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Research Paper

PARAMETER OPTIMIZATION OF SHELL AND TUBE TYPE HEAT EXCHANGER FOR IMPROVE ITS EFFICIENCY

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In order to tackle such an optimization problem in present work the Taguchi method is applied to perform screening of experiments and to identify the important significant parameters which are affecting the efficiency of shell and tube type heat exchanger. The prefix parameters (tube diameter, mass flow rate and pitch length) are used as input variable and the output parameter is maximum temperature difference of shell and tube heat exchanger. Nine different models are made in Solid Works 2012 software and CFX analysis is carried out in ANSYS 12.0. The Minitab 16 software is used for Taguchi analysis. Result obtained from the Taguchi analysis shows that which combination of design parameter gives the minimum outlet temperature of water. The most affected parameter on temperature of water from tube diameter, pitch length and mass flow rate is found out from Taguchi analysis. Also the Taguchi results are validated by performing experiment for L9 array.

Keywords: Heat exchanger, ANSYS 12.0, Minitab 16, Solid works 2012

MODELLING OF SHELL AND TUBE TYPE HEAT EXCHANGER

1. Shell – 750 mm long provided with end boxes
2. Tubes 7.525 I.D., 9.525 O.D., 750 mm copper tubes

TAGUCHI METHOD FOR SINGLE OBJECTIVE OPTIMIZATION

Taguchi's methods of experimental design provide a simple, efficient, and systematic approach for the optimization of experimental designs for performance quality and cost. The main purpose of Taguchi method is reducing the variation in a process through robust design of experiments. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources.

[1] xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

Figure 1: Shell and Tube Type Heat Exchanger

Figure 2: Solid Work Model of Shell and Tube Type Heat Exchanger

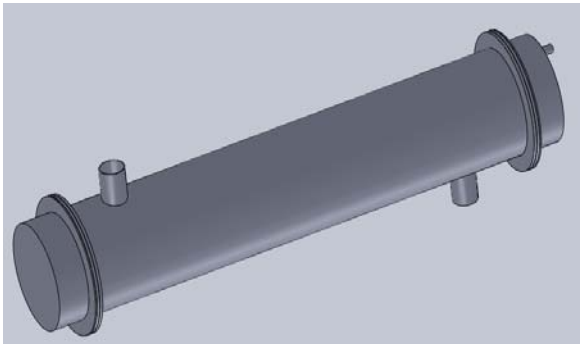
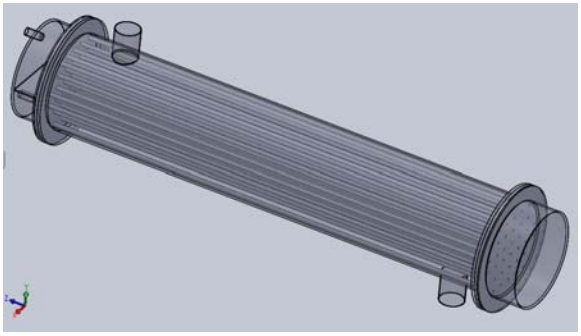


Figure 3: 3D Model of Shell and Tube Type Heat Exchanger



Selection of Process Variable

From past literature survey I found that several factors influence the effectiveness of the heat exchanger. Shell and tube heat exchanger is widely used in the industries therefore it is taken for the analysis. The effectiveness of the shell and tube heat exchanger depends upon the many parameters like tube diameter, pitch length of the tube. Longitudinal pitch, mass flow rate, tube material, shell material, types of the baffles, baffles angles, etc. So form the study I show that tube diameter, pitch length and mass flow rate is most effective parameter for effectiveness of the heat exchanger.

Selection of Process Variable Levels

From study of literature of past researcher, heat exchanger manufacturing association technical specification catalogue, the varying levels of process parameter (like tube diameter, pitch length, mass flow rate) are selected as three parameter are varying in three level. The variation levels value for each parameters are given in Table 1.

