Simulation Study of Corrugated Heat Exchanger using Different Fluids with Taguchi Technique

[1]Chandra Shekhar Pandey, [2]Harimohan Sharma, [3]Sheetal Kumar Jain

[1]M. Tech Student, [2]Assistsnt Professor, [3]Ph.D Scholar

[1,2] Apex Institute of Engineering and Technology , Jaipur, India

[3] Malaviya National Institute of Technology Jaipur, India

Abstract— Heat transfer from one fluid to another is important application in engineering science, various type of heat exchanger devices was developed by engineers from previous decades. Research on these devices continues in present era to improve thermal performance. Various shapes are used by engineers to improve thermal performance. Main common shapes are like simple straight pipe, curved shape pipe, twisted shape pipe, custom shape pipes like corrugated plate heat exchanger. In present study three type of corrugated plates are selected which are following simple flat plate, circular plate, angular plate type heat exchangers are investigated in present thesis. Simple U bend tubes are experimental investigated and validated with numerical simulation and present in research work. Design of experiment (DOE) "Taguchi" method is selected for this research work and total 16 experiments are selected and solved by using Ansys fluent software. Signal to noise ratio analysis and ANOVA analysis is performed for outlet temperature.

Index Terms— Corrugated plate heat exchanger; CFD; DOE; Taguchi method; ANOVA

I. INTRODUCTION

Heat exchanger is mechanical thermal equipment which is used to transfer thermal energy between two or more fluid, between fluid and solid surface (Practical), at different temperature in thermally contact. It does not require any external heat and work interaction. The purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact. It is using in various practical application filed such as heating and cooling of fluids, space heating, refrigeration, air conditioning, power stations, chemical plant, petroleum refinery, sewage treatment etc. Some common heat exchangers are shell and tube, condensers, evaporator, automobile radiator, cooling tower and air pre-heater. In heat exchanger, tube is important role play to transfer energy therefore many research works are carried out to improved heat exchanger tube by using heat enhancement techniques. Wei Li et al. [1] study on numerical and test investigation on precipitation and particulate fouling increased plate heat exchangers with various geometric parameters. M.A. Khairul et al. [2] studied on Heat exchangers which have been broadly utilized for effective heat exchange starting with one medium then onto the next. The heat exchange coefficient of Cu/water Nano fluids expanded around 18.50 to 27.20%with the upgrade of Nano-particles volume fixation from 0.50 to 1.50% contrasted with water. Besides, change in heat exchange rate was watched for Nano fluids. A.E. Kabeel et al. [3] studied on the creased PHE is a standout amongst the most adaptable and wide utilizing Kinds of heat exchangers. In this investigation, an exploratory test circle has been developed to ponder the PHE warm attributes; heat exchange coefficient, adequacy, transmitted power and weight drop at various concentrated volume portions of AL2O3 Nano-material (1e4%) in unadulterated fluid water as a base liquid. The most extreme increment in heat exchange coefficient is achieved 13% for a Nano-liquid centralization of 4% vol. Be that as it may, the expansion in heat exchange coefficient is up to 13% under a vulnerability of 9.8%, at steady Re number. Xiaoqing Huang et al. [4] studied on the heat and mass exchange attributes of layered plate splash humidification air coolers as a new air cooling innovation under wet working conditions. As far as the air cooling impact, the splash cooling qualities correlations of a similar spout under various formats are made. The TF6 spout shower with a design of 500 mmx500 mm is embraced as the ideal working condition for the heat and mass exchange attributes. Azher M.Abed et al. [5] studied on completely created turbulent stream and heat move conduct in trapezoidal channels utilizing Nano fluids are numerically examined. This examination assesses the impacts of four unique Kinds of nanoparticles, Al 2O3, Cu, SiO2, and No, with various volume portions (0% to 4%) and widths (20 nm to 80 nm) under steady heat motion (6 KW/m2). M. Khoshvaght-Aliabadi et al. [6] studied on Plate-balance heat exchangers (PFHEs), after tubular heat exchangers, are the most well-Known sorts of heat trade instruments in warm designing applications. Harika Sammeta et al. [7] studied on Gasket plate heat exchangers (PHEs) are utilized as a part of refrigeration and heat pump plants and are broadly utilized as a part of the handling of sustenance and beverages, where the simplicity of plate cleaning also, re-gasket (in)g are critical. Existing literary works give an account of the estimation strategy, execution examination for various stream arrangements, CFD displaying and reenactment for diverse number of plates with different stream designs and in addition passes, examination outlines for level PHE, and so forth.

II. DOE GENERATION

For the present experimental work, the five process parameters each at four levels have been decided for Taguchi method. It is desirable to have three minimum levels of process parameters to reflect the true behavior of output parameters of study. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters/factors are given in Table 1. Table 2 shows the L16 orthogonal array of desired design of experiments and Table 3 shows the response table of these 16 experiments where response is outlet temperature of pipe of heat exchanger.

