HEAT TRANSFER ANALYSIS IN COUNTER FLOW SHELL AND TUBE HEAT EXCHANGER USING DESIGN OF EXPERIMENTS

by

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In this research aimed to estimate the overall heat transfer coefficient of counter flow shell and tube heat exchanger. Heat transfer is the phenomenon to analysis of heat transfer from one medium of fluid to another medium of fluid, it is considered as a major role in industrial applications. Numerous heat exchangers are available, in this research considered as shell and tube heat exchanger. Overall heat transfer coefficient informed that three major factors are influenced as passing of fluid (film) media coefficient inside the tubes, circulating of fluid (film) media coefficient over in the shell, and the resistance of wall made on metal. In this study Taguchi L9 orthogonal array is executed to found the overall heat transfer coefficient with effective process parameters. Three major parameters are considered for this work are coil diameter (25 mm, 30 mm, and 35 mm), baffle thickness (15 mm, 20 mm, and 25 mm) and baffle gap (200 mm, 300 mm, and 400 mm. Baffle plate thickness is highly significant factor for this experiment.

Key words: heat transfer, coil diameter, baffle thickness, DOE, heat exchanger, Taguchi

Introduction

In the heat transfer applications heat exchanger is contribute major use with supporting of heat carrying fluid. Heat exchangers are varied based on the applications; in general plate and shell and tube heat exchangers are preferable one in the industrial sectors. This unit exchange of heat with different fluid media at various temperature. Selection of fluid medium, material of the tube, baffle arrangements flow direction and process temperatures are deciding

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factors of increasing overall heat transfer coefficient (OHTC). Shell and tube heat exchangers are applicable for elevated pressure utilization process [1]. The bundles of tubes are mounted inside the shell with rigid conditions to carry the fluid media in all tubes. Heat transfers are carried out between tube and shell otherwise in shell and tube [2, 3]. Normally heat exchangers are subdivided into two categories that is single phase heat exchangers and two phase heat exchangers based on the working media. Tubular Exchanger Manufactures Association is developed the shell and tube heat exchangers effectively with standardization. Avoid the expansion of the tubes due to higher temperature deviation expansion bellows are integrated and reduce the too much of stresses induced by expansion.

In general shell and tube heat exchangers the available of tube sizes are 12.7 mm to 50.8 mm diameters. Applying of steam as fluid it can be controlled by using of control valve to adjust the flow rate as well as pressure. Normally the failures obtained due to unsupported of tubes in the shell. In this analysis considered the all factors such as coil diameter, baffle thickness, and baffle gap to optimize and increase the OHTC based on the study of exists enormous research articles [4-7]. The literature survey support the successful completion of this work. Taguchi technology involved to found the accurate value of OHTC [8]. The modeling techniques such as artificaial neural network, Teaching learning optimization method, *etc*., has been used for optimization and modeling [9].

Experimental work

The materials of copper tubes are selected for this investigation and the bundle of the tubes is mounted inside of the shell with supporting of tube plates. The distilled water was circulated inside the tube as well as surrounding of tubes.

Figure 1 illustrated the counter flow shell and tube heat exchanger with number of baffle plates and tubes. The OHTC of the heat exchanger is studied by the selected three process parameters. Table 1 presented the process parameters (coil diameter, baffle thickness, and baffle gap) and three levels of analysis the OHTC [9].

From this analysis all the nine experiments were carried out and the maximum value of OHTC was obtained as 320.12 W/m^2K in the 4^{th} experiment. Moderate coil diameter, minimum baffle thickness, and moderate baffle gap offered better OHTC. [10, 11]

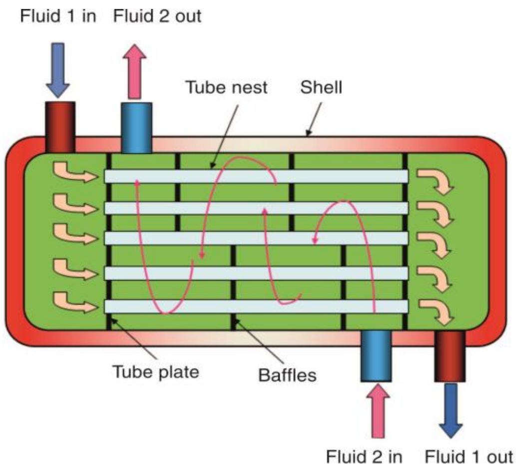

Figure 1. Counter flow shell and tube heat exchanger

The tabs. 3 and 4 presented the response table for signal to noise (S/N) ratios (OHTC) and response table for means (OHTC), respectively. The heat transfer rate is expected to be maximum. The S/N ratio for the response is calculated based on eq. (1).

