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Thermal Analysis of Shell & Tube Heat Exchanger by using HTRI

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Abstract — *Shell and Tube heat exchangers are having special importance in boilers, oil coolers, and condensers. The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations. Analytical method was used to develop correlation for the performance analysis. The user -friendly computer software using HTRI Xchanger suite v5.0 is developed for Thermal design of shell and tube heat exchangers. Initially Thermal Design related calculations of shell and tube heat exchangers will be performed and then using HTRI validification will be carried out after that varying different thermal parameters such as pressure drop and heat transfer co-efficient effect will be studied and finally thermal design optimization will be the outcome.*

Keywords- *HTRI analysis; Shell and tube heat exchanger; Baffles; Performance analysis; Tube layout; Heat transfer; Pressure drop.*

I. INTRODUCTION

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. Heat exchanger are devices that provide the flow of thermal energy between two or more fluids at different temperatures. The fluids can be single or two phase and, depending on the exchanger type, may be separated or in direct contact. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment.

Shell-and-tube heat exchanger provides relatively large rations of heat transfer area to volume and weight and they can be easily cleaned. They offer great flexibility to meet almost any service requirement. Reliable design methods and shop facilities are available for their successful design and construction. Shell-and-tube heat exchangers can be designed for high pressures relative to the Various front and rear head types and shell types have been standardized by TEMA(Tabular Exchanger manufactures association). They are identified by an alphabetic character, as shown in Figure 1.

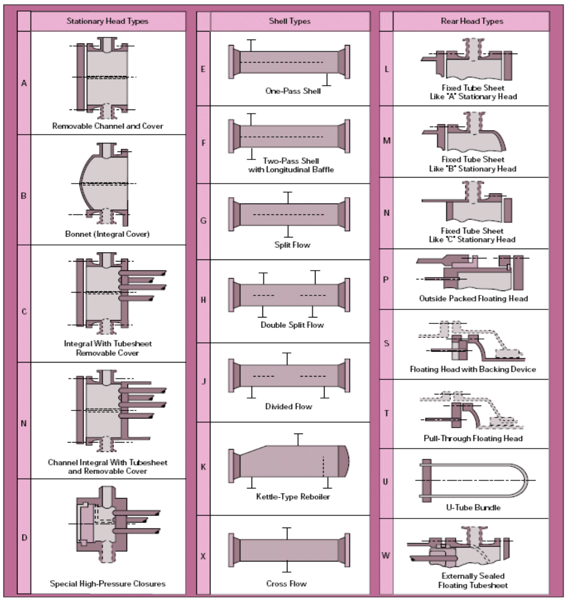

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Figure 1. Shell types

II. LITERATURE SURVEY

- The Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) in this paper presents performance analyses of shell and tube heat exchangers. Analytical method was used to develop correlation for the performance analysis. A program was written in MATLAB to check for the thermal and hydraulic suitability of the heat exchangers.[Ebieto, C.E and Eke G.B].
- The International Journal of Modern Engineering Research (IJMER) In this paper The sophisticated and user-friendly computer software using Visual Basic 6.0 (As a Programming Language) is developed for the hydraulic design of shell and tube heat exchangers based on the D.Q. Kern method by the VB programming language . The use of this software will bridge the gap between engineering practice and teaching of shell and tube heat exchanger design.This software enable the user to predict about the suitability of heat exchanger or service.[Chandrakant B. Kothare].
- The Bachelor of Technology in Chemical Engineering in this paper the process in solving simulation consists of modeling and meshing the basic geometry of shell and tube heat exchanger using CFD package ANSYS 13.0. The objective of the project is design of shell and tube heat exchanger with helical baffle and study the flow and temperature field inside the shell using ANSYS software tools. The heat transfer and flow distribution is discussed in detail and proposed model is compared With increasing baffle inclination angle. The model predicts the heat transfer and pressure drop with an average error of 20%. Thus the model can be improved. [Anil Kumar Samal]. In this paper Heat transfer area and pressure drops and checking whether the assumed design satisfies all requirement or not. The purpose of this paper is how to design the shell and tube heat exchanger which is the majority type of liquid –to- liquid heat exchanger. General design considerations and design procedure are also illustrated in this paper. In design calculation HTRI software is used to verify manually calculated result. There is increase in pressure drop with increase in fluid flow rate in shell and tube heat exchanger which increases pumping power. Genetic algorithm provide significant improvement in the optimal designs compared to the traditional designs. Genetic algorithm application for determining the global minimum heat exchanger cost is significantly faster and has an advantage over other methods in obtaining multiple solutions of same quality. Thus, providing more flexibility to the designer.[Sandeep K. Patel, Professor Alkesh M. Mavani].
- Thermal Analysis of Unconventional Process Condenser Using Conventional Software in this paper The field of thermal-hydraulic design of process and power apparatuses for heat exchange. There are several world-renowned software systems for both analyses of existing heat exchangers and for design of new equipment. The most-used ones are those developed by Heat Transfer Research, Inc. (HTRI), Aspen Technology, Inc. (Aspen Shell & Tube Exchanger) and Chemstations, Inc. (Chemstations™ CHEMCAD™).Advantages of these sophisticated software systems are particularly in the field of conventional heat exchanger solutions. .HTRI Xchanger Suite contains a rather large set of functionalities necessary for evaluation of unconventional heat exchange equipment. Still, this package has its limitations which can pose problems should the apparatus geometry be even more uncommon than in case of the discussed condenser. Nonetheless, suitability of HTRI Xchanger Suite for such tasks is superior compared to the other two packages, which is supported by the results presented in this paper. The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations.

