TO STUDY OF EXPERIMENTAL ANALYSIS OF TUBE BUNDLE GEOMETRY IN STHE

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ABSTRACT

The Shell and Tube Heat Exchangers are most commonly used in industries. This research is intended to assist anyone with some general technical experience, but perhaps limited specific knowledge of heat transfer equipment. This research is about the analysis of Tube Bundle Geometry in Shell and tube heat exchanger. In practical applications Tube Thickness, Tube Pitch Ratio of heat exchanger is the major factor which directly affects the performance of the heat exchanger. The optimal values of tube thickness at various pitch ratio and related heat transfer in heat exchanger, with trial and error method optimal performance condition is estimated. The effect of tube thickness and pitch ratio on other thermal parameters such as Heat Duty, Over Design, Tube Side heat transfer coefficient, Tube Side pressure drop, Tube Side Velocity, Overall heat transfer coefficient in clean and fouled condition is analysed. Efficient Results are achieved by varying tube thickness in operating limits. In this dissertation attempt is made to overcome some major theoretical assumptions and serve practical approach as much as possible for shell tube heat exchanger. It is hoped that the software will bridge the gap between engineering fundamentals and the existing industry practice of shell and tube heat exchanger design.

Keywords: - *rear end head, Head Flange, lifting lug, lantem ring, floating head making device*

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1. INTRODUCTION - 1

Shell and tube heat exchangers are most versatile type of heat exchangers, used in process industries, in conventional and nuclear power station as condenser, in steam generators in pressurized water reactor power plants, in feed water heaters and in some air conditioning refrigeration systems. Shell and tube heat exchanger provide relatively large ratio of heat transfer area to volume and weight and their construction facilitates disassembly for periodic maintenance and cleaning. Shell and tube heat exchanger offer great flexibility to meet almost any service requirement. Shell and tube heat exchanger can be designed for high pressure relative to the environment and high pressure difference between the fluid streams.

1.1 Basic Components of Shell and Tube Heat Exchanger - 1

Shell and tube heat exchangers consist of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and a second fluid flows within the space between the tubes and the shell, the major components of this exchanger are tubes (tube bundles), shell, front end head, rear end head, baffles and tube sheets. Typical parts and their arrangement are show in figure 1.

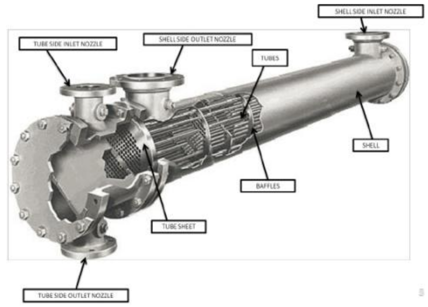


Fig. 1 Basic components of Shell and Tube Heat Exchanger

1.2 TEMA Standards - 2

The standard of the Tubular Exchanger Manufacturers Association (TEMA) describe various components in detail of shell and tube heat exchanger (STHE). STHE is divided into three parts: the front head, the shell and the rear head. Figure 2 illustrates the TEMA nomenclature for the various construction possibilities. Exchangers are described by the letter codes for the three sections.

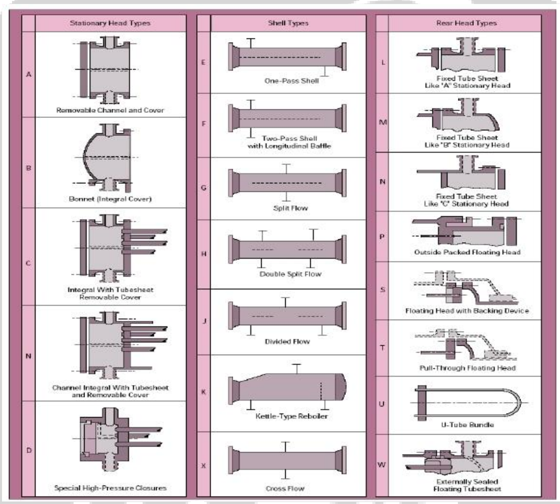


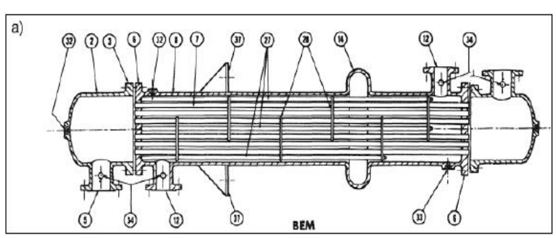
Fig. 2 TEMA Construction types (TEMA standards), 1988.

Each part has different construction and specific function. The construction of front and rear head as well as flow patterns in the shell are defined by the TEMA standards- for example, a BFL exchanger has a bonnet cover, a two-pass shell with a longitudinal baffle and a fixed tube sheet rear head.

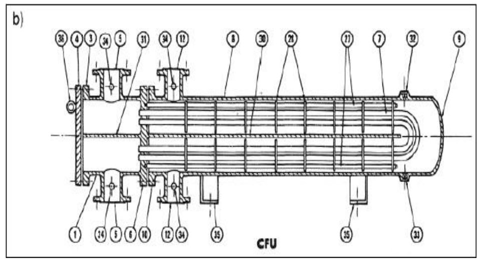
2. Classification Based on TEMA Construction - 2

There three basic classification based on TEMA based on their end connection and shell type

a. BEM b. CFUc. AES



(a)



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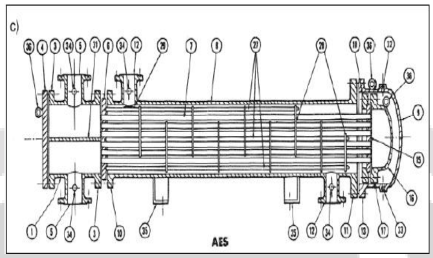

Fig. 3 (a, b, c) Construction Parts and Connections

1. Stationary (Front) Head—Channel
2. Stationary (Front) Head—Bonnet
3. Stationary (Front) Head Flange
4. Channel Cover
5. Stationary Head Nozzle
6. Stationary Tube sheet
7. Tubes
8. Shell
9. Shell Cover
10. Shell Flange—Stationary Head End
11. Shell Flange—Rear Head End
12. Shell Nozzle
13. Shell Cover Flange
14. Expansion Joint
15. Floating Tube sheet
16. Floating Head Cover
17. Floating Head Flange
18. Floating Head Backing Device
19. Split Shear Ring
20. Slip-on Backing Flange
21. Floating Tube sheet Skirt
22. Floating Tube sheet Skirt
23. Packing Box Flange
24. Packing
25. Packing Follower Ring
26. Lantern Ring
27. Tie Rods and Spacers
28. Transverse Baffles or Support Plates
29. Impingement Baffle or Plate
30. Longitudinal Baffle
31. Pass Partition
32. Vent Connection
33. Drain Connection
34. Instrument Connection
35. Support Saddle
36. Lifting Lug
37. Support Brack

2.1 Fixed Tube sheet Heat Exchanger - 1

A fixed-tube sheet heat exchanger has straight tubes that are secured at both ends to tube sheets welded to the shell. (Figures 2 and 3) The construction may have removable channel covers (e.g., AEL), bonnet-type channel covers (e.g., BEM), or integral tube sheets (e.g., NEN). The principal advantage of the fixed tube sheet construction is its low cost because of its simple construction. In fact, the fixed tube sheet is the least expensive construction type, as long as no expansion joint is required. A disadvantage of this design is that since the bundle is fixed to the shell and cannot be removed, the outsides of the tubes cannot be cleaned mechanically.

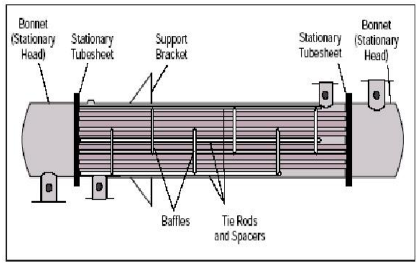

Fig. 4 Fixed tube sheet Heat Exchanger.

2.2 U-tube Heat Exchanger - 2

As the name implies, the tubes of a U-tube heat exchanger are bent in the shape of a U. There is only one tube sheet in a U-tube heat exchanger. However, the lower cost for the single tube sheet is offset by the additional costs incurred for the bending of the tubes and the somewhat larger shell diameter (due to the minimum U-bend radius), making the cost of a U-tube heat exchanger comparable to that of a fixed tube sheet exchanger. The advantage of a U-tube heat exchanger is that because one end is free, the bundle can expand or contract in response to stress differentials. In addition, the outsides of the tubes can be cleaned, as the tube bundle can be removed. The disadvantage of the U-tube construction is that the insides of the tubes cannot be cleaned effectively, since the U-bends would require flexible- end drill shafts for cleaning. Thus, U-tube heat exchangers should not be used for services with a dirty fluid inside tubes.

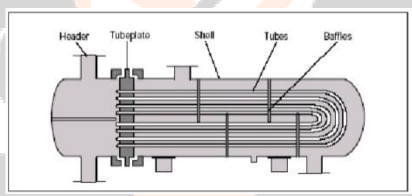

Fig. 5 U-tube Heat Exchanger.

2.3 Floating Head - 3

The floating-head heat exchanger is the most versatile type of STHE, and also the costliest. In this design, one tube sheet is fixed relative to the shell, and the other is free to “float” within the shell. This permits free expansion of the tube bundle, as well as cleaning of both the insides and outsides of the tubes. Thus, floating-head SHTEs can be used for services where both the shell side and the tube side fluids are dirty, making this the standard construction type used in dirty services, such as in petroleum refineries.

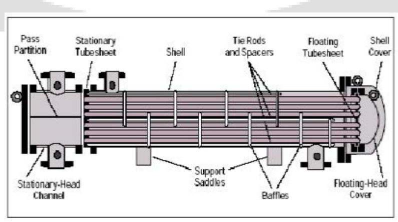

Fig. 6 Floating Head Heat Exchanger (TEMA S)

There are various types of STHE, but most of process industries and chemical industries mostly use fixed-tube sheet shell and tube type heat exchanger because of its low cost, simple construction and low maintenance cost. From industrial point of view it is necessary to operate shell and tube heat exchanger at optimal condition thus it reduce an operating and maintenance cost.

3. Tube Layout - 3

Tube layout is characterized by the included angle between tubes as shown in figure 6.

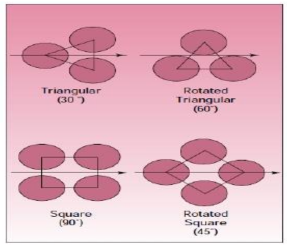

Fig. 7 Tube Layout patterns

There are four tube layout patters (Fig. 6.)

- Triangular (300)
- Rotated Triangular (600)
- Square (900)
- Rotated Square (450)

A triangular pattern will evidently accommodate more tubes than a square pattern. Further, a triangular pattern produces high turbulence and, therefore, a high heat transfer coefficient. However, a triangular (or rotated triangular) pattern does not permit mechanical cleaning of tubes for the normally used tube pitch as access lanes for cleaning are not available. Consequently, a triangular layout pattern is limited in use to clean services on the shell side. For services which require mechanical cleaning on the shell side, a square pitch has to be used. A rotated triangular pattern does not offer any advantage over a triangular pattern in the conversion of pressure drop to heat transfer and, hence its use is rare. For dirty services on the shell side, the usual practice is to use a square layout pattern.

Mass velocity strongly influences the heat-transfer coefficient. For turbulent flow, the tube side heat-transfer coefficient varies to the 0.8 power of tube side mass velocity, whereas tube side pressure drop varies to the square of mass velocity. Thus, with increasing mass velocity, pressure drop increases more rapidly than does the heat-transfer coefficient. Consequently, there will be an optimum mass velocity above which it will be wasteful to increase mass velocity further. The construction geometry and thermal parameters such as mass flow rate, heat transfer coefficient etc. are strongly influenced by each other. A detail study of research of design procedures, effect and variation of thermal parameters under different conditions and optimization methods implemented for STHE has been carried out in literature review.

3.1 LITERATURE REVIEW - 1

The subject of shell and tube heat exchanger (STHE) has a wide variety of process and phenomena. A vast amount of the material is published regarding STHE which depicts various factors affecting the thermal efficiency of the STHE. On the basis of that a brief summary is reviewed as follows:

3.2 Literature Review Related to Design of STHE - 2

Yusuf Ali Kara, Ozbilen Guraras [2004][4] Prepared a computer based design model for preliminary design of shell and tube heat exchangers with single phase fluid flow both on shell and tube side. The program determines the overall dimensions of the shell, the tube bundle, and optimum heat transfer surface area required to meet the specified heat transfer duty by calculating minimum or allowable shell side pressure drop. He concluded that circulating cold fluid in shell-side has some advantages on hot fluid as shell stream since the former causes lower shell-side pressure drop and requires smaller heat transfer area than the latter and thus it is better to put the stream with lower mass flow rate on the shell side because of the baffled space.