Table 1: Process Variable Range

Variation level	Tube Diameter m m (A)	Pitch Length m m (B)	Mass Flow Rate kg/s (C)
1	8.525	23	1.3
2	9.525	25	1.6
3	10.525	27	1.9

Selection of Orthogonal Array

The selection of orthogonal array for experiment was done by use Minitab-16 statistical software. By putting parameter variation levels as per Table 1 in Minitab-16 statistical software the Minitab suggest that mix level L9 (1*2, 3*3) fractional factorial orthogonal array is most compatible for our experiment. The experiment table suggested by Minitab- 16 for L9 orthogonal array is shown in Table 2.

Table 2: Standard Experiment Design

Ex No.	Tube Diameter m m	Pitch Length m m	Mass Flow Rate kg/s
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The final experiment are designed by proving selected parameters values as per Table 3, suggested by heat exchanger manufacturing association in Minitab- 16 statistical software is shown in Table 2. The experiment suggested by this table is specifying the parameter level value of that particular experiment for find out the response value.

Table 3: Experiment Design with Expected Range

Ex No.	Tube Diameter m m	Pitch Length m m	Mass Flow Rate kg/s
1	8.52	23	1.3
2	8.52	25	1.6
3	8.52	27	1.9
4	9.52	23	1.3
5	9.52	25	1.9
6	9.52	27	1.3
7	10.52	23	1.9
8	10.52	25	1.3
9	10.52	27	1.6

CFD ANALYSIS OF TAGUCHI SELECTED ARRAY

CASE 1

Pitch length = 23 mm, tube diameter= 8.525 mm, mass flow rate: 1.3 kg/s

Figure 4: Model of Heat Exchanger for Case-1

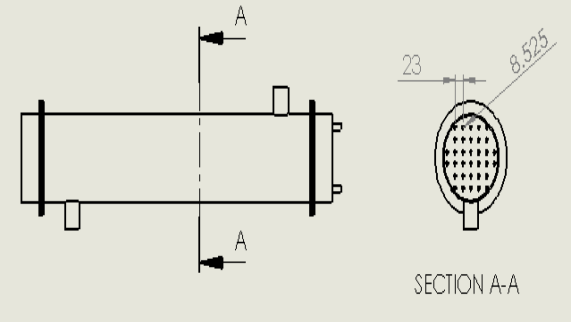
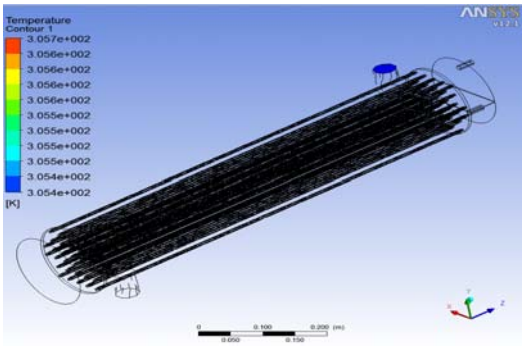


Figure 5: Outlet Temperature of Water for Case-1 Outlet Temperature = 305.66 K



CASE 2

Pitch length: 25 mm, tube diameter: 8.525 mm, mass flow rate: 1.6 kg/s

Figure 6: Model of Heat Exchanger for Case-2

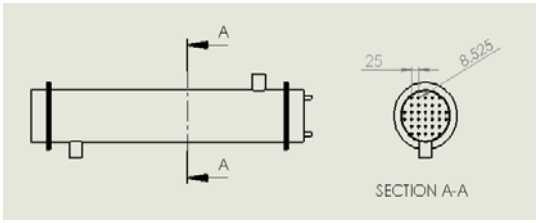
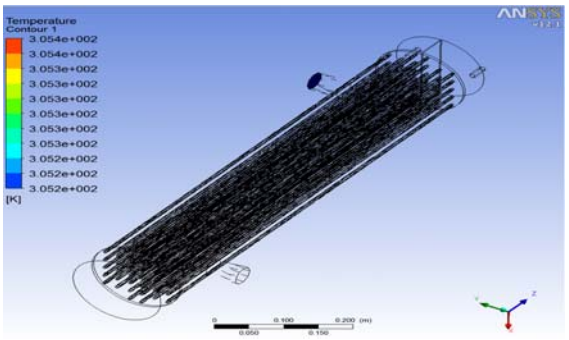