Larger the better (heat transfer coefficient – maximization):

$$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right) \tag{1}$$

Table 1. Process parameters and their values

Notation	Factors	Level 1	Level 2	Level 3
A	Coil diameter [mm]	25	30	35
B	Baffle thickness [mm]	15	20	25
C	Baffle Gap [mm]	200	300	400

Table 2. Summary of the L9 orthogonal array (OHTC)

Experimental No.	Coil diameter [mm]	Baffle thickness [mm]	Baffle gap [mm]	OHTC [$Wm^{-2}K^{-1}$]	SNRA1
1	25	15	200	300.54	49.5580
2	25	20	300	282.5	49.0204
3	25	25	400	304.36	49.6678
4	30	15	300	320.12	50.1063
5	30	20	400	279.85	48.9385
6	30	25	200	302.47	49.6136
7	35	15	400	291.63	49.2966
8	35	20	200	298.59	49.5015
9	35	25	300	318.76	50.0693

Table 3. Response table for means (OHTC**)**

Level	Coil diameter [mass]	Baffle thickness [mm]	Baffle gap [mm]
1	295.8	304.1	300.5
2	300.8	287	307.1
3	303	308.5	291.9
Delta	7.2	21.6	15.2
Rank	3	1	2

Table 4. Response table for S/N ratios (OHTC) larger is better

Level	Coil diameter [mass]	Baffle thickness [mm]	Baffle gap [mm]
1	49.42	49.65	49.56
2	49.55	49.15	49.73
3	49.62	49.78	49.3
Delta	0.21	0.63	0.43
Rank	3	1	2

All the input datas are converted into the mean and S/N ratio values to find the response value of the investigation. The result of this investigations clearly illustrated in the tables such as baffle thickness was major influencing factor followed by baffle gap and coil diameter. The preference of the factors were obtained through delta value and rank order. The selection of buffle plate was one of the major consideration for this study. The optimal process parameters of this analysis were found to be coil diameter of 35 mm, baffle thickness of 25 mm, and baffle gap of 300 mm. The using of optimum value of parameters the OHTC was attained as 318.76 W/m^{2}K.

Figures 2 and 3 illustrated the main effects plot for mean and main effect plot for S/N ratios of OHTC, respectively. An increase of coil diameter from 25 mm to 35 mm increases the OHTC. Higher value of baffle thickness (25 mm) and the moderate value of baffle gap (300 mm) increase the OHTC. The higher value 400 mm of baffle gap decreases the OHTC.

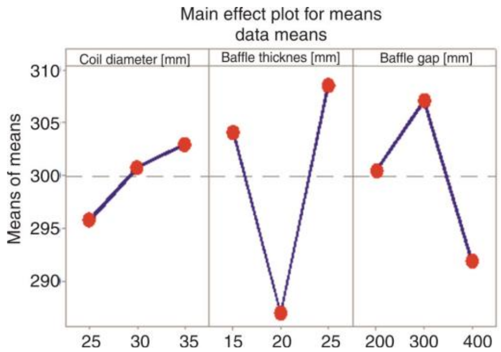

Figure 2. Main effects plot for means (OHTC)

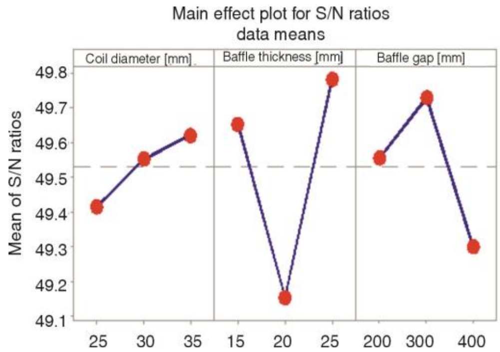

Figure 3. Main effects plot for S/N ratios (OHTC)

The probability plot of OHTC was presented in the fig. 4; it was informed that the selected values of the parameters are closer to the probability line then the preferred model was accurate one.

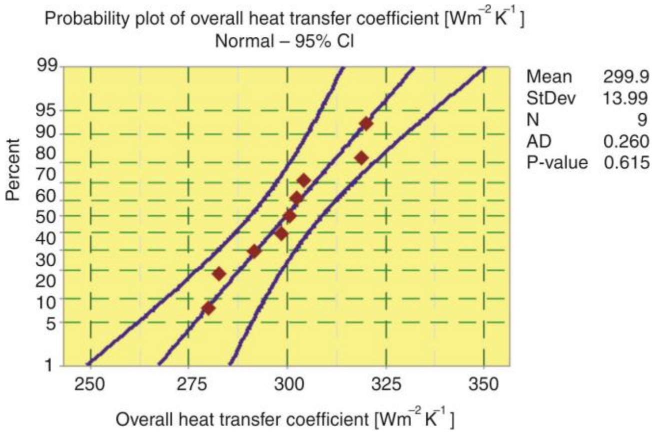

Figure 4. Normal probability plot of OHTC

Figures 5-7 presented the contour plot for OHTC. Figure 5 clearly illustrates that the higher values of baffle gap and coil diameter increase the OHTC. Figure 6 presented that the increasing value of overall heat transfer were recorded by involved of higher plate thickness (25 mm) and moderate baffle gap (300 mm). Figure 7 revealed that the influencing of 300 mm of baffle gap and 35 mm of coil diameter were increases the OHTC.

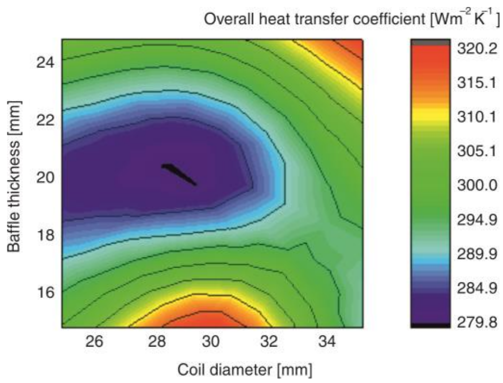

Figure 5. Contour plot for OHTC: Coil diameter and baffle thickness

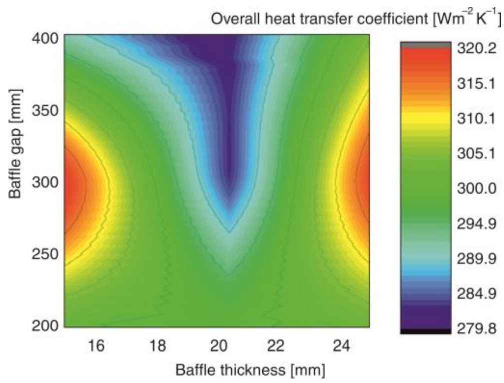

Figure 6. Contour plot for OHTC: Baffle thickness and baffle gap

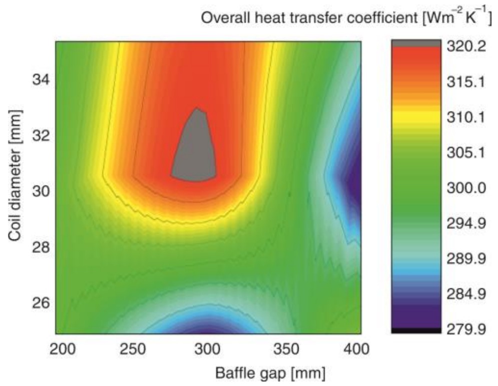

Figure 7. Contour plot for OHTC: Baffle gap and coil diameter

Conclusions

The heat transfer analysis of counter flow shell and tube heat exchanger was carried out successfully with the aid of Taguchi route. All three factors were effectively utilized and increased value of OHTC was found effectively the final result of this work was concluded as the following manner.

- From this analysis the baffle thickness was found to be a major influencing factor connected by baffle gap and coil diameter. Baffle plate selection was one of the major contribution to increase the OHTC of this study. Among three process parameters the optimal values were found to be coil diameter of 35 mm, baffle thickness 25 mm, and baffle gap 300 mm.
- Based on the optimum value the OHTC was obtained as 318.76 W/m^{2}K. Increasing of coil diameter from 25 mm to 35 mm increases the OHTC. The higher value of baffle thickness such as 25 mm and moderate value of baffle gap such as 300 mm increase the OHTC.

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