of the
shell diameter by the tubes, due to necessary clearance between the shell and the outer
tube circle and tube omissions due to tube pass lanes for multiple pass design .

CTP = 0.93 for one-pass exchanger
CTP = 0.9 for two-pass exchanger
CTP = 0.85 for three-pass exchanger

$$\text{Shade Area} = CL.PP_t^2 \tag{10}$$

where CL is the tube layout constant.

$$CL = 1 \text{ for square-pitch layout} \tag{11}$$

$CL = sin(60°) = 0.866$ for triangular-pitch layout

Plugging in equation 10 and 11 gives

$$N_t=\frac{\pi}{4}\left(\frac{CTP}{CL}\right)\frac{D_s^2}{P_t^2}=\frac{\pi}{4}\left(\frac{CTP}{CL}\right)\frac{D_s^2}{P_r^2 d_0^2} \tag{12}$$

6. Design and Fabrication of Components

6.1. Design

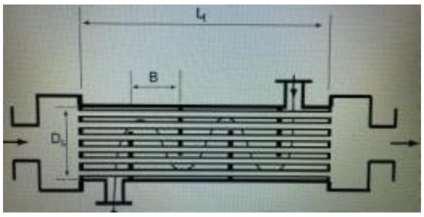

Figure 1 Dimensions of shell and tube heat exchanger

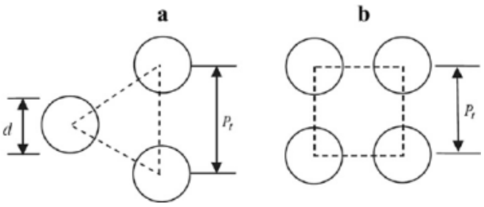

Figure 2 Square and triangular pitch Square and triangular

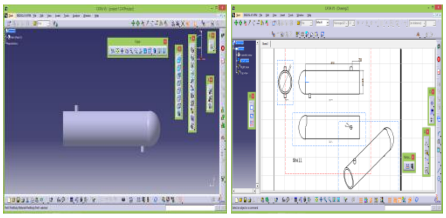

Figure 3 Shell Design

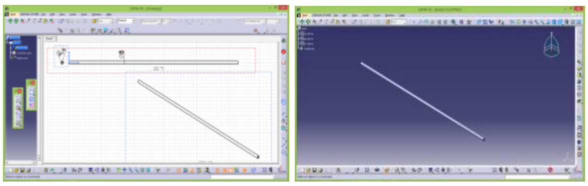

Figure 4 Copper Tubes Design

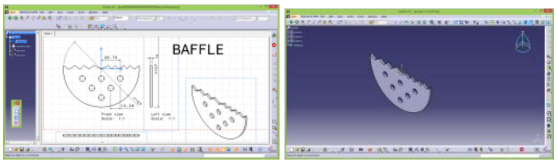

Figure 5 Baffles Design

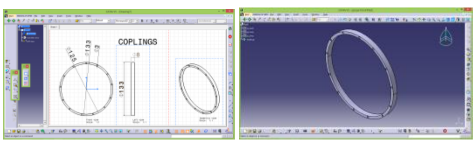

Figure 6 Couplings Design

6.2. Fabrication

Figure 7 Shell fabrication

Figure 8 Copper Tubes Fabrication

Figure 9 Tube sheet Fabrication

Figure 10 Placing of Baffles

Figure 11 Final Setup

7. Geometric Modelling

Heat exchanger length L	500
Shell inside diameter (D_i)	108
Tube outside diameter (dD)	10
Tube inner diameter (di)	9.25
Number of baffles (Nb)	4
Number of tubes (Nt)	16
Helix angles	5^0, 10^0,15^0,20^0
Pitch diameter	1.25*d_0

Conclusions

After this study it is said that the shell and tube heat exchanger has given the respect among all the classes f heat exchanger due to their virtues like comparatively large ratios of heat transfer area to volume and weight and many more.

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References

Master, B. I., Chunangad, K. S.,and Pushpanathan, V., 2003, Fouling Mitigation Using Helixchanger Heat Exchangers,Proceedings of the ECI Conference on Heat Exchanger Fouling and Cleaning: Fundamentals and Applications, Santa Fe, NM, May 18–22, pp. 317–322

Bell, K. J., 1981, Delaware Method for Shell Side Design,Heat ExchangersThermal Hydraulic Fundamentals and Design, S. Kakac, A. E. Bergles, and F.Mayinger, eds., Taylor & Francis, Washington, DC.

Bell, K. J., 1986, Delaware Method of Shell Side Design,Heat ExchangerSourcebook, J. W. Pallen, ed., Hemisphere, Washington, DC.

Bell, K. J., 1988, Delaware Method of Shell-Side Design,Heat TransferEquipment Design, R. K. Shah, E. C. Sunnarao, and R. A. Mashelkar, eds.,Taylor & Francis, New York.

Schlünder, E. U., ed., 1983,Heat Exchanger Design Handbook, Vol. 3, Hemi-sphere, Washington, DC

Stehlik, P., Nemcansky, J., and Kral, D., 1994, Comparison of CorrectionFactors for Shell-and-Tube Heat Exchangers With Segmental or HelicalBaffles, Heat Transfer Eng.,151, pp. 55–65.

Schlünder, E. U., ed., 1983Heat Exchanger Design Handbook, Vol. 2, Hemisphere, Washington, DC.

Gaddis, E. S., and Gnielinski, V., 1997, Pressure Drop on the Shell Side ofShell-and-Tube Heat Exchangers With Segmental Baffles, Chem. Eng. Pro-cess.,362, pp. 149–159.

Kuppan, T., 2000,Heat Exchanger Design Handbook, Marcel Dekker, NewYork.

J.P. Holman, Heat Transfer, 9thEdition, McGraw-Hill, 2002.

Peters, M.S., Timmerhaus, K.D., and West, R.E., Plant Design and Economics for Chemical Engineers,McGraw-Hill, New York, 2003.