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RESEARCH ARTICLE

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THERMAL DESIGN OF SHELL AND TUBE HEAT EXCHANGER FOR KEROSENE – COOLING WATER SYSTEM USING HTRI SOFTWARE

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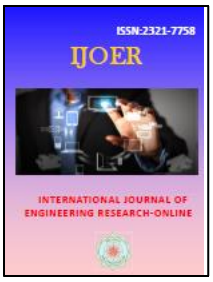

ABSTRACT

Heat exchangers are equipment that transfers heat from one medium to another. Among various types of heat exchangers, the shell and tube heat exchangers are widely used because of their flexibility in design to allow for a wide range of pressure and temperature. The proper design, operation and maintenance of heat exchanger will make the process energy efficient and minimize energy losses. Heat exchanger performance can deteriorate with time, off design operations and other interferences such as fouling, scaling etc. It is necessary to assess periodically the heat exchanger performance in order to maintain them at a high efficiency level. The objective of the present work is to perform thermal design of a shell and tube heat exchanger that using HTRI software to makes the process energy efficient. The shell and tube heat exchanger optimization can be done by considering the following variables: tube outside diameter, tube length, tube pitch, tube layout, number of tube passes, tube count and shell diameter. From our study, the design parameters such as area, heat duty and overall heat transfer co-efficient were determined.

Keywords: Shell and tube heat exchanger, thermal design, optimization, HTRI.

1. INTRODUCTION

A heat exchanger is a device that allows transfer of heat 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. Typical applications of heat exchangers involve heating or cooling of a fluid stream of concern evaporation or condensation of single or multicomponent fluid streams. In most heat exchangers, the heat transfer between fluids takes place through a separating wall or into out of the wall in a transient manner. Heat exchangers are widely used in chemical and petroleum plants, food processing industry, biochemical processing, pharmaceuticals and dairy industry[1].

There are various types of heat exchangers[2] such as Shell and tube, Plate and frame, double pipe, air cooled heat exchanger etc. Among them the shell and tube heat exchangers are preferred extensively because they are very flexible in size, mechanically robust, ease in cleaning and the components can be replaced easily. Shell and tube Heat Exchangers have the ability to transfer large amounts of heat in relatively low cost. They can provide large amounts of effective tube surface while minimizing the requirements of floor space, liquid volume and weight.

Shell and tube heat exchangers are comprised of multiple tubes through which liquid flows. The tubes are divided into two sets: the first set contains the liquid to be heated or cooled. The second set contains the liquid responsible for triggering the heat exchange, and either removes heat from the first set of tubes by absorbing and transmitting heat away—in essence, cooling the liquid—or warms the set by transmitting its own heat to the liquid inside. The major components of this exchanger are tubes (or tube bundle), shell, front-end head, rear-end head, baffles, and tube sheets. A schematic representation of a Shell-and-tube exchanger with one shell pass and one tube pass is shown in Fig 1. Shell and tube Heat Exchangers represent the most widely used vehicle for the transfer of heat in industrial process applications. The major industrial applications include gas-gas exchangers, gas coolers, partial and total condensers, kettle reboilers, waste-heat boilers, boiler feed water pre-heaters, steam generators and super heaters[3].

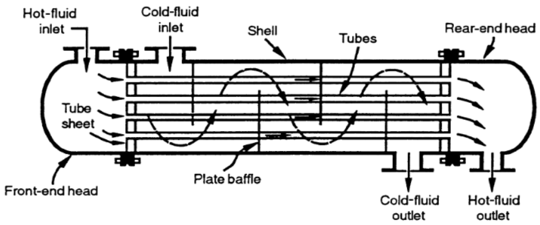

Fig 1: Schematic representation of a Shell-and-tube exchanger with one shell pass and one tube pass

2. MATERIALS AND METHODS

2.1.1 Design of shell and tube heat exchanger: The design of shell and tube heat exchanger is done by using HTRI software. This is very user-friendly and convenient to optimize and produce a near perfect design for a given application. Xist model in the software is used to design the shell and tube heat exchanger. Xist operates in three modes: rating, simulation and design. In our study, design mode was applied, where the partial exchanger geometry and enough process conditions were specified. The required heat duty, expected heat-transfer co-efficient and pressure drop were calculated.

2.1.2 Design data:

i. The system taken for study is a liquid – liquid exchanger. Kerosene was taken as hot fluid. Cooling water was taken as cold fluid. Cooling water is in fluid state at both inlet and outlet.

ii. Flow rates of hot and cold fluid are 42200 and 15600 Kg/hr respectively.

iii. Inlet and outlet temperatures of hot fluid are 56^{o}C and 46^{o}C respectively. Inlet and outlet temperatures of cold fluid are 33^{o}C and 45^{o}C respectively.

iv. Operating pressures of the hot and cold fluid are 12.19 and 4.97 kg/cm^2 (g) respectively.

v. The allowable pressure drop for both fluids is a very important factor for design of heat exchanger. For liquids, the allowable pressure drop per shell[4] is 0.5-0.7 kg/cm^2. The pressure drop for hot and cold fluid was taken as 0.3 and 0.7 kg/cm^2 respectively.

vi. Fouling in the heat transfer surface reduces the effective heat transfer due to relatively low thermal conductivity. Therefore, the net heat transfer with clean surface should be higher to compensate the reduction in performance during operation. The effect of fouling is considered in heat exchanger design by including the shell side and tube side fouling resistances were taken as 0.004 and 0.003 hr m^{2}C/kcal respectively.

vii. The physical properties of hot fluid are displayed in Table 1, whereas for cold fluid it was taken from the HTRI library[5].

Table 1 : Physical properties of hot fluid

Temp (C)	Vapour fraction	Density (kg/m^3)	Viscosity (cP)	Thermal conductivity (Kcal/(hr.m.C))	Heat capacity (Kcal/(kg C))
55	0	822	1.266	0.106	0.43
53.4	0	823.2	1.298	0.106	0.43
51.7	0	824.5	1.332	0.107	0.43
50.1	0	825.7	1.367	0.107	0.43
48.4	0	826.9	1.404	0.107	0.43
46.4	0	828.2	1.443	0.107	0.43

45.1	0	829.4	1.483	0.107	0.42
43.4	0	830.7	1.526	0.108	0.42
41.7	0	832.0	1.57	0.108	0.42
40	0	833.2	1.617	0.108	0.42

viii. The principal components of the exchanger such as shell, shell cover, tubes, tubesheets, baffles, channel and channel cover were made of carbon steel. So the material of construction was chosen as carbons steel.

3. RESULTS AND DISCUSSIONS

3.1.1 Tube side design: Tube outside Diameter: The tube outside diameter[6] may vary from 19.05mm to 25.4mm for a shell and tube heat exchanger. Here in our study the tube outer diameter was chosen as 25.4mm

Tube length: The tube length of 1828.8, 2438.4, 3657.6, 4876.8, 6096 and 7315.2 mm are preferably used. Longer the tube length the cheaper the exchanger, here the tube length was taken as 6096 mm.

Tube pitch: It is the shortest centre to centre distance between the adjacent tubes. The smallest allowable pitch of 1.25 times the tube OD is normally used. Here we have taken the tube pitch as 31.75mm.

Tube layout: 45 or 90 degree layouts are chosen if mechanical cleaning is required, otherwise a 30 degree layout is often used. Here 30 degrees was used because it provides a higher heat transfer and hence smaller exchanger.

Number of tube passes: The tube passes vary from 1 to 16. The tube passes of 1,2, 4 are common. Here the number of tube passes is taken as 2 to get the required tube side fluid velocity to obtain greater heat transfer co-efficient and also to reduce the scale formation.

Tube count: The number of tubes that can be accommodated in a given shell is called tube count. The tube count depends on factors like outer diameter of the tube, tube pitch, tube layout, number of tube passes, type of heat exchanger, shell inside diameter and design pressure. Maximum number of tubes in the shell increases the turbulence and also it is the most efficient condition for heat transfer, here the number of tubes was taken as 62.

3.1.2 **Shell side design:**Shell Diameter: 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 to the tube bundle. Typically the shell diameter ranges from 152mm to 3000mm. Here in our study the shell diameter was taken as 337mm.

3.1.3 **Baffle design :**Baffles are used to increase the fluid velocity by diverting the flow across the tube bundle to obtain high heat transfer co-efficient. Single segmental baffle was chosen as there is no pressure drop constraint or vibration problem. The distance between adjacent baffles is called baffle spacing. The baffle spacing of 0.2 to 1 times of the inside shell diameter is commonly used. In our study, the baffle spacing was taken as 0.742 times of inside shell diameter.

The various parameters for the design of heat exchangers were optimized with the use of HTRI software and the optimized design parameters are displayed below in Table 2.

Table 2: Optimized design parameters of shell and tube exchanger

PARAMETER	VALUE	UNIT
Tube outside diameter	25.4	mm
Tube length	6096	mm
Tube pitch	31.75	mm
Tube layout	30	degrees
Number of tube passes	2	--
Tube count	62	--
Shell diameter	337	mm
Baffle type	Single -segmental	
Baffle orientation	Perpendicular	
Baffle spacing	249.622	mm
Heat duty	0.1841	MM kcal/hr
Area	29.907	m^2
Actual Heat transfer co-efficient	632.28	Kcal/m^2-hr-C
Required heat- transfer co-efficient	620.06	Kcal/m^2-hr-C

4. CONCLUSION

The observed parameters like heat transfer area, heat duty and overall heat transfer co-efficient were satisfy the design needs. It was also observed that the cost will be more for larger diameter tubes, so use of 25.4mm is preferable. If the length of the tube is large, the cost of the exchanger will be less. Increasing the number of tube passes increases the heat transfer rate. Also the overdesign was observed to be only 1.97% which is acceptable. Thus design parameters of shell and tube heat exchanger were optimized using HTRI software. These optimized results will be helpful for industries handling shell and tube heat exchangers.

References

[1]. Agarwal, P.; Sikand, A.; Shanthi, V., Application of heat exchangers in bioprocess industry: a review. International Journal of Pharmacy and Pharmaceutical Sciences 2014**,** 6 (1), 24-28.

[2]. Shah, R. K.; Sekulic, D. P., Fundamentals of heat exchanger design. John Wiley & Sons: 2003.

[3]. Gentry, C.; Gentry, M.; Scanlon, G., Shell and tube heat exchanger applications. PETROLEUM TECHNOLOGY QUARTERLY 1999, 95-102.

[4]. Mukherjee, R., Effectively design shell-and-tube heat exchangers. Chemical Engineering Progress 1998**,** 94 (2), 21-37.

[5]. HTRI Design Manual. D6.2.1 (Rev.1).

[6]. TEMA, Standards of Tubular Exchanger Manufacturers Association. 7th ed.; New York, 1988.