Figure 7: Outlet Temperature of Water for Case-2 Outlet Temperature = 305.37 k



CASE 3

Pitch length: 27 mm, tube diameter: 8.525 mm; mass flow rate: 1.9 kg/s

Figure 8: Model of Heat Exchanger for Case-3

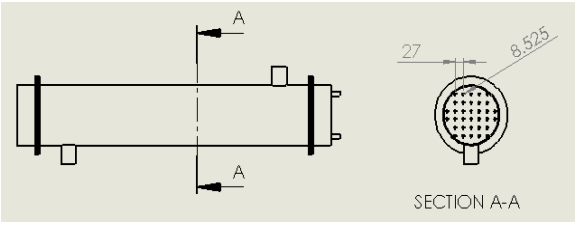
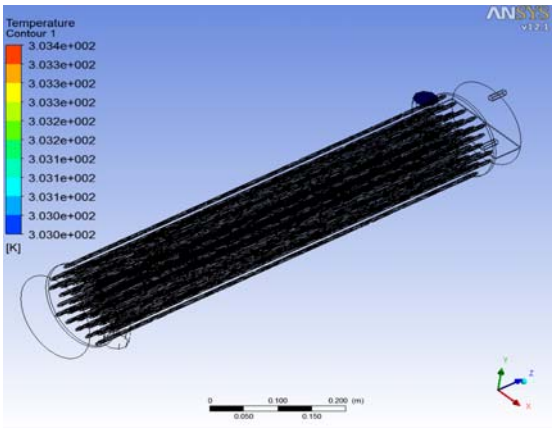


Figure 9: Outlet Temperature of Water for Case-3 Outlet temperature = 303.38 k



CASE 4

Pitch length: 23 mm, tube diameter: 9.525 mm, mass flow rate: 1.6 kg/s

Figure 10: Model of Heat Exchanger for Case-4

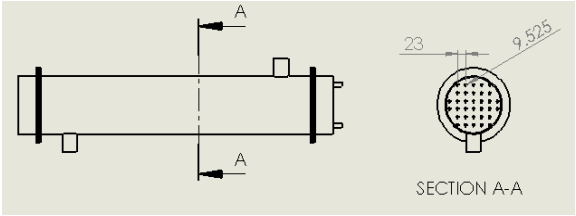
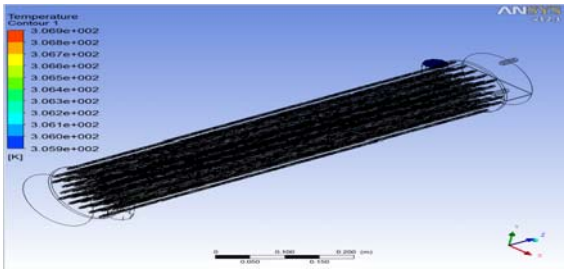


Figure 11: Outlet Temperature of Water for Case-4 Outlet Temperature = 306.86 k



CASE 5

Pitch length: 25 mm, tube diameter: 9.525 mm, mass flow rate: 1.9 kg/s

Figure 12: Model of Heat Exchanger for Case-5

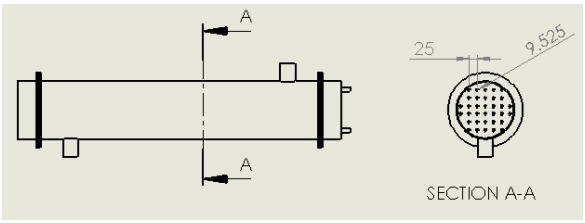
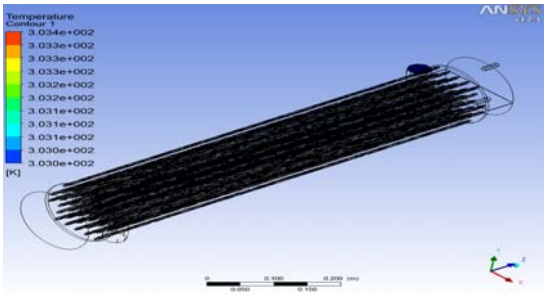


