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Shell & Tube Type Heat Exchangers: An Overview

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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.

Key words: shell & tube type heat exchangers; constructional details; design methods and the reasons for the wide acceptance.

1. 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. The heat exchange between the two fluids takes through the wall of the tubes.

2. Components Details[1]

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.

[1] Some contents under this heading have been cited from Wolverine Tube Heat Transfer Data Book.

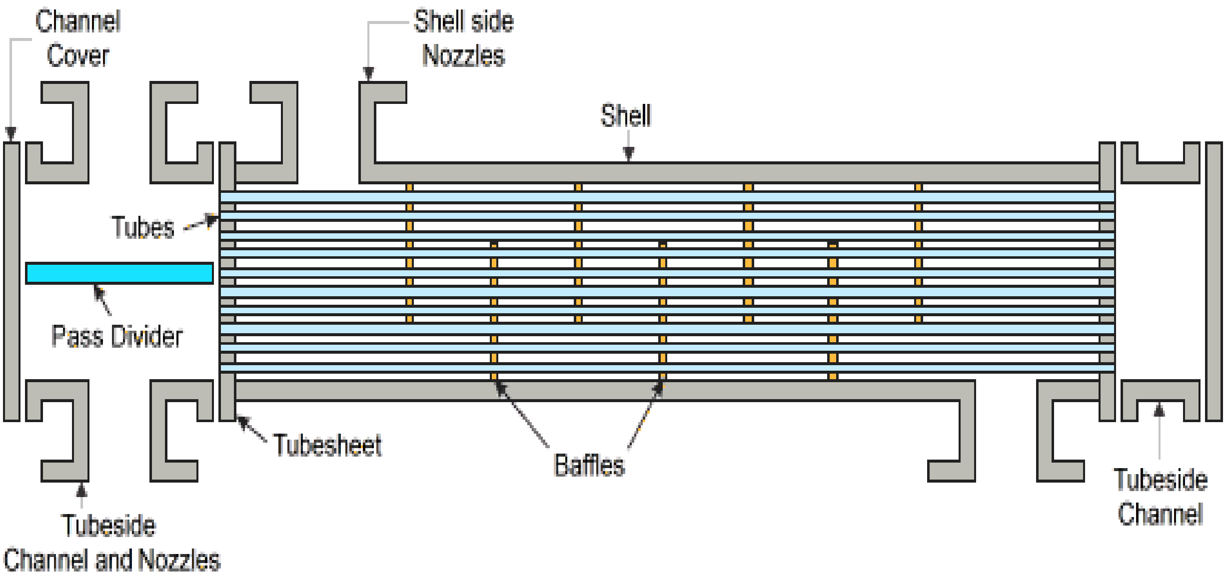

Figure1. Components Schematic of Shell and Tube Type Heat Exchanger

3. Design Methods[2]

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:

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 $\Delta T_2 = t_{h2}-t_{c1}$.

iii. Our next step is to calculate the area required of the heat exchanger (on the basis of assumed U_0), number of tubes, tube bundle diameter, diameter of shell and its thickness with the help of following expressions:

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[2] The contents under this heading are already accepted by Global Journals Inc. for publication of paper titled as "Steady State Thermal Analysis of Shell and Tube Type Heat Exchanger to Demonstrate the Heat Transfer Capabilities of Various Thermal Materials Using Ansys" by the same authors in GJRE Volume 14 Issue4.

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

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

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

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

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

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

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

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

vi. 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.

4. Works Reviewed

While reviewing the works of renowned scholars it has been seen that significant amount of works has been done in fields of shell and tube type heat exchangers (STHE). Some important works have been described in detail as under:

Ahmad Fakheri[1] in his paper shows that how to calculate the efficiency of the heat exchangers based on the second law of thermodynamics. He says that corresponding to every heat exchanger there is an ideal balanced counter flow heat exchanger which has the properties of same UA, same AMTD and minimum entropy generation corresponding to minimum losses and irreversibility. The efficiency of the heat exchanger may be calculated by comparing the heat transfer capability of actual heat exchanger with that of the ideal heat exchanger. Ahmad Fakheri[2] in this article extends the concept of heat exchanger efficiency to the networks of heat exchangers. This paper provides a simple equation that can be used to calculate the efficiency of heat exchangers in networks. It also assists for calculating the effectiveness or efficiency of individual heat exchangers as well as the number of heat exchangers required for the purpose. Rajeev Mukherjee[3] 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. Jiangfeng Guo et.al[4] took some geometrical parameters of the shell-and-tube heat exchanger as the design variables and the genetic algorithm is applied to solve the associated optimization problem. It is shown that for the case that the heat duty is given, not only can the optimization design increase the heat exchanger effectiveness significantly, but also decrease the pumping power dramatically. A. Pignotti[5] in his paper established relationship between the effectiveness of two heat exchanger configurations which differ from each other in the inversion of either one of two fluids. This paper provides the way by which if the effectiveness of one combination is known in terms of heat capacity rate ratio and NTUs then the effectiveness of the other combination can be readily known. M. S. Bohn[6] in his article presents a method of calculating the electric power generated by a thermoelectric heat exchanger. The method presented in this paper is an extension of the NTU method used to calculate heat-exchanger's heat-transfer effectiveness. The effectiveness of thermoelectric power generation is expressed as the ratio of the actual power generated to the power that would be generated if the entire heat-exchanger area were operating at the inlet fluid temperatures. V.K. Patel and R.V. Rao[7] 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 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. Hetal Kotwal and D.S Patel[8] focus on the various researches on Computational Fluid Dynamics (CFD) analysis in the field of heat exchanger. Different turbulence models available in CFD tools i.e. Standard k-ε model, k-ε RNG model, Realizable k-ε, k-ω and RSM model in conjunction with velocity pressure coupling scheme and have been adopted to carry out the simulation. The steady increase in computing power has enable model to react for multi- phase flows in realistic geometry with good resolution. The quality of the solution has proved that CFD is effective to predict the behaviour and performance of heat exchanger. Shiv Kumar Rathore and Ajeet Bergaley[9] worked with the aim to identify the advantages of low-finned tube Heat Exchangers over Plain tube (Bare Tube) units. To use finned tubes to advantage in this application, several technical issues were to be addressed; (1) Shell side and tube side Pressure, (2) Cost, (3) Weight and (4) Size of Heat Exchanger, Enhanced tubular heat exchangers results in a much more compact design than conventional plain tube units, obtaining not only thermal, mechanical and economical advantages for the heat exchanger, but also for the associated support structure, piping and skid package unit, and also notably reduce cost for shipping and installation of all these components. A more realistic comparison is made on the basis of respective cost per meter of tubing divided by the overall heat transfer coefficient for the optimized units, which gives a cost to performance ratio. This approach includes the entire thermal effect of internal and external heat transfer augmentation and fouling factors in the evaluation. This is typically quite close to reality and easy for the thermal designer to evaluate himself. The results of this analysis shows that the finned tube heat exchanger is more economical than Conventional Bare tube Exchanger, The tube side pressure drop and fluid velocity is higher than the conventional bare tube exchanger, which prevent fouling inside the tubes, The shell side pressure drop is some lesser but fluid velocity is higher than the conventional heat exchanger which saves the outer surface of tubes from fouling creation and fluid transfer time. The shell diameter of finned tube Exchanger is lesser than Conventional bare tube heat exchanger, which saves sheet material and reduces the size of the shell, which helps to easily installation in the plant. Hari Haran et.al[10] 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. The result after comparing both was that they were getting an error of 0.0274 in effectiveness.

5. 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)
C_p	specific heat of fluid (J/kg-°C)
t	temperature of fluid (°C)
LMTD (or ΔT)	Logarithmic Mean Temperature Difference (°C)
Q	amount of heat transfer taking place (watts)
U (or U_o)	overall heat transfer coefficient (w/m^2°c)
A	area of heat exchanger (m^2)
l	length of heat exchanger (m)
N	number of tubes
D_b	tube bundle diameter (mm)
d	diameter of tubes (mm)
D	diameter of shell (mm)
B	baffle spacing (mm)
P_r	Prandtl number
R_e	Reynold's number
Nu	Nusselt number
h	heat transfer coefficient (w/m^2°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
max	maximum amount of the quantity
Constants	
K_1 , n_1	constants depending on the pitch and type of pass

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 by entropy generation minimization and genetic algorithm", Applied Thermal Engineering 29 (2009) 2954–2960.

5. A. Pignotti, "Relation Between the Thermal Effectiveness of Overall Parallel and Counter flow Heat Exchanger Geometries", J. Heat Transfer 111(2), 294-299 (May 01, 1989), asme.org.

6. M. S. Bohn, "Heat-Exchanger Effectiveness in Thermoelectric Power Generation", J. Heat Transfer 103(4), 693-698 (Nov 01, 1981), asme.org.

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.

13. Vindhya Vasiny Prasad Dubey, Raj Rajat Verma, Piyush Shanker Verma, A. K. Srivastava, "Steady State Thermal Analysis of Shell and Tube Type Heat Exchanger To Demonstrate The Heat Transfer Capabilities Of Various Thermal Materials Using Ansys", Global Journals Inc., GJRE Volume 14, Issue 4, ISSN- 0975-5861.

14. Vindhya Vasiny Prasad Dubey, Raj Rajat Verma, Piyush Shanker Verma, A. K. Srivastava, " Performance Analysis Of Shell & Tube Type Heat Exchanger Under The Effect Of Varied Operating Conditions", International Organization of Scientific Researches.

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