A review on Modelling, Simulation & Optimization of shell and tube heat exchanger

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Abstract:

The review presents extensive literature about Shell and Tube heat exchangers various parameters like Baffles spacing, Baffle inclination angles, and Baffle cut to optimize heat transfer coefficient. This paper exclusively summarizes the research works concerning the optimization of HE (shell and tube). We have compared various results of shell and tube heat transfer to find the optimum product. So, therefore, this review paper may turn into complete information in one place, and it may be beneficial to the industrial design and successive researchers to choose the direction of their research work in the field of parameter optimization of HE(shell and tube).

Key Words: Shell and Tube Heat Exchanger (STHE), Optimization, Baffles spacing, Baffle cut.

1.INTRODUCTION

The heat exchanger is a system used to transfer heat between two fluids at different temperatures with or without contact with each other. The heat exchanger has various types such as that recuperator, regenerator, tube, plat, etc. A shell and tube heat exchanger (THE) is the widespread type of heat exchanger. The STHEs are used in the process industries, steam generators in pressurized and water reactor plants, feedwater heaters, conventional and nuclear power stations as condensers, etc. It is a better type of heat exchanger used in oil corporations and other most significant chemical processes.

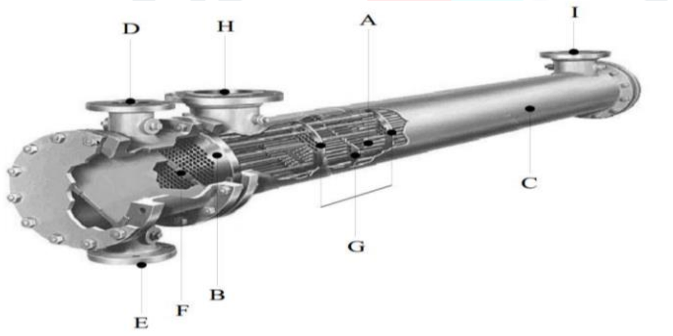

Fig.1 Parts of Shell and tube heat exchanger, A: Tubes, B: Tube sheets, C: Shell, D: Tube -side Inlet(Outlet Nozzle), E: Tube -side Outlet(Inlet Nozzle), F: Pass Divider, G: Baffles, H: Shell-side Inlet (Outlet Nozzle), I: Shell-side outlet(inlet nozzle)

It is a sufficient condition for high pressure and temperature.

Their name mentions that type of heat exchanger includes a shell (large pressure vessel) with many tubes inside the shell. One fluid flow through tubes, and other fluids flow around the tube (through the shell) to transmit heat between fluids. The set of tubes is called a tube bundle, and various types of tubes: plain, helical, longitudinally, finned. This type of heat exchanger has a larger ratio of heat transfer surface area to volume. They are easy to produce in the high range of size and flow. Another essential part baffles during the process and helps to prevent vibration. Second, it's providing a flow path of shell fluid for effective velocity and flow.

2. LITERATURE REVIEW

The main purpose of research is to modify and improve THE for reducing pressure drop, pumping cost, and fouling with maximizing heat transfer coefficient, heat transfer rate, performance, and effectiveness.

2.1 Baffle inclination angle

Sirous et al., Tasouji et al., and Wenjing et al. mentioned that helical baffles with an inclination angle of 40° give higher heat transfer for the same pressure drop [27,35]. Yong et al. pointed out that inclinational helix angle is dependent on the Reynolds number for the working fluid on the shell side [11]. Jian-Fei Zhang et al. also experimented with different angles (20°, 30°, 40°, and 50°) and found that a helix angle of 40° gives the best performance. The graph in Fig. 7 is plotted by readings taken from the article [40].

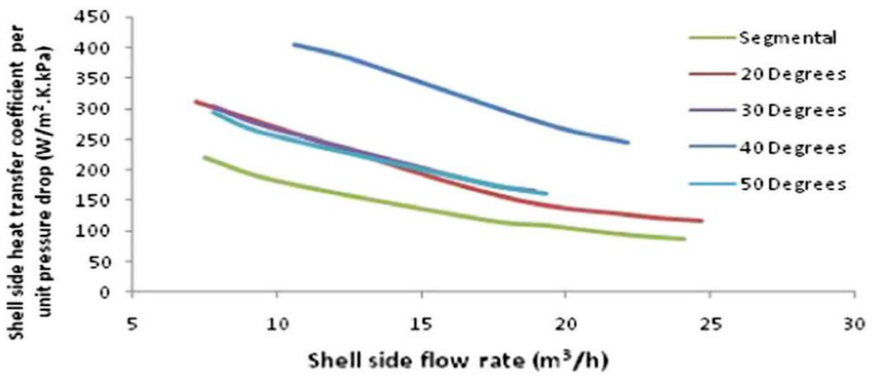

Fig.2 Performance comparison of baffles with different angles

An angle of 40° is an optimum one for DCHB. In contrast, the most optimum angle for CHB is 45°, as shown by Yong et al. He also verified that performance of THE increases with the increase of baffle inclination angle up to 45°, and the performance decreases when the angle is beyond 45° [6]. **Xiaoming et al.** later showed that a helical baffle tilt angle of 40° is no longer the best selection if the Prandtl number for the shell side fluid increases. When the Prandtl number is large enough, the heat exchanger with a smaller baffle tilt angle comes out to be the optimal choice [5].

2.2 . Baffle spacing

With increasing baffle space, the pressure gradient decreases. Increasing the baffle space at the same mass flow rate reduces heat transfer coefficient while increasing the baffle spacing at the same pressure drop increases heat transfer coefficient. Baffle spacing also depends on the requirement of the process. For higher heat transfer coupled with a low heat transfer area, low baffle spacing is optimal. If the pressure drop is an important factor, longer baffle spacing is required, which lowers pressure drop and reduces power consumption as well [2,8]. Increasing baffle spacing increases flow velocity, which leads to the enhancement of heat transfer due to a reduction in leakage through baffle-shell clearance [7]. There is no precise criterion to determine the optimum baffle spacing, although baffle spacing is a very important factor that affects the capital as well as operating costs of the heat exchanger. Computer programs are generally used to determine the optimum baffle spacing for a particular heat exchanger type [9,10].

2.3 **Effects of baffle cut on pressure drop and heat transfer**

The baffle cut value of 25% and effects of the baffle cut on the heat transfer and the pressure drop are investigated [4]. The calculation procedure is the same as the previous section. Similar to the previous sections, the shell side outlet temperature, the shell side pressure drop, and the total heat transfer rate values are obtained directly from the CFD runs. The percent differences between the analytical calculations and the CFD analysis results are presented in Table 2. The analytical calculations are taken as the base values for the percent difference calculations. By comparing the results in Table 2 with the ones in Table 1, the agreement with the Kern method results is better for 25% baffle cut case since the Kern method assumes Bc = 25%. The agreement still can be considered acceptable only for 0.5 kg/s mass flow rate. When Bell–Delaware results are taken as the reference values, it is observed that for all Nb values, the agreements in heat transfer coefficient and pressure drop are better in the case of Bc = 25%. We can be attributed to the fact that 25% baffle cut is the most common baffle cut; thus, a large part of the Bell–Delaware data is obtained from heat exchangers with 25% baffle cut. Therefore, it should be expected for Bell–Delaware to provide more accurate results at that baffle cut. Although it is hard to compare both Bc results because the percent differences are in single digits or even below 1%, in general, the agreement is slightly better for Bc = 25%. When the percent differences with the Bell–Delaware results in Tables 1 and 2 are examined together, it is observed that Nb = 10 and

Bc = 25% combination gives the smallest difference in both heat transfer coefficient and pressure drop results and shows very well covered cross flow window. Agreement in Nb = 12 and Bc = 25% case is comparatively worse, probably due to the reflections from the next baffle, For Bc = 36%, Nb = 12 gives the best results both according to differences in Table 1 values.

Table 1

Percent differences between analytical calculations and CFD analysis for B_c = 36%.

Number of baffles	Mass flow rate (kg/s)	Heat transfer coeff.		Press drop	Total heat transfer rate
		% difference w.r.t. Kern method	% difference w.r.t. Bell–Delaware	% difference	% difference
6	0.5	17.1	13.6	22.0	0.5
	1	21.7	13.5	34.2	4.5
	2	50.8	34.7	33.9	8.0
8	0.5	4.9	4.5	11.7	3.8
	1	14.6	7.7	22.1	0.5
	2	43.9	31.5	19.7	0.5
10	0.5	3.6	2.2	16.2	0.9
	1	9.9	6.9	11.5	1.2
	2	39.8	30.2	7.3	1.0
12	0.5	1.0	7.3	5.9	1.5
	1	18.2	3.9	0.1	1.3
	2	52.3	28.2	4.5	0.9

Table 2

Percent differences between analytical calculations and CFD analysis for B_c = 25%.

Number of baffles	Mass flow rate (kg/s)	Heat transfer coeff.		Press drop	Total heat transfer rate
		% difference w.r.t. Kern method	% difference w.r.t. Bell–Delaware	% difference	% difference
6	0.5	13.7	9.5	18.4	0.1
	1	20.1	12.3	32.6	0.8
	2	43.6	28.3	30.8	0.8
8	0.5	5.0	4.3	7.1	0.4
	1	11.7	7.4	17.1	2.7
	2	41.7	24.3	19.0	1.9
10	0.5	5.5	5.2	3.4	1.3
	1	15.9	10.6	10.5	1.8
	2	43.0	29.2	7.2	0.7
12	0.5	1.2	9.2	3.3	1.3
	1	16.4	0.4	10.4	1.6
	2	38.5	24.5	5.1	0.9

Conclusion:

Shell and Tube Heat exchangers are an integeral part of all thermal systems. Their designs should be adapted well to the applications in which they are used; otherwise, their performances will be deceiving and their costs excessive. Shell and Tube Heat exchanger design can be a complex task, and advanced optimization tools are useful to identify the best and cheapest heat exchanger for a specific duty.

The current study covers some of the essential factors affecting the performance of STHEs, and then a comparison of helical baffles with the traditional segmental baffles has been made. It was evident from the comparison that helical baffles give better results than the segmental ones due to better heat transfer performance, less fouling and less fluid-induced vibrations. The effectiveness of the heat exchangers with two-layer helical baffles is higher than that of the heat exchanger with single-layer helical baffles. Helical baffles in shell and tube heat exchanger gives the most optimum results with DCHB (discontinuous helical baffles) instead of CHB (continuous helical baffles) Sextant type helical baffles Inclination angle of 40° Low baffle spacing Fold baffles instead of plain baffles.

Many publications can be found on the inclination angle of helical baffles and baffle spacing, but only a few articles can be found regarding sealing strips baffle shape and the use of fold baffles. Most of the previous studies in the literature lacked an integrative approach and focused on some of the many factors affecting the performance criteria of STHE. No experimentation has been recorded yet on the performance of STHE with folded sextant type helical baffles. Further research can be done on fold baffles and the effects of sealing strips using folded sextant baffles.

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