Table 1. Process Parameters and their Levels (Taguchi Method)

Factor	Parameter	Unit	Level			
			L1	L2	L3	L4
A	MFR	kg/sec	0.10	0.15	0.20	0.25
B	Heat Input	W	1000	1100	1200	1300
C	Design-HE	-	1	2	3	4
D	Fluid-Type	-	1	2	3	4
E	Inlet Temperature	K	305	307	309	311

Table 2. L16 orthogonal array

Case No	A	B	C	D
1	0.10	1000	1	1
2	0.10	1100	2	2
3	0.10	1200	3	3
4	0.10	1300	4	4
5	0.15	1000	2	3
6	0.15	1100	1	4
7	0.15	1200	4	1
8	0.15	1300	3	2
9	0.20	1000	3	4
10	0.20	1100	4	3
11	0.20	1200	1	2
12	0.20	1300	2	1
13	0.25	1000	4	2
14	0.25	1100	3	1
15	0.25	1200	2	4
16	0.25	1300	1	3

Case No	A	B	C	D	E
1	0.10	1000	1	1	305
2	0.10	1100	2	2	307
3	0.10	1200	3	3	309
4	0.10	1300	4	4	311
5	0.15	1000	2	3	311
6	0.15	1100	1	4	309
7	0.15	1200	4	1	307
8	0.15	1300	3	2	305
9	0.20	1000	3	4	307
10	0.20	1100	4	3	305
11	0.20	1200	1	2	311
12	0.20	1300	2	1	309
13	0.25	1000	4	2	309
14	0.25	1100	3	1	311
15	0.25	1200	2	4	305
16	0.25	1300	1	3	307

Table 3. L16 orthogonal array for response

III. Result and Discussion

Taguchi method develop a technique which helps to predict the rank of factors, which are responsible for response effectiveness for product, so in present study Signal to Noise ratio test is performed to get rank of factors for both responses.

3.1 S/N ratio for T (out)

Signal to ratio analysis is performed for temperature at outlet of heat ex-changer setup and present in Table 4. Mean ratio analysis is performed and presented in Table 5. As seen in Table 4, best ranked factor is inlet temperature of fluid, it means inlet temperature play important role for this case, second ranked factor is heat exchanger designs least factor is mass flow rate of fluid.

Table 4. Response table for signal to noise ratios larger is batter

LEVEL	A	B	C	D	E
1	49.93	49.90	49.89	49.96	49.85
2	49.94	49.94	49.91	49.95	49.95
3	49.96	49.96	49.96	49.97	49.96
4	49.93	49.96	50.01	49.90	50.01
DELTA	0.03	0.06	0.12	0.07	0.16
RANK	5	4	2	3	1

Like S/N ratio analysis mean ratio analysis is also performed for outlet temperature and present in Table 5, from Table 5, it was clear that the results are same like S/N ratio analysis results. Although the difference among maximum and minimum S/N ratio not much high so we can say that all factors are play important for this study.

Table 5: Response table for mean ratio

LEVEL	A	B	C	D	E
1	313.8	312.7	312.4	314.7	311.0
2	314.2	314.1	313.1	314.4	314.4
3	314.9	315.0	314.7	315.1	314.7
4	313.8	314.9	316.5	312.5	316.6
DELTA	1.1	2.2	4.2	2.6	5.7
RANK	5	4	2	3	1

3.2 Rank Calculation for parameters

Taguchi analysis is also useful to predict best case from selected experimental cases. In present study one response named outlet temperature is selected and S/N ratio results are discussed in previous chapters. Figure 1 and 2 represent the Mean ratio and S/N ratio results for responses, outlet temperature respectively.

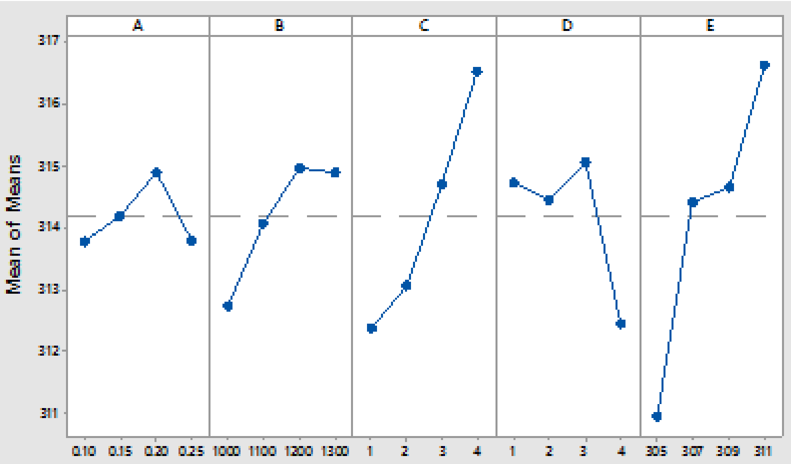

Fig. 1. Mean Ratio analysis for T (out)

Both figures, figure 1 and 2 show profile for T (out) for present study. The profile for T (out) is highest for inlet temperature and least for mass flow rate.

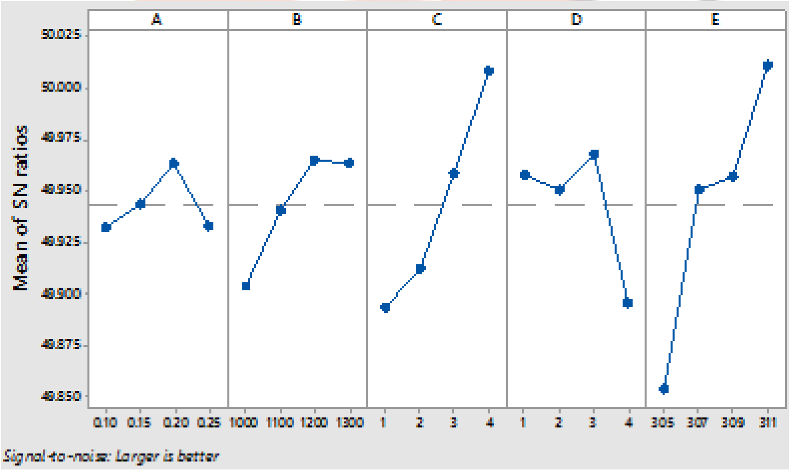

Fig. 2. S/N ratio Ratio analysis for T (out)

3.3 Regression modeling for parameters outlet temperature and nu number

Taguchi analysis is performed for this study and it tells us about factors importance based on response variables, but in present study regression equations are also developed for both response T (out) using linear regression modeling tool MINITAB software.

Table 6: ANOVA analysis for T (out) response

SOURCE	DF	Adj SS	Adj MS	F-Values	P-Values
Regression	5	118.046	23.6093	10.43	0.001
A	1	0.125	0.1248	0.06	0.819
B	1	10.849	10.8486	4.79	0.053
C	1	39.818	39.8184	17.59	0.002
D	1	7.638	7.6385	3.37	0.096
E	1	59.616	59.6160	26.34	0.000

SOURCE	DF	Adj SS	Adj MS	F-Values	P-Values
Error	10	22.634	2.2634		
Total	15	48.3437			

Table 6 and figure 3 represent the ANVOA results and residual figures for first response outlet temperature. As seen in Table 6, most of the factors are significant but one factor mass flow rate is not significant. Figure 3 present the residual plot for T (out) response and it was seen from figure that residual error is not much high for this response.

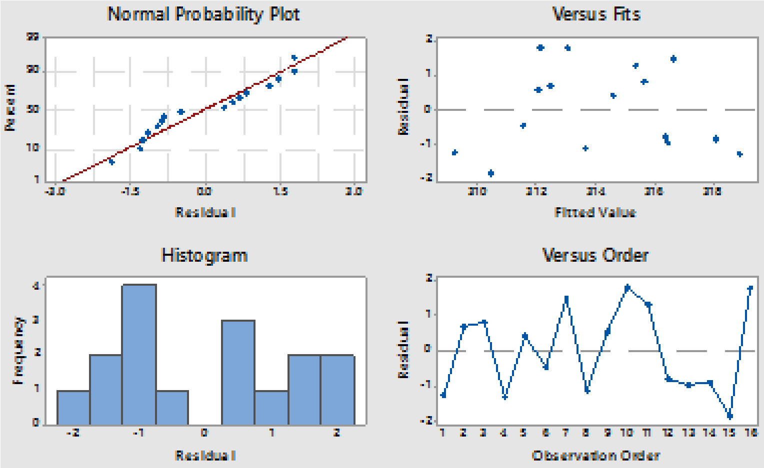

Fig. 3. Residual analysis for T (out) response

IV. Conclusion

In present study special type of heat exchanger named corrugated type plate heat ex-changer is investigated using design of experiment (DOE) technique "Taguchi Method". Total five factors are selected for this study having four levels, total sixteen experiments are carried out in present study and discussed in previous chapter in detail. Main conclusions of this research work are present in following section:

1. Taguchi method analysis present rank of factors for selective response (outlet temperature) and present in Table 7 for responses for present study. Rank of factors are different for responses, which show the differences among responses due to their working methodologies or formulas capability.

Table 7: Factor Rank Based S/N Ratio

	A	B	C	D	E
T (out)	5	4	2	3	1

2. Taguchi analysis also present the best case among all experiments carried out for this research study and results are present in Table 8 for response. It was clear that the best-case parameter shows equal-ness for response, which indicate that response have same conditions for best case among all L16 experiments.

Table 8: Best Case (On the Basis Of S/N Ratio)

	A	B	C	D	E
T (out)	0.20	1200	4	3	311

3. Linear regression modeling is also performed for response and the generated model equation is present in this section with model summary parameters. These model equations are useful for future application of this type of devices. Model summary represents the values of different statically parameters.

$$T\ (out) = 37.6 + 1.58\ A + 0.00736\ B + 1.411\ C - 0.618\ D + 0.863\ E$$

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.50446	83.91%	75.87%	48.41%

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