M.Serna and A.Jimenez [2005][5] have presented a compact formulation to relate the shell-side pressure drop with the exchanger area and the film coefficient based on the full Bell–Delaware method. In addition to the derivation of the shell side compact expression, they have developed a compact pressure drop equation for the tube-side stream, which accounts for both straight pressure drops and return losses. They have shown how the compact formulations can be used within an efficient design algorithm. They have found a satisfactory performance of the proposed algorithms over the entire geometry range of single phase, shell and tube heat exchangers.

Andre L.H. Costa, Eduardo M. Queiroz [2007][6] Studied that techniques were employed according to distinct problem formulations in relation to: (i) heat transfer area or total annualized costs, (ii) constraints: heat transfer and fluid flow equations, pressure drop and velocity bound; and (iii) decision variable: selection of different search variables and its characterization as integer or continuous. This paper approaches the optimization of the design of shell and tube heat exchangers. The formulation of the problem seeks the minimization of the thermal surfaces of the equipment, for certain minimum excess area and maximum pressure drops, considering discrete decision variables. Important additional constraints, usually ignored in previous optimization schemes, are included in order to approximate the solution to the design practice.

Su Thet Mon Than, Khin Aung Lin, Mi Sandar Mon [2008] [7] evaluated data for heat transfer area and pressure drop and checking whether the assumed design satisfies all requirement or not. The primary aim of this design is to obtain a high heat transfer rate without exceeding the allowable pressure drop. The decreasing pattern of curves of Reynolds Number and heat transfer coefficient shown in figure 8 and figure 9 shows that the Re and h are gradually decreases corresponding as high as tube effective length. Gradual decrease in Reynolds Number means there is significant decrease in pressure drop respectively.

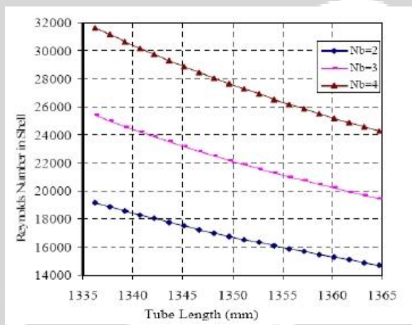

Fig. 8 Reynolds Number on Number of Baffles and Length of Tube

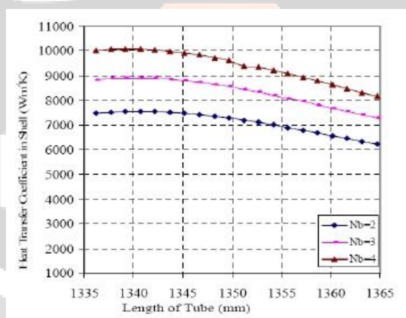

Fig. 9 Heat Transfer Coefficient on Number of Baffles and Length of Tube

M. M. El-Fawal, A. A. Fahmy and B. M. Taher [2011][8] prepared a computer program for economical design of shell and tube heat exchanger using specified pressure drop is established to minimize the cost of the equipment. The design procedure depends on using the acceptable pressure drops in order to minimize the thermal surface area for a certain service, involving discrete decision variables. Also the proposed method takes into account several geometric and operational constraints typically recommended by design codes, and provides global optimum solutions as opposed to local optimum solutions that are typically obtained with many other optimization methods.

4. Literature Review Related to Experimental and Method for Evaluating Shell side Heat Transfer Coefficient - 4

Zahid H. Ayub [2005][9] prepared a new chart method to calculate single- phase shell side heat transfer coefficient in a typical TEMA style single segmental shell and tube heat exchanger. A case study of rating water-to-water exchanger is shown to indicate the result from this method with the more established procedures and software's available in the market. The results show that this new method is reliable and comparable to the most widely known HTRI software.

