

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

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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 (OHTC) 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.

1. 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 factors of increasing overall heat transfer coefficient. 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. TEMA- Tubular Exchanger Manufacturers 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 overall heat transfer coefficient 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 overall heat transfer coefficient [8]. The modeling techniques such as Artificial Neural Network, Teaching Learning Optimization method, etc ., has been used for optimization and modeling [9].

2. 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.

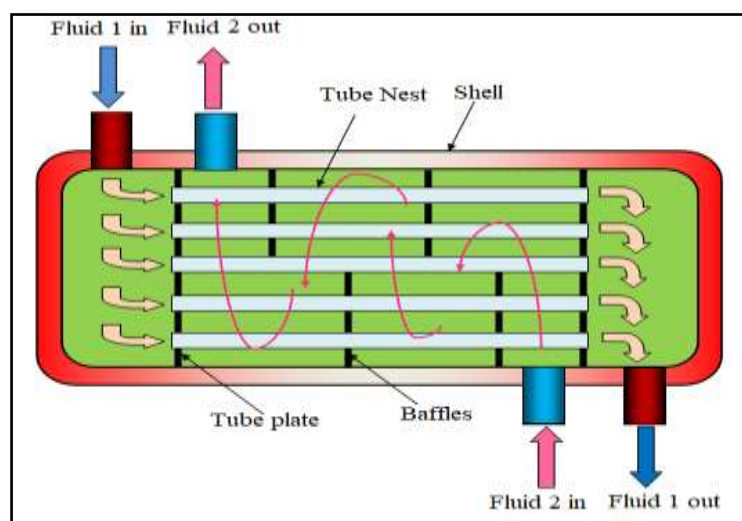


Figure 1. Counter flow Shell and Tube Heat Exchanger

Figure 1 illustrated the Counter flow Shell and Tube Heat Exchanger with number of baffle plates and tubes. Overall heat transfer coefficient 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 overall heat transfer coefficient [9].

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 (Overall Heat transfer coefficient)

| Exp. No | Coil diameter (mm) | Baffle thickness (mm) | Baffle gap (mm) | Overall heat transfer coefficient (W/m ² .K) | 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 |

From this analysis all the nine experiments were carried out and the maximum value of overall heat transfer coefficient was obtained as 320.12 W/m².K in the fourth experiment. Moderate coil diameter, minimum baffle thickness and moderate baffle gap offered better overall heat transfer coefficient. [10,11]

The Table 3 and Table 4 presented the response table for Signal to Noise Ratios (Overall heat transfer coefficient) and response table for means (Overall heat transfer coefficient) respectively. The heat transfer rate is expected to be maximum. The S/N ratio for the response is calculated based on eqn (1) .

Larger the better (Heat Transfer Coefficient - Maximization):

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

Table 3 Response Table for Means (Overall heat transfer coefficient)

| Level | Coil diameter (mm) | 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 Signal to Noise Ratios (Overall heat transfer coefficient) Larger is better

| Level | Coil diameter (mm) | 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 data 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 baffle 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 Overall heat transfer coefficient was attained as 318.76 W/m².K.

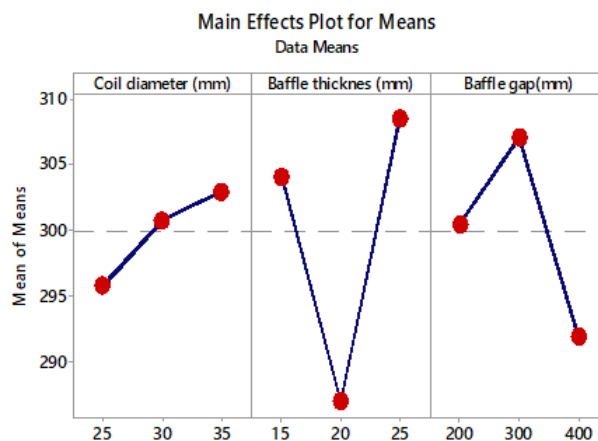


Figure 2. Main Effects plot for Means (Overall heat transfer coefficient)

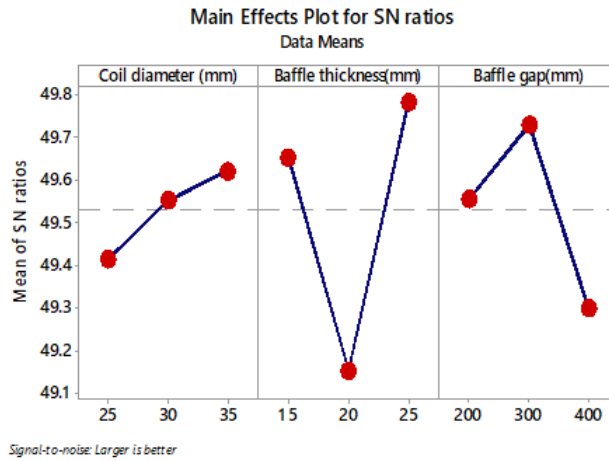


Figure 3. Main Effects plot for S/N ratios (Overall heat transfer coefficient)