III. THERMAL ANALYSIS

A heat exchanger is to be designed to heat raw water according to TEMA standards from Table 1 With 124 tubes for a 2-P shell-and-tube heat exchanger , re-rate this heat exchanger for the given process specifications by using the Kern method. The Preliminary estimation is carried out by using following formulas,

The Heat transfer or the size of heat exchanger is calculated by using,

$$Q=U_0A_0{}^{\Delta T}$$

where U_o is Overall heat transfer coefficient.

The overall heat transfer coefficient, Uo based on the outside diameter of tube, can be estimated from the estimated value of individual heat transfer coefficients, Wall and fouling resistance, and the overall surface efficiency calculated by using,

$$\frac{1}{U_o}=\frac{A_o}{A_i}\left[\frac{1}{\eta_i h_i}+\frac{R_{fi}}{\eta_i}\right]+A_oR_w+\frac{R_{fo}}{\eta_o}+\frac{1}{\eta_o h_o}$$

It is useful to determine the distribution of the thermal resistance under clean and fouled conditions.

We need to calculate the LMTD for countercurrent flow from the four given inlet/outlet temperatures. If three temperature are known, the fourth one can be found from the heat balance,

$$\Delta T_{lm,cf} = \frac{(T_{h1}-T_{c2})-(T_{h2}-T_{c1})}{\ln\frac{(T_{h1}-T_{c2})}{(T_{h2}-T_{c1})}}$$

The heat transfer coefficient outside the tube bundles is referred to as the shell-side heat transfer coefficient. When the tube bundles employs baffles the heat transfer coefficient is higher than the coefficient for undisturbed flow condition along the axis of tubes without baffles. McAdams suggested following correlation for the shell side heat transfer coefficient,

$$\frac{h_o D_e}{k} = 0.36\left(\frac{D_e G_s}{\mu}\right)^{0.55}\left(\frac{c_p \mu}{k}\right)^{1/3}\left(\frac{\mu_b}{\mu_w}\right)^{0.14}$$

Where h_o is the shell-side heat transfer coefficient, De is the equivalent diameter on the shell side, and G_s is the shell-side mass velocity.

The friction factor for the shell calculated from,

$$f = \exp(o.576 - 0.19 \ln \mathrm{Re}\ )$$

For the tube side calculation,
$Re=\rho u_m d_i/\mu_t$

Using Gnielinski's correlation,

$$Nu_b = \frac{(f/2)(\mathrm{Re}-1000)\,\mathrm{Pr}}{1+12.7(f/2)^{1/2}(\mathrm{Pr}^{2/3}-1)}$$

$$f = (1.58\ \ln(\mathrm{Re})-3.28)^{-2}$$

Pressure Drop, ΔP_t

$$\Delta P_t = \left(4f\frac{LN_p}{d_i} + 4N_p\right)\frac{\rho u_m{}^2}{2}$$

To calculate overall heat transfer coefficient,

$$U_f = \frac{1}{\frac{d_o}{d_i h_i} + \frac{d_o R_{fi}}{d_i} + \frac{d_o \ln(d_o/d_i)}{2k} + R_{fo} + 1/h_o}$$

$$U_C = \frac{1}{\frac{d_o}{d_i h_i} + \frac{d_o \ln(d_o/d_i)}{2k} + 1/h_o}$$

Table 1.Result Table

PROPERTIES	MANUAL CALCULATED RESULTS
SHELL SIDE	
Pressure drop(psi)	**1.5**
Heat transfer coefficient-h(w/m^2-k)	**4715.4**
Reynolds Number-Re	**28715**
Hot temperature outlet(^{0}c)	**53.2**
TUBE SIDE	
Pressure drop(psi)	**3.6**
Heat transfer coefficient-h(w/m^2-k)	**3586.1**
Reynolds Number-Re	**13049.9**
Velocity(m/s)	**0.67**
Overall Heat transfer Coefficient U_f(w/m^2-k)	**1428.4**
Overall Heat transfer Coefficient U_c(w/m^2-k)	**1908.09**
LMTD(K)	**31.3**
Heat exchanged(Q)(KW)	**801**

IV. CONCLUSION

The robustness and medium weighted shape of Shell and Tube heat exchangers make them well suited for high pressure operations. Analytical method was used to develop correlation for the performance analysis. Manually calculated results are based on inlet and outlet conditions as well as with major assumption explained in theories. Results shown in above table While HTRI calculate the results at different point on the length from the inlet of heat exchanger. So, further design modification is essential for optimal performance of shell and tube heat exchanger for this purpose HTRI software required.

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