TO STUDY OF PARAMETRIC ANALYSIS OF SHELL AND TUBE HEAT EXCHENGER

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ABSTRACT

The Shell and Tube Heat Exchangers are most commonly used in industries. The shell-and-tube heat exchanger which is the majority type of liquid-to-liquid heat exchanger is used as feed water cooler in process industries, refineries, chemicalplants and power plants. It is necessary to operate heat exchanger at optimumcondition which serves high thermal efficiency in allowable condition and lowrunning cost.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.

KEYWORD *:pressure drop, fouling factors, Baffle Spacing, Single Segmental, tube bundle*

1. INTRODUCTION

Heat Exchanger is a device which provides a flow of thermal energy between two or more fluids at different temperatures. Heat exchangers are used in a wide variety of engineering applications like power generation, waste heat recovery, manufacturing industry, air-conditioning, refrigeration, space applications, petrochemical industries etc. Heat exchanger may be classified according to the following main criteria.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.

2. BASIC DESIGN PROCEDURE OF HEAT EXCHANGER

A selected Shell and Tube heat exchanger must satisfy the process requirements with the allowable pressure drops until the next scheduled cleaning of the plant. The basic logical structure of the process heat exchanger design procedure is shown in fig. 1.

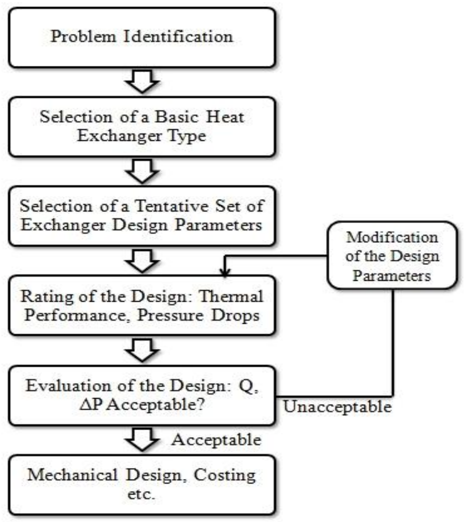

Fig. 1 Basic Logic Structure for process heat exchanger design

First, the problem must be identified as completely as possible. Not only matters like flow rates and compositions, inlet and outlet temperatures, and pressures of both the streams, but also the exact requirements of the process engineer and the additional information needed for the design engineer must be discussed in detail. The main duty of the process engineer is to supply all the information to the heat exchanger designer. At this point in the design process, the basic configuration of the heat exchanger must be tentatively selected, i.e., whether it is to be U-tube, baffled single-pass shell, a tube pass, baffled single-pass shell with fixed tubes, or a shell and tube heat exchanger with a floating head to accommodate differential thermal expansion between the tube and the shell, if one is not unconditionally desired. The next step is to select a tentative set of exchanger design parameters. A preliminary estimate of the heat exchanger size can be made, as outlined in section 3.1.1. Then the initial design will be rated; that is, the thermal performance and the pressure drops for both streams will be calculated for this design.

2.1 Preliminary Estimation - 1

Heat transfer or the size of heat transfer exchanger can be obtained from equation

$Q = U_o A_o \Delta T_m$

The overall heat transfer coefficient Uo, based on the O.D. of tubes, can be estimated from the estimated values of individual heat transfer coefficients, wall and fouling resistance, and the overall surface efficiency using equation

1 A 1 R Ro 1

U o A i hi i o oho

For the single tube pass, purely counter current heat exchanger, F= 1.00. For preliminary design shell with any even number of tube side passes, F may be estimated as 0.9. Heat load can be estimated from the heat balance as: Q = (mCp)c (Tc2 – Tc1) = (mCp)h (Th2 – Th1)

If one stream change phase: Q = mhfg, LMTD (Log Mean Temperature Difference Method) calculation:If three temperatures are known, the fourth one can be found from the heat balance,

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

Heat transfer area can be calculated from equation. Number of tubes of diameter (do), shell diameter (Ds) to accommodate the number of tubes (N t), with given tube length (L) can be estimated, $A_o = \pi d_o N_t L$

One can find the shell diameter (Ds), which would contain the right number of tubes (Nt), of diameter (do).