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

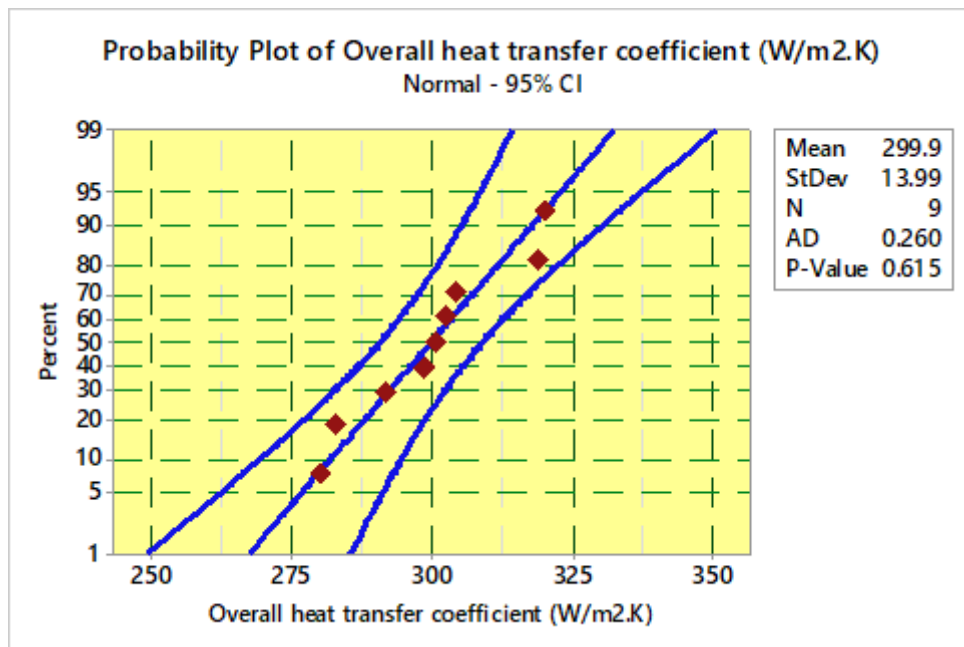


Figure 4. Normal probability plot of overall heat transfer coefficient

The probability plot of overall heat transfer coefficient was presented in the Figure 4; it was informed that the selected values of the parameters are closer to the probability line then the preferred model was accurate one.

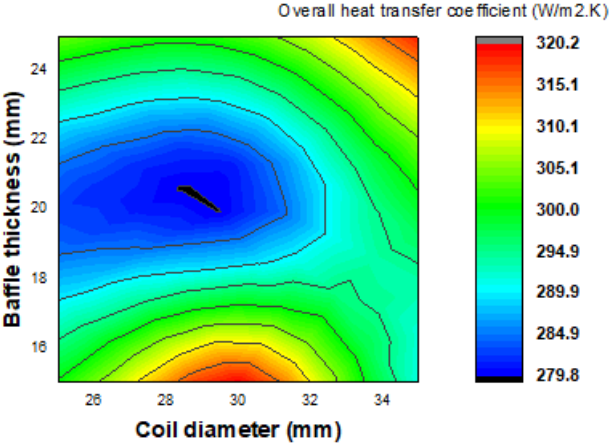


Figure 5. Contour plot for overall heat transfer coefficient: Coil diameter and Baffle thickness

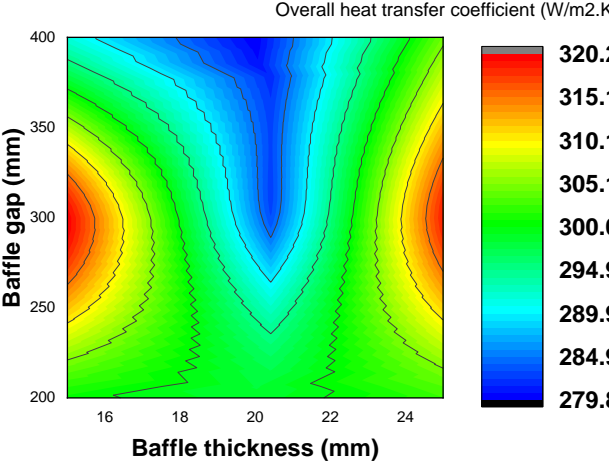


Figure 6. Contour plot for overall heat transfer coefficient: Baffle thickness and Baffle gap

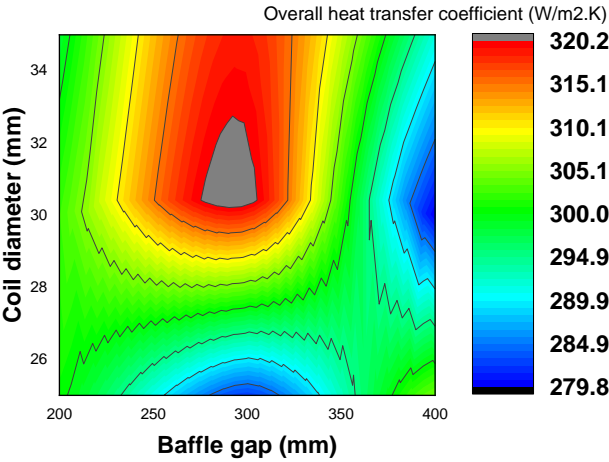


Figure 7. Contour plot for overall heat transfer coefficient: Baffle gap and Coil diameter

Figure 5-7 presented the contour plot for overall heat transfer coefficient. Figure 5 clearly illustrates that the higher values of baffle gap and coil diameter increase the overall heat transfer coefficient. 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 overall heat transfer coefficient.

4. Conclusion

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 overall heat transfer coefficient 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 Overall heat transfer coefficient 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 overall heat transfer coefficient was obtained as 318.76 W/m².K. Increasing of coil diameter from 25 mm to 35 mm increases the overall heat transfer coefficient. The higher value of baffle thickness such as 25 mm and moderate value of baffle gap such as 300 mm increase the overall heat transfer coefficient.

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