R. Hosseini, A. Hosseini-Ghaffar, M. Soltani [2006][10] experimentally obtained the heat transfer coefficient and pressure drop on the shell side of a shell- and-tube heat exchanger for three different types of copper tubes (smooth, corrugated and with micro-fins). Also, experimental data has been compared with theoretical data available. Experimental work shows higher Nusselt number and pressure drops with respect to theoretical correlation based on Bell's method. The optimum condition for flow rate (for the lowest increase of pressure drop) in replacing the existing smooth tube with similar micro-finned tube bundle was obtained for the oil cooler of the transformer under investigation.

4.1 Literature Review Related to Different Optimization Techniques - 1

Resat Selbas, Onder Kızılkan, Marcus Reppich [2005] [11] applied genetic algorithms (GA) for the optimal design of shell-and-tube heat exchanger by varying the design variables: outer tube diameter, tube layout, number of tube passes, outer shell diameter, baffle spacing and baffle cut. From this study it was concluded that the combinatorial algorithms such as GA provide significant improvement in the optimal designs compared to the traditional designs. GA 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.

G.N. Xie, Q.W. Wang, M. Zeng, L.Q. Luo [2006] [12] carried out an experimental system for investigation on performance of shell-and-tube heat exchangers, and limited experimental data is obtained. The ANN is applied to predict temperature differences and heat transfer rate for heat exchangers. BP algorithm is used to train and test the network. It is shown that the predicted results are close to experimental data by ANN approach. Comparison with correlation for prediction heat transfer rate shows ANN is superior to correlation, indicating that ANN technique is a suitable tool for use in the prediction of heat transfer rates than empirical correlations. It is recommended that ANNs can be applied to simulate thermal systems, especially for engineers to model the complicated heat exchangers in engineering applications.

B.V. Babu, S.A. Munawarb [2007][13] presented study for the first time DE, an improved version of genetic algorithms (GAs), has been successfully applied with different strategies for 1,61,280 design configurations using Bell's method to find the heat transfer area. In the application of DE, 9680 combinations of the key parameters are considered. For comparison, GAs is also applied for the same case study with 1080 combinations of its parameters. For this optimal design problem, it is found that DE, an exceptionally simple evolution strategy, is significantly faster compared to GA and yields the global optimum for a wide range of the key parameters. José M. Ponce-Ortega et al. [2008] [14] presented an approach based on genetic algorithms for optimum design of shell and tube heat exchanger and for optimization major geometric parameters such as the number of tube-passes, standard internal and external tube diameters, tube layout and pitch, type of head, fluids allocation, number of sealing strips, inlet and outlet baffle spacing, and shell side and tube-side pressure drops were selected. Genetic algorithms provide better expectations to detect global optimum solutions than gradient methods, in addition to being more robust for the solution of non-convex problems.

M. Fesanghary et al. [2008][15] explores the use of global sensitivity analysis (GSA) and harmony search algorithm (HSA) for design optimization of shell and tube heat exchangers (STHXs) from the economic viewpoint. Comparing the HSA results with those obtained using genetic algorithm (GA) reveals that the HSA can converge to optimum solution with higher accuracy. Jiangfeng Guo et al. [2009] [16] 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. Sepehr Sanaye, Hassan Hajabdollahi [2010][17] considered seven design parameters namely tube arrangement, tube diameter, tube pitch ratio, tube length, tube number, baffle spacing ratio as well as baffle cut ratio. Fast and elitist non-dominated sorting genetic algorithm with continuous and discrete variables was applied to obtain the maximum effectiveness (heat recovery) and the minimum total cost as two objective functions.

V.K. Patel, R.V. Rao [2010] [18] explores 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.

5. CONCLUSIONS

In the present thesis, it could be shown that orientation of tube layout has a significant influence on tube side pressure drop and heat transfer of the heat exchangers..Looking at the satisfactory results, various analyses are made on different tube layouts in HTRI software and accordingly the results are plotted. Heat transfer for 90o tube layout is better as compared to other layouts. Over Design for 90o tube layout is better as compared to other layouts. Heat Transfer and over design are found to be the least for 60 o layout. Experimental work on different tube layouts can be carried out and the samecan be validated with the help of HTRI software.This dissertation identifies the advantages of having the appropriate exchanger and optimal design condition can be obtained in less time. Number of iterations and their comparison can be analysed easily.

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