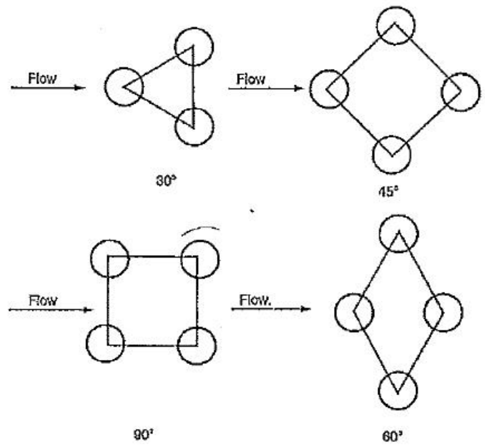

Fig. 2 Tube Layout angles

The total number of tubes, Nt, can be predicted in fair approximation as function of the shell diameter by taking the shell circle and dividing it by the projected area of the tube layout (figure 1) pertaining to a single tube A1.

$$N_t = (CTP)\frac{\pi D_s^2}{4 A_1}$$

where CTP is the tube count calculation constant that accounts for the incomplete coverage of the shell diameter by the tubes. Based on fixed tube sheet the following values are suggested:

- One tube pass: CTP = 0.93
- Two tube pass: CTP = 0.90
- Three tube pass: CTP = 0.85
- A1 = (CL) (PT)2

Where CL is the tube layout constant: CL = 1.0 for 90o and 45o CL = 0.87 for 30o and 60o

2.2 Tube Side Pressure Drop - 2

The tube side pressure drop can be calculated by knowing the number of tube passes (Np) and length (L) of heat exchanger. The change of direction in the passes introduces an additional pressure drop due to sudden expansions and contractions that the tube fluid experiences during a return that is accounted for allowing four velocity head per pass.

2.3 Shell Side Pressure Drop - 3

The shell side pressure drop depends on the number of tubes, the number of times the fluid passes the tube bundle between the baffles and the length of each crossing. The pressure drop on the shell side is calculated by the following expression:

$$\Delta P_s = \frac{F G^2 (N+1) D}{22 D_s \phi_s}$$

Where, ϕs = (µb+ µs) 0.14, Nb = Number of baffles, (Nb + 1) = Number of times fluid passes to the tube bundle, Friction factor (f) calculated from: $f = \exp(0.576 - 0.19 \ln Re_s)$

Where,

The correlation has been tested based on data obtained on actual exchangers. The friction coefficient also takes entrance and exit losses into account.

2.4 Pumping Power And Pressure Drop - 4

The fluid pumping power is proportional to the pressure drop in the fluid across a heat exchanger, the equation can be given a $P = \underline{\dot{m}\,\Delta P}/\rho\,\eta_p$

Where η_p is the pump or fan efficiency. (η_p = 0.80 to 0.85)The cost in terms of increased fluid friction requires an input of pumping work greaterthan the realized benefit of increased heat transfer. For gases and low density fluidsand also for very high viscosity fluids, pressure drop is always of equal importance tothe heat transfer rate and it has a strong influence on the design of heat exchangers.

2.5 The Rating of Preliminary Design - 5

After determining the tentative selected and calculated constructional design parameters, i.e., after a heat exchanger is available with process specifications, then this data can be used as inputs into a computer rating program or for manual calculations. The rating program is shown schematically in figure 3.

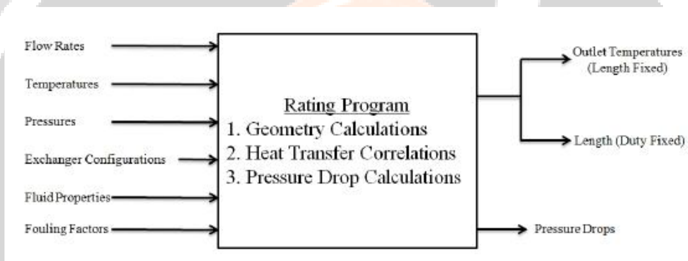

Fig. 3The Rating Program

For the rating process, all the preliminary geometrical calculations must be carried out as the input into the heat exchanger and the pressure drop correlations. When the heat exchanger is available, then all the geometrical parameters are also known. In the rating process, the other two basic calculations are the calculations of heat transfer and the pressure drops for each stream specified. If the length of the heat exchanger is fixed, then the rating program calculates the outlet temperatures of both streams. If the heat duty is fixed, then the result from the rating program is the length of the heat exchanger required to satisfy the fixed heat duty of the exchanger. In both the cases, the pressure drops for both streams in the heat exchanger are calculated.

3. RESULTS AND DISCUSSIONS

3.1 Feed Water Cooler - 1

Water cooling is a method of heat removal from components and industrial equipment. As opposed to air cooling, water is used as the heat conductor. Water cooling is commonly used for cooling automobile internal combustion engineslarge industrial facilities such as steam electric power.

3.2 Problem Definition - 2

Data for feed water cooler is taken from thesis entitled “Shell and Tube Heat Exchanger Thermal Design with Optimization of Flow Pressure Drop due to Fouling”, by Parmar Nirmal S., which is the courtesy of CCPL (Charisma Career Pvt. Ltd.). Both the fluids are in liquid phase. It is liquid to liquid heat transfer process and there is counter flow in the heat exchanger. It is assumed that the shell and tubes are made of carbon steel.

• **TEMA**	AES
• **DUTY**	136 KW
• **SHELL SIDE**	
Fluid	Sour Water
Mass Flow Rate (kg/s)	3.6575
Internal Diameter (mm)	475
Inlet Temperature (oC)	45.9
Fouling Factor (m2K/W)	0.000334
Baffle Type	Single Segmental
Baffle Spacing (mm)	170
• **TUBE SIDE**	
Fluid	Tube Count
Inlet Temperature (oC)	Cooling water
Outlet Temperature (ozC)	33
Mass flow rate (kg/s)	37
Outer Diameter (mm)	8.1737
Internal Diameter (mm)	27
Tube Length (mm)	25
Tube Pitch (mm)	6000
Tube Layout	32
	30o
	106

3.3 Different Tube Layouts (90o, 60o, 45o, 30o) - 3

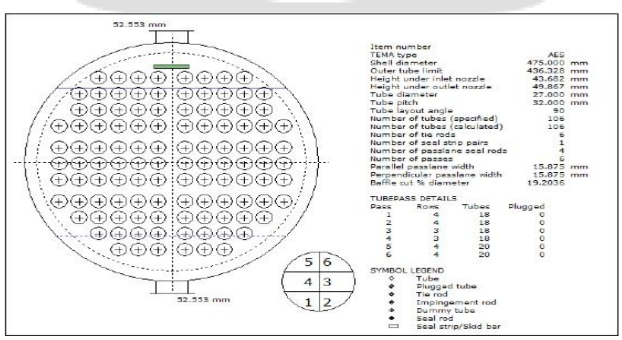

Fig. 4 Tube layout for 90o

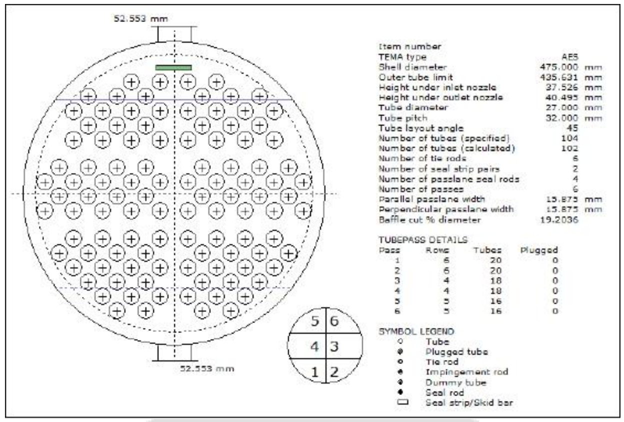

Fig. 5 Tube layout for 45o

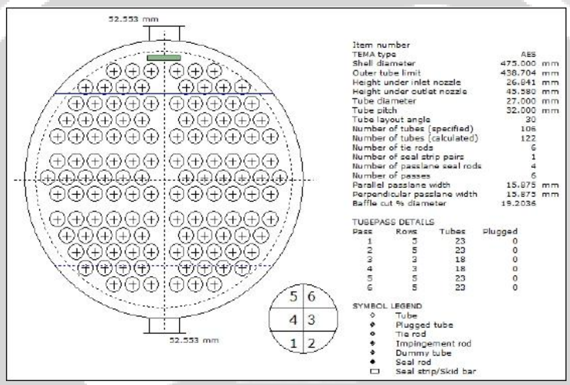

Fig. 6 Tube Layout for 30o

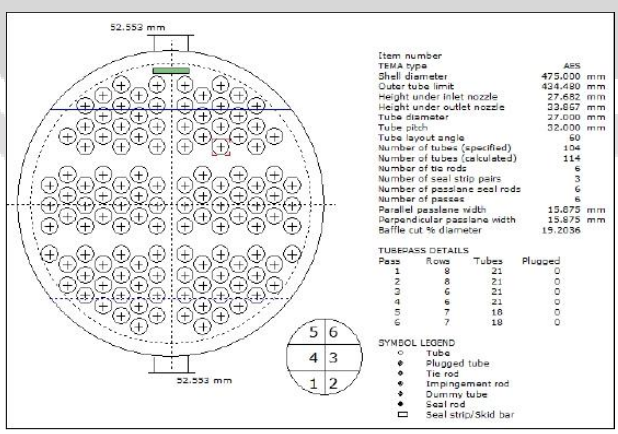

Fig. 7 Tube Layout for 60o

3.4 Output 3D CAD Model of Feed Water Cooler - 4

Three dimensional model of shell tube type heat exchanger made in HTRI Exchanger is shown in figure.

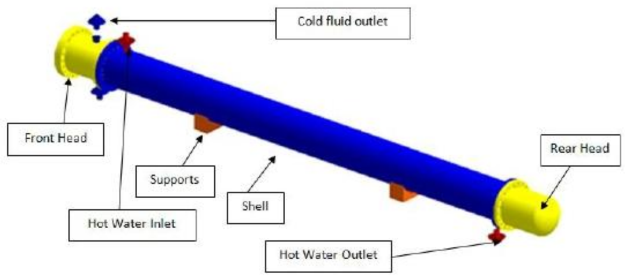

Fig. 8 The internal construction of shell and tube heat exchanger. The baffle and tubes arrangements are shown.

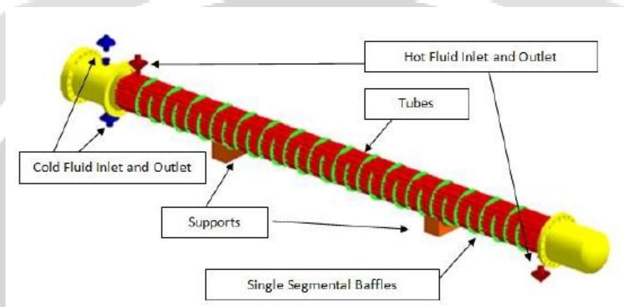

Fig. 9 3D Model Internal Construction of Shell and Tube Heat Exchanger

3.5 Effect of Gradual Increase of Tube Thickness for different Tube Layouts (90o, 60o, 45o, 30o) - 5

Different 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 foul condition are affected by varying tube thickness. These phenomena can be presented by iterating the heat exchanger data for different tube thickness. Here tube thickness is varied from '0.559' to '3.048' with the help of HTRI Xsit software. The results are shown as below:

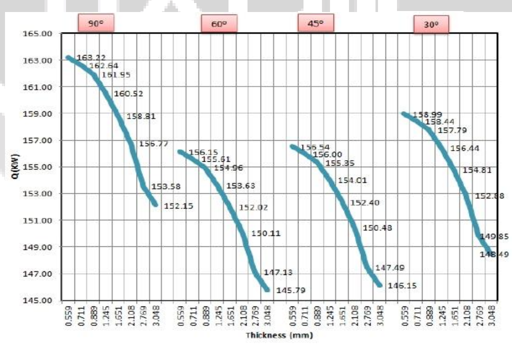

Chart 1 Heat Duty vs Tube Thickness

From the above graph it is observed that Heat Duty for all the different layouts decreases with increase in tube thickness. Also it is noticed that 90o layout is having the maximum heat duty. Moreover it is also seen that there is a greater decrease in the graph if the tube thickness is increased beyond the value 2.108 mm

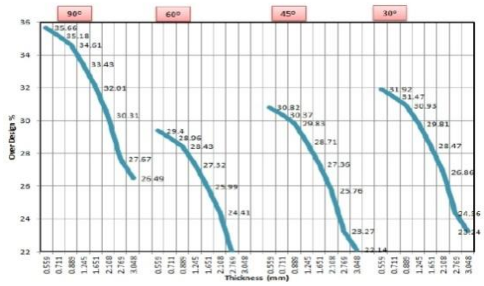

Chart 2 Over Design vs Tube Thickness

From this graph it is noticed that with the increase in tube thickness, over design decreases. Also 90o layout is being over designed better than the 45 o layouts, 60o layout and 30o layout. Also the over design reduces at a high rate if the tube thickness is increased beyond 2.108. Moreover it is observed that 600 layout is the least over designed.

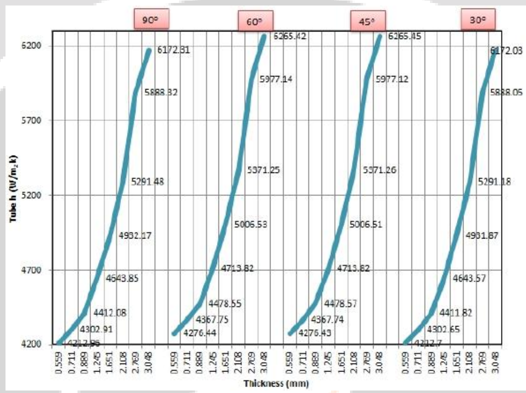

Chart 3 Tube Side Heat Transfer Coefficient vs Tube Thickness

From the above graph it is seen that there is a noticeable change in tube side heat transfer coefficient with the increase in tube thickness. 45o layout and 60o layout are providing greater tube side heat transfer coefficient compared to 90o layout and 30o layout.

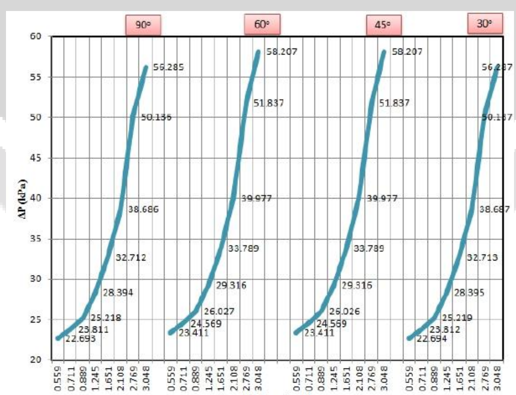

Chart 4 Tube Side Pressure Drop vs Tube Thickness

From the above graph it is seen that there is a noticeable change in tube side pressure drop with the increase in tube thickness. After increasing the thickness beyond 2.108, there is drastic increase in the pressure drop which goes beyond the pressure limit. Both the graphs i.e. pressure drop and heat transfer coefficient are following the same pattern for all types of layouts.

4. 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. In the present work validations of the data has been carried out and the following were the noticeable results found: 1. Increase in Heat exchanged by 11.04%. 2. Decrease in pressure drop in tube side by 29.59%. 3. Decrease in heat transfer coefficient in tube side by 11.2%. 4. Increase in Uf and Uc by 1.97% & 0.5% respectively.

Looking at the satisfactory results, various analyses are made on different tube layouts in HTRI software and accordingly the results are plotted (figure 4.7 to 4.14). 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.

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