ANALYSIS OF FIN CHARACTERISTICS FOR OVERALL HEAT TRANSFER IN BOILER ECONOMIZER

by

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The boiler efficiency is improved with the help of economizer it is one of the main accessory part in the boiler. Boiler feed water is preheated with the entry of re-used flue gas through economizer. This present work is planned to analyse the overall heat flux and overall heat transfer in the boiler economizer. Higher amount of flue gases passing around the economizer to preheat the feed water at the same time much more heat is transferred. The heat transfer is analysed by statistical method with influence of different process parameters. Economizer fin dimensions are major consideration to taken for this analysis and estimate the overall heat flux and overall heat transfer. The process parameters of this study are named as thickness of the fin (3.5 mm, 4 mm, 4.5 mm, and 5 mm), height of the fin (4 mm, 5 mm, 6 mm, and 7 mm), fin gap (12 mm, 14 mm, 16 mm, and 18 mm, and tube diameter (44 mm, 46 mm, 48 mm, and 50 mm). The response values are finding as overall heat flux and overall heat transfer.

Key words*: fin gap, tube diameter, economizer, heat transfer, Taguchi, DOE*

Introduction

Economizer is one of the major part as well as mechanical component in all types of power plant units. The feed water is preheated before entered into the steam drum by using of economizer, it is also termed as heat exchanger. The preheated of boiler feed water is achieved by flue gas and reduced the thermal energy need in the boiler that is reduced the fuel usage. Increasing of heat transfer in the boiler (between boiler feed water and flue gas) by projection parts in the outer tube of economizer is named as fins. The finned tube can be classified into two types concerned with the processing methods [1]. One type of finned tube revealed that a continuous arrangement of fins by either welding process or mounting with the

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assist of interference fit on the outer surface of the tubes. This finned arrangement is referred as spiral finned tube, slotted finned tube and H-type finned tube [2-4]. In this type need more process, difficult to production and fix the fins in the tube is also complicated one. The second type is simplest method to form a fin that is no need of fins is required to mount on the surface of the tube [5]. It is formed by 3-D technology also termed as 3-D finned tube such as shape and size of the fins can be cut on the outer surface area of the tube [6]. The machine tool is involved to cut the fin in the surface of the tube continually. This type of fin formation avoid the contact surface among fin and tube and also no need of extra material as well as extra projection while in fabrication process [7-9]. The main aim of this work statistically estimates the fin characteristics for heat transfer in boiler operation and also analysis the thermal performance of boiler. The dimensional behaviour of the fins are aimed to analysed with influence in the output response such as overall heat flux as well as heat transfer [10, 11].

Experimental procedure

In this work the number of fins is arranged in outer surface of the feed water tube as shown in fig. 1. All the fins are projected from the outer surface of the tube is considered in the dimensions height of the fin, thickness of the fin, fin gap and tube diameter.

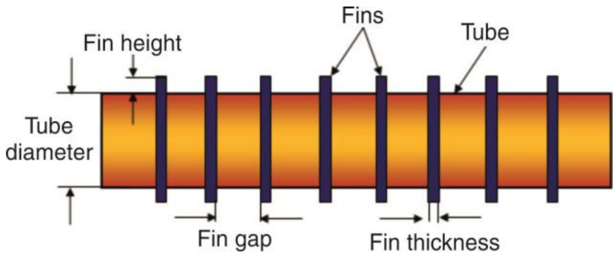

Figure 1. Construction of finned tube economizer

Hot flue gas and cooling water are the medium of this investigation, the hot air was passed away outside of the tubes and the water is flow inside the tube. The economizer mainly consists of a hot flue gas travelling system and a feed water flow system the two systems are insulated properly to avoid and minimize the heat loss [12]. While the flue gas passes across the tube arrangement it temperature can be transferred to the water side and induced the heat. After transfer the heat to the water tube further it can be went to outside [13].

The process parameters and the values are illustrated in the tab. 1 effectively. The selected parameters are thickness of the fin (3.5 mm, 4 mm, 4.5 mm, and 5 mm), height of the fin (4 mm, 5 mm, 6 mm, and 7 mm), fin gap (12 mm, 14 mm, 16 mm, and 18 mm), and tube diameter (44 mm,46 mm, 48 mm, and 50 mm). The number of trails has been identified based on Taguchi's orthogonal array. Since there are four parameters with three levels each and the interaction between the parameters are omitted, L_{16}, orthogonal array was used for experimentation [14-16].

Table 1. Process parameters and their values

Parameters	Level 1	Level 2	Level 3	Level 4
Thickness of the fin [mm]	3.5	4	4.5	5
Height of the fin [mm]	4	5	6	7
Fin gap [mm]	12	14	16	18
Tube diameter [mm]	44	46	48	50

Results and discussion

In this investigation focused to evaluation of overall heat flux and overall heat transfer with the help of four process parameters. Both the output parameters were expected to be maximum. Hence, the optimization was carried out or *lager the better* condition.

Overall heat flux

In the tab. 2 presented the summary of overall heat flux with L_{16} orthogonal array, the signal to noise (S/N) ratio of the test are illustrated clearly. The maximum overall heat flux was registered in the 13th experimental runs and the overall heat flux was 33565.4 W/m^2 also S/N ratio was 90.5178. The MINITAB software (Version 17) has been used for generating the experimental design and analysis of the obtained results.

Table 2. Summary of overall heat flux (L_{16} orthogonal array)

Trials	Thickness of the fin [mm]	Height of the fin [mm]	Fin gap [mm]	Tube diameter [mm]	Overall heat flux [Wm^{-2})]	S/N ratios
1	3.5	4	12	44	32545.3	90.2498
2	3.5	5	14	46	33474.2	90.4942
3	3.5	6	16	48	32847.3	90.3300
4	3.5	7	18	50	32278.6	90.1783
5	4.0	4	14	48	33145.5	90.4085
6	4.0	5	12	50	33285.4	90.4451
7	4.0	6	18	44	32054.9	90.1179
8	4.0	7	16	46	33189.4	90.4200
9	4.5	4	16	50	32658.3	90.2799
10	4.5	5	18	48	32905.4	90.3453
11	4.5	6	12	46	31054.9	89.8426
12	4.5	7	14	44	32454.7	90.2256
13	5.0	4	18	46	33565.4	90.5178
14	5.0	5	16	44	32451.5	90.2247
15	5.0	6	14	50	31456.2	89.9541
16	5.0	7	12	48	32754.3	90.3054

The response tables for means and S/N ratios are presented in the tabs. 3 and 4, respectively. The input parameter values are changed into response values of means and S/N ratios.

Table 3. Response table for means (steam generation)

Level	Thickness of the fin [mm]	Height of the fin [mm]	Fin gap [mm]	Tube diameter [mm]
1	32786	32979	32410	32377
2	32919	33029	32633	32821
3	32268	31853	32787	32913
4	32557	32669	32701	32420
Delta	650	1176	377	537
Rank	2	1	4	3

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

Level	Thickness of the fin [mm]	Height of the fin [mm]	Fin gap [mm]	Tube diameter [mm]
1	90.31	90.36	90.21	90.20
2	**90.35**	**90.38**	90.27	90.32
3	90.17	90.06	**90.31**	**90.35**
4	90.25	90.28	90.29	90.21
Delta	0.17	0.32	0.10	0.14
Rank	2	1	4	3

I
n the test revealed that the height of the fin was more effecting factor in the test compared to other factors in the maximize of overall heat flux. The second factor is thickness of the fin, third factor is tube diameter, and fourth factor is fin gap, all the factors influencing are re-

vealed that by rank order as well as delta value. The optimal process parameters of the overall heat flux was found to be: height of the fin 5 mm, thickness of the fin 4 mm, tube diameter 48 mm, and fin gap 16 mm.

Main effects plot for mean and main effect plot for S/N ratios of overall heat flux are illustrated in the figs. 2 and 3, respectively. From the fig. 4 mm thickness of the fin, 5 mm height of the fin, 16 mm of fin gap, and 48 mm of tube diameter offered the maximum overall heat flux effectively. Lower value of overall heat flux can be attained by 4.5 mm thickness of the fin, 6 mm height of the fin, 12 mm fin gap, and 44 mm tube diameter.

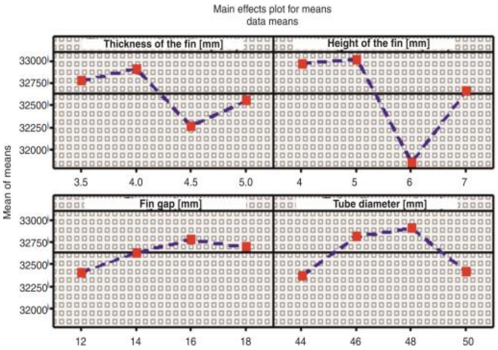

Figure 2. Main effects plot for means of overall heat flux

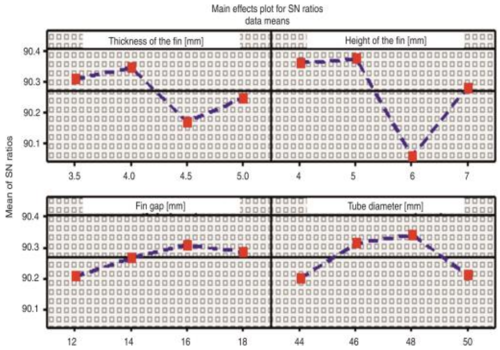

Figure 3. Main effects plot for S/N ratios of overall heat flux

Overall heat transfer

From the tab. 5 clearly explain the summary for L_{16} orthogonal array of overall heat transfer, S/N ratio, and relations of four process parameters. The maximum heat transfer was obtained as 20975.7 W with influence of 4th experimental trails and the parameters of 3.5 mm of thickness of the fin, 7 mm height of the fin, 18 mm of fin gap, and 50 mm of tube diameter. The maximize S/N ratio value of the overall heat transfer was recorded as 86.4343. The L_{16} orthogonal array was shows all the statistical values with inter relations between all four parameters.

Table 5. Summary of overall heat transfer (L_{16} orthogonal array)

Trials	Thickness of the fin [mm]	Height of the fin [mm]	Fin gap [mm]	Tube diameter [mm]	Overall heat transfer [W]	S/N ratios
1	3.5	4	12	44	19542.5	85.8196
2	3.5	5	14	46	20457.3	86.2170
3	3.5	6	16	48	20876.4	86.3931
4	3.5	7	18	50	20975.7	86.4343
5	4.0	4	14	48	19897.5	85.9760
6	4.0	5	12	50	20145.3	86.0835
7	4.0	6	18	44	20357.9	86.1747
8	4.0	7	16	46	19945.6	85.9969
9	4.5	4	16	50	20758.2	86.3438
10	4.5	5	18	48	20683.4	86.3124
11	4.5	6	12	46	19584.2	85.8381
12	4.5	7	14	44	20756.3	86.3430
13	5.0	4	18	46	20438.1	86.2088
14	5.0	5	16	44	20934.2	86.4171
15	5.0	6	14	50	20378.7	86.1835
16	5.0	7	12	48	20735.8	86.3344

The tab. 6 illustrates the response table for means for overall heat transfer and the tab. 7 presented the response table for S/N ratios of overall heat transfer. Response values are taken as maximum hence this analysis considered as larger is better.

Table 6. Response table for means (overall heat transfer)

Level	Thickness of the fin [mm]	Height of the fin [mm]	Fin Gap [mm]	Tube diameter [mm]
1	20463	20159	20002	20398
2	20087	20555	20372	20106
3	20446	20299	20629	20548
4	20622	20603	20614	20564
Delta	535	444	627	458
Rank	2	4	1	3

Table 7. Response table for S/N ratios (overall heat transfer) larger is better

Level	Thickness of the fin [mm]	Height of the fin [mm]	Fin gap [mm]	Tube diameter [mm]
1	86.22	86.09	86.02	86.19
2	86.02	86.26	86.18	86.07
3	86.21	86.15	**86.29**	86.25
4	**86.29**	**86.28**	86.28	**86.26**
Delta	0.23	0.19	0.27	0.20
Rank	2	4	1	3

The significant parameters for both the outputs have been identified based on the response table for the corresponding outputs of S/N ratio. From the tables visibly presented the fin gap has a high influence factor compared to other factors. The second influencing factor is thickness of the fin and third and fourth rank of tube diameter and height of the fin. The optimal parameters are found to be thickness of the fin 5 mm, height of the fin 7 mm, 16 mm of fin gap, and 50 mm of tube diameter.

Figure 4 illustrated the main effects plot for means of overall heat transfer and the fig. 5 main effects plot for S/N ratios of overall heat transfer. From the figures clearly shows that the increasing of thickness of the fin, increasing of height of the fin as well as tube diameter was recorded high heat transfer. Increasing of fin gap also increases the heat transfer, further it can be increased the heat transfer turned to decreases. The maximum values of 5 mm thickness of the fin, 7 mm height of the fin, 16 mm fin gap, and 50 mm tube diameter was maximize the heat transfer.

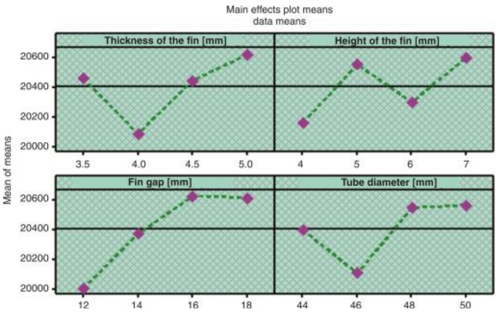

Figure 4. Main effects plot for means of overall heat transfer

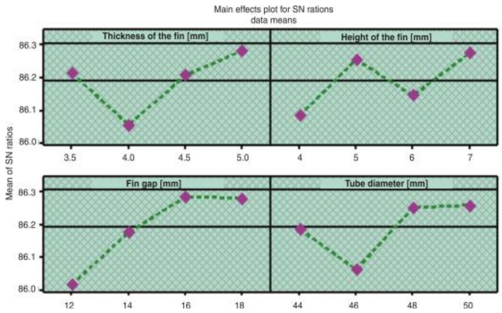

Figure 5. Main effects plot for S/N ratios of overall heat transfer

Figures 6-8 visibly shows that the overall heat transfer obtained by interaction of two process parameters. Figure 6 presented the height of the fin *vs.* fin gap to obtain maximum heat transfer. Maximum height of the fin 7 mm and fin gap of 16 mm offered maximum heat transfer. Figure 7 reveals that the fin gap and tube diameter, the fin gap 16 mm and tube diameter 50 mm produced maximum heat transfer. Figure 8 presented that the tube diameter and thickness of the fin, the 50 mm of fin diameter and 5 mm thickness of the fin offered good heat transfer.

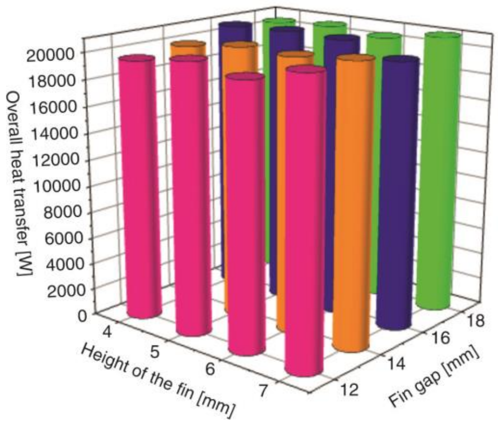

Figure 6. Overall heat transfer: height of the fin *vs*. fin gap

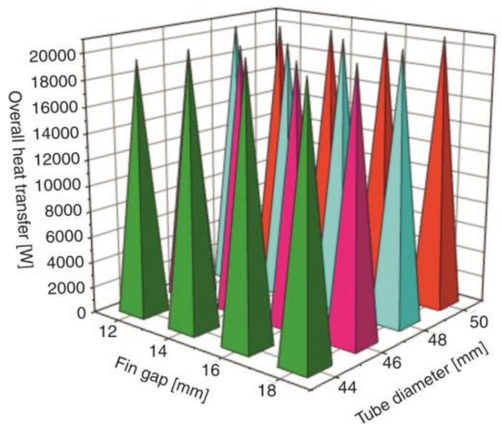

Figure 7. Overall heat transfer: fin gap *vs*. tube diameter

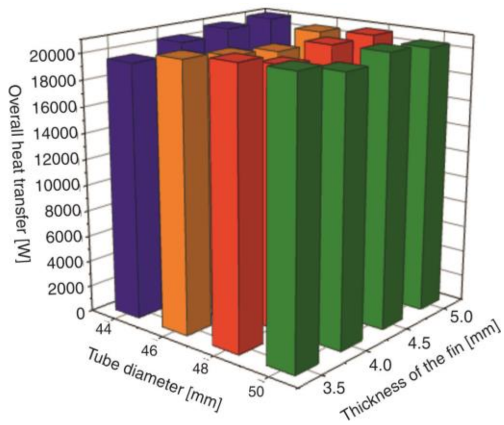

Figure 8. Overall heat transfer: tube diameter *vs*. thickness of the fin

Conclusions

This work attempted to maximize the total heat flux and overall heat transfer by manipulating four process parameters in a DOE mode using Taguchi. The experimental work was performed successfully, and the following results were observed as follows.

- From the analysis the maximum overall heat flux was found in the 13th experimental runs and the result of overall heat flux was obtained as 33565.4 W/m^2 also S/N ratio was 90.5178. Optimal process parameters of the overall heat flux was recorded as: height of the fin 5 mm, thickness of the fin 4 mm, tube diameter 48 mm, and fin gap 16 mm.
- In the residual plot analysis 4 mm thickness of the fin, 5 mm height of the fin, 16 mm of fin gap, and 48 mm of tube diameter registered the maximum overall heat flux effectively. Contrarly lower value of overall heat flux can be found by the influencing of 4.5 mm thickness of the fin, 6 mm height of the fin, 12 mm fin gap, and 44 mm tube diameter.
- The maximum heat transfer was obtained as 20975.7 W with influence of the parameters of 3.5 mm of thickness of the fin, 7 mm height of the fin, 18 mm of fin gap, and 50 mm of tube diameter. The maximize S/N ratio value of the overall heat transfer was recorded as 86.4343. The optimal parameters are found to be thickness of the fin 5 mm, height of the fin 7 mm, 16 mm of fin gap, and 50 mm of tube diameter.

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