Figure 13: Outlet Temperature of Water for Case-5 Outlet temperature = 306.4 k



CASE 6

Pitch length: 27 mm, tube diameter: 9.525 mm, mass flow rate: 1.3 kg/s

Figure 14: Model of Heat Exchanger for Case-6

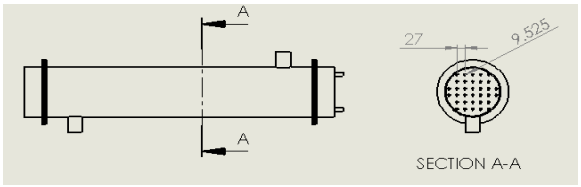
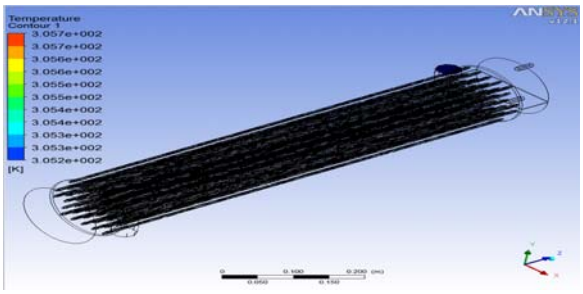


Figure 15: Outlet Temperature of Water for Case-6 Outlet Temperature = 305.7 k



CASE 7

Pitch length: 23 mm, tube diameter: 10.525 mm, mass flow rate: 1.9 kg/s

Figure 16: Model of Heat Exchanger for Case-7

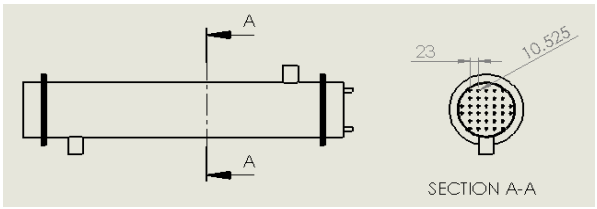
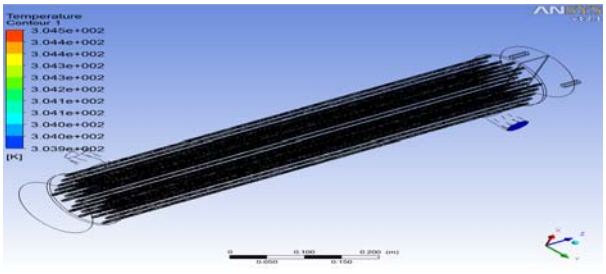


Figure 17: Outlet Temperature of Water for Case-7 Outlet Temperature = 304.51 k



CASE 8

Pitch length: 25 mm, tube diameter: 10.525 mm, mass flow rate: 1.3 kg/s

Figure 18: Model of Heat Exchanger for Case-8

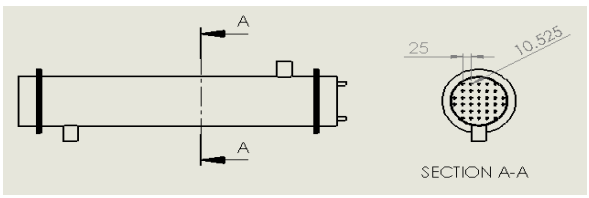
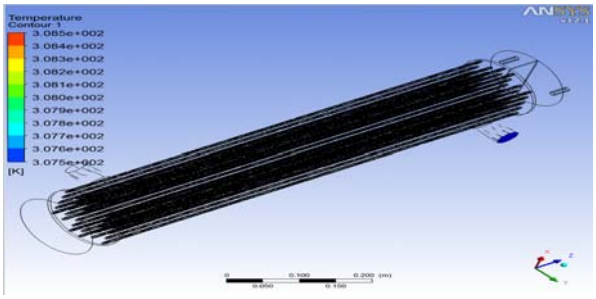


Figure 19: Outlet Temperature of Water for Case-8 Outlet Temperature = 308.46 k



CASE 9

Pitch length: 27 mm, tube diameter: 10.525 mm, mass flow rate: 1.6 kg/s

Figure 20: Model of Heat Exchanger for Case-9

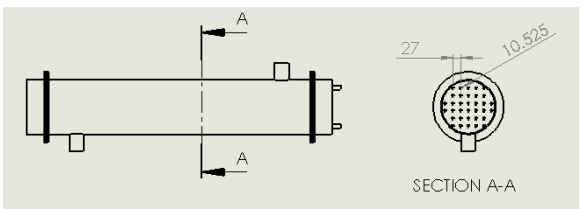
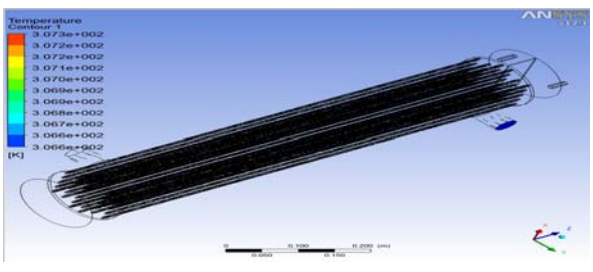


Figure 21: Outlet Temperature of Water for Case-9 Outlet Temperature = 307.31 k



RESULTS

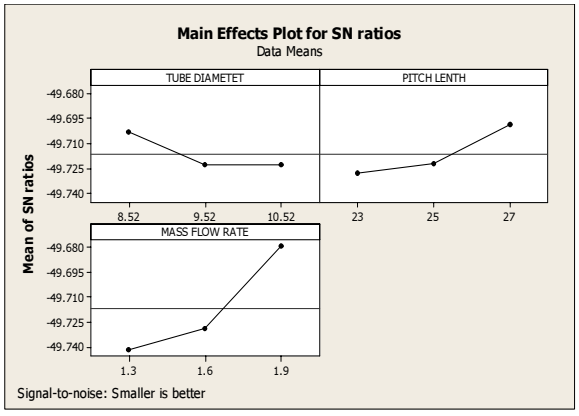
Main Effects Plot of Outlet Temperature

The main effects plot for S/N ratio of outlet temperature verses tube diameter, pitch length and mass flow rate which is generate from the value of S/N ratio of outlet temperature as per Table 4 in Minitab-16 statistical software is useful to find out optimum parameter value for response variable. The graph generate by use of Minitab-16 statistical software for outlet temperature is shown in Figure 22.

Table 4: Result of Nine Cases

Ex No.	Pitch of the Tube	Mass Flow Rate	Outer Temperature (K)
8.52	23	1.3	305.66
8.52	25	1.6	305.37
8.52	27	1.9	303.38
9.52	23	1.6	306.86
9.52	25	1.9	306.4
9.52	27	1.3	305.7
10.52	23	1.9	304.51
10.52	25	1.3	308.46
10.52	27	1.6	307.31

Figure 22: Main Effects Plot for SN Ratio



From the Figure 22 it is conclude that the optimum combination of each process parameter for lower outlet temperature is meeting at tube diameter (8.52 mm), pitch length (27 mm) and mass flow rate (1.9 kg/s).

The S/N of the outlet temperature for each level of the each parameter can be computed in Minitab 16 and it is summarized for finding out rank of each effective parameter for response. The analyzed value of mean of outlet temperature by use of Minitab 16 statistical software is shown in Table 5.

Table 5: Response Table of S/N Ratio for Outlet Temperature

Level	Tube Diameter	Pitch Length	Mass Flow Rate
1	-49.68	-49.71	-49.73
2	-49.72	-49.74	-49.73
3	-49.74	-49.70	-49.68
Delta	0.06	0.04	0.05
Rank	1	3	2

From Table 5 it is show that the value of delta for each parameter tube diameter, pitch length and mass flow rate are 0.06, 0.04 and 0.05, respectively for outlet temperature. From the delta value of each parameter it is conclude that for outlet temperature the most effective parameter is tube diameter followed by mass flow rate and pitch length.

CONCLUSION

In present work for improving the efficiency of shell and tube heat exchanger, the optimization of heat exchanger parameters tube diameter, mass flow rate and pitch length done successfully using Taguchi approach and CFD analysis. From the study of analysis result it is concluded that

- The optimum parameter conditions for increase the efficiency of shell and tube heat exchanger is meeting at outlet temperature 303.38 K are tube diameter 8.52 mm, pitch length 27 mm and mass flow rate 1.9 kg/s.
- The tube diameter is the most significant parameter which is followed by mass flow rate and pitch length for minimum outlet temperature.

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