THERMO-HYDRAULIC PERFORMANCE ENHANCEMENT OF A RIBBED CHANNEL DUCT USING ANN & TAGUCHI APPROