Design Of Shell And Tube Heat Exchanger

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Abstract

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. From different types of heat exchangers, the shell and tube heat exchangers with straight tubes and single pass is to be under study. There is a wide application of shell and tube type of heat exchanger in the field of brewery and other industrial applications for its enhanced heat transfer characteristics and compact structure. Researches are going on to improve the heat transfer rate of the heat exchanger. Here, we have fabricated the shell and tube heat exchanger with selecting the materials on the primary objective of enhancing the heat transfer effectiveness for brewery applications.

Keywords*—Baffles, Heat transfer, Tubes, FEA, CFD, Kern's Method, Pressure drop.*

I. 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:

1. Recuperators and Regenerators.
2. Transfer process: Direct contact and Indirect contact.
3. Geometry of construction: tubes, plates and extended surfaces.
4. Heat transfer mechanisms: single phase and two phases.
5. Flow arrangements: parallel, counter and cross flows.

The principal components of a shell and tube heat exchanger are shell, shell cover, tubes, channel, channel cover, tube sheet, nozzles, and baffles as shown in Figure [1]

Large ratio of heat transfer area to volume is provided by the shell and tube heat exchanger and weight and they can be easily cleaned. Great flexibility is always provided by the shell and tube heat exchangers 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.[5]

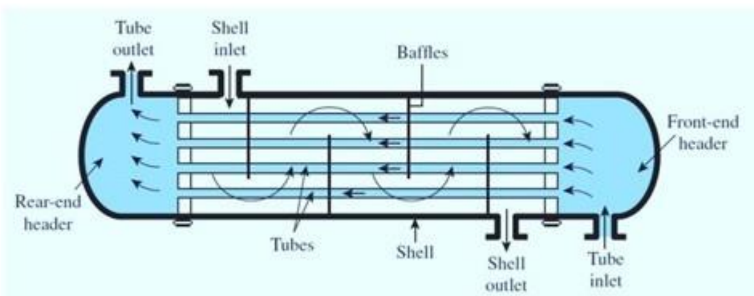

Fig. 1 A simple diagram of principal components of a shell and tube heat exchanger.

ISSN: 2233-7857 IJFGCN

II. LITERATURE SURVEY AND CLASSIFICATION:

The various types of S&THXs are commonly designated according to the Tubular Exchanger Manufacturers Association (TEMA) standard, as shown in Fig 2. This TEMA-type designation comprises three capital letters. The first letter describes the stationary head type at the front end of the apparatus, according to the first column of Fig 2: five different alternatives are possible. The second letter describes the heat exchanger shell, selected from the seven types shown in the middle column of Fig. 2. Finally, the third letter, chosen from the eight alternatives shown in the third column of Fig.2, describes the stationary or floating head type at the rear end. For example, an AES TEMA-type S&THX is an exchanger with a channel and removable cover front head, a one-pass shell, and a floating head with backing device rear end. The three most common types of shell-and tube exchangers are A. Fixed tube-sheet design (L, M, and N type rear header) This is a very popular version as the heads can be removed to clean the inside tubes. The front head piping must be unbolted to allow the removal of front head, if this is undesired this can be avoided by applying a type a front head. It is not possible to clean the outside surface of the tubes as these are inside the fixed part. Chemical cleaning can be used. B. U-tube design (front header and M type rear header) It permits unlimited thermal expansion the tube bundle can be removed for cleaning and small bundle to shell clearance can be achieved C. Floating-head type (P, S, T, W type rear headers) A floating head is excellent for applications where the difference in temperature between the hot and cold fluid causes unacceptable stresses in the axial direction of the shell and tubes. The floating head can move. Thus, in all three types, the front-end head is stationary while the rear-end head can be either stationary or floating depending on the thermal stresses in the shell, tube, or tube sheet, due to temperature differences as a result of heat transfer.[2]

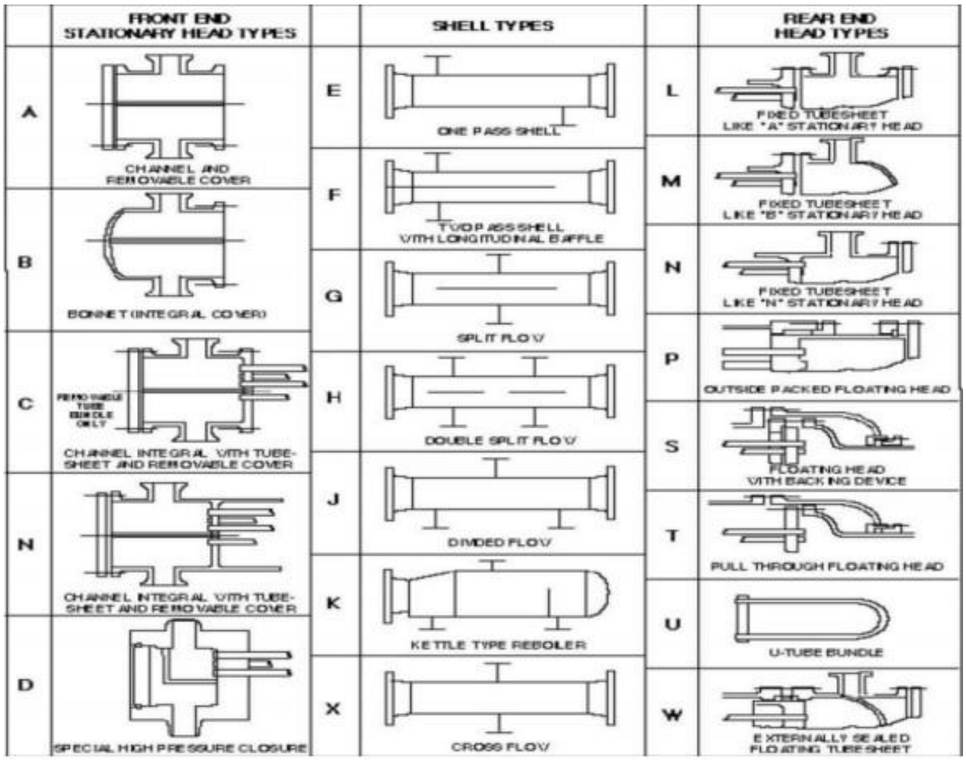

Fig. 2 TEMA nomenclature (Tubular Exchanger Manufacturers Association)

ISSN: 2233-7857 IJFGCN

Durgesh Bhatt, Priyanka M Javhar[1]

Durgesh Bhatt, Priyanka M Javhar conducted a Shell and Tube Heat Exchanger Performance Analysis It is observed that by changing the value of one variable the by keeping the rest variable as constant we can obtain the different results. Based on that result we can optimize the design of the shell and tube type heat exchanger.[1] Higher the thermal conductivity of the tube metallurgy higher the heat transfer rate will be achieved. Less is the baffle spacing, more is the shell side passes, higher the heat transfer but at the cost of the pressure drop.

JAY J. BHAVSAR, V K. MATAWALA-[2013]

The previous works carried out by different authors were limited to helical coil heat exchanger and spiral plate heat exchanger. The spiral tube heat exchanger is compact in size and more heat transfer can be carried out. The objective of present work is to streamline design methodology of spiral tube heat exchanger. The designed spiral tube heat exchanger is required to be developed and experiments will be performed on it to analyses pressure drop and temperature change in hot and cold fluid on shell side and tube side.[10]

Vindhya Vasiny Prasad Dubey, Raj Rajat Verma-[2014]

Dubey and Verma conducted a Performance Analysis of Shell & Tube Type Heat Exchanger under the Effect of Varied Operating Conditions and concluded that It may be said that the insulation is a good tool to increase the rate of heat transfer if used properly well below the level of critical thickness. Amongst the used materials the cotton wool and the tape have given the best values of effectiveness. Moreover the effectiveness of the heat exchanger also depends upon the value of turbulence provided. However it is also seen that there does not exists direct relation between the turbulence and effectiveness and effectiveness attains its peak at some intermediate value.[11] The ambient conditions for which the heat exchanger was tested do not show any significant effect over the heat exchanger's performance.

Dawit Bogale[2]

Dawit Bogale conducted a experiment on shell and tube heat exchangers showing optimization and redesign of the machine is done for both mechanical and thermal designs and the simulation for the heat transfer between the two fluid is analyzed using the concept of CFD (Computational Fluid Dynamics) using Gambit and Fluent software's. The final result of the STHEx in HBSC which is the redesigned STHEX can achieve or efficiently work to achieve the required outlet temperature 340˚C the temp at which is ready for customer for use.[2]

V.K. Patel and R.V. Rao[3]

They explore the use of a nontraditional 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. Four different case studies are presented to demonstrate the effectiveness and accuracy of proposed algorithm. The results of optimization using PSO technique are compared with those obtained by using genetic algorithm.[3]

Rajeev Mukharji[4]

He 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[4]

III. BAS IC CONSTRUCTION OF S & T EXCHANGER

A variety of different internal constructions are used in shell and-tube exchangers, depending on the desired heat transfer and pressure drop performance and operating pressures and temperatures, to control corrosion, to accommodate highly asymmetric flows, and so on. Basic components of the tube and shell type heat exchanger are as follows;

A. Tubes:

The tubes are the basic components of a shell and tube type heat exchanger. Tubes may be seamless or welded having diameters 5/8 inch, 3/4inch, and 1inch. Tubes materials should be highly thermal conductive for proper heat transfer.[13] Most commonly it is made up of copper and Steel alloys. Other alloys of nickel, titanium, or aluminum may also be required for specific applications.

B. Tube sheet

Tubes are fixed with tube sheet that form the barrier between the tube and shell fluids. The tubes can be fixed with the tube sheet using ferrule and a soft metal packing ring. The tubes are attached to tube sheet with two or more grooves in the tube sheet wall by „tube rolling‟ . The tube metal is forced to move into the grooves forming an excellent tight seal. This is the most common type of fixing arrangement in large industrial exchangers. The tube sheet thickness should be always greater than the tube outside diameter to make a good seal.[13]

B. Shell

Shell is the container for the shell fluid and the tube bundle is placed inside the shell. Shell diameter should be selected in such a way to give a close fit of the tube bundle. The clearance between the tube bundle and inner shell wall depends on the type of exchanger. Shells are usually fabricated from standard steel pipe with satisfactory corrosion allowance.

C. Baffles

Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain higher transfer coefficient. The distance between adjacent baffles is called baffle-spacing. Baffles are held in positioned by means of baffle spacers. Closer
baffle spacing gives greater transfer co-efficient by inducing higher turbulence. The pressure drop is more with closer baffle spacing.[13]

D. Tube side channels and nozzles

This are made up of alloy material and it is used to control the flow of the tube side into and out of the tubes of the exchanger.

F. **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.[13]

ISSN: 2233-7857 IJFGCN

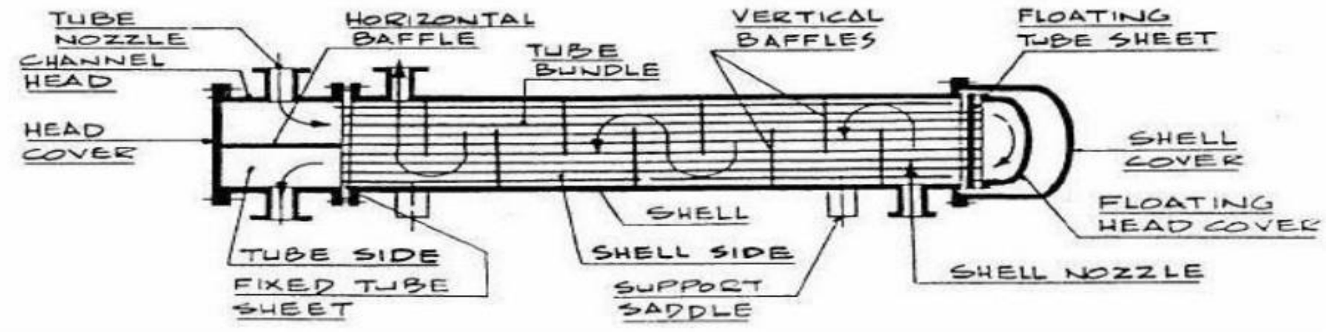

Fig. 3 Heat exchanger parts

IV. .Methodology

- Creation of general arrangement layout
- Material Selection
- Analytical Calculations of heat exchanger for dimensioning
- Designing of components
- CFD analysis
- Manufacturing Drawings
- Costing and Bill of material

SUMMARY OF PROPOSED SHELL AND TUBE HX			
1	Shell diameter	0.590	m
2	Number of tubes	373.69	
3	Length of tubes(Allowancefor tubesheet not included)	26.827	m
4	Tube outside diameter	0.019	m
5	Tube inside diameter	0.016	m
6	Baffle spacing (baffle cut at 25%)	2.500	m
7	Tube pitch	0.025	
8	Number of passes	1.000	
9	Thermal Conductivity of tubes	50.000	W/m - K
10	Tube side heat transfer coefficient	8530.47	W/m2 - K
11	Shell side heat transfer coefficient	3126.68	W/m2 - K
12	Clean overall heat transfer coefficient	2033.81	W/m2 - K
13	Fouled overall heat transfer coefficient	1497.71	W/m2 - K
14	Tube side pressure drop	85.60	Kpa
15	Shell side pressure drop	4.85	Kpa
TUBE SIDE :	**HOT SIDE**		
1	Inlet temperature	200	oC
2	Mass flowrate	150	kg/s
3	Density	998.2	kg/m3
4	Thermal Conductivity	0.6044	W/m - K
5	Dynamic viscocity	0.0009832	N.s/m2
6	Specific Heat	4186	J/kg - K
7	Prandtl number	6.809522171	
8	Velocity of fluid inside the tubes	2	m/s
9	Total fouling factor	0.000176	m2 - K/W
SHELL SIDE:	**COLD SIDE**		
1	Inlet temperature	160	oC
2	Outlet temperature	280	oC
3	Average temperature	220	oC
4	Mass flowrate	100	kg/s
5	Density	996.4	kg/m3
6	Thermal Conductivity	0.6144	W/m - K
7	Dynamic viscocity	0.0008292	N.s/m2
9	Specific Heat	4186	J/kg - K
10	Prandtl number	5.649464844	

Tabel No.:1 Heat exchanger results summary

ISSN: 2233-7857 IJFGCN

ADVANTAGES

These are the main advantages of shell-and-tube heat exchangers

1. Condensation or boiling heat transfer can be accommodated in either the tubes or the shell, and the orientation can be horizontal or vertical. You may want to check out the orientation of the heat exchanger in our laboratory. Of course, single phases can be handled as well.
2. The pressures and pressure drops can be varied over a wide range.
3. Thermal stresses can be accommodated inexpensively.
4. There is substantial flexibility regarding materials of construction to accommodate corrosion and other concerns. The shell and the tubes can be made of different materials.
5. Extended heat transfer surfaces (fins) can be used to enhance heat transfer.
6. Cleaning and repair are relatively straightforward, because the equipment can be dismantled for this purpose

V. CONCLUSION

On the basis of above study it is clear that Shell and tube heat exchanger is the most versatile type of heat transfer apparatus, and for this reason it is the most used in a variety of applications. It has given a great respect among all the classes of heat exchangers. Moreover well designed as well as described methods are available for its designing and analysis. It has great advantages of pressures and pressure drops can be varied over a wide range, thermal stresses can be accommodated inexpensively and Cleaning and repair are relatively easy. The literature survey also shows the importance of this class of heat exchangers among other heat exchanger

ACKNOWLEDGMENT

All the authors wish to acknowledge our guide and SKNCOE's Mechanical Department and Mechatol Engineering Solutions Pvt.Ltd and other contributors for developing and helping us to complete the study.

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ISSN: 2233-7857 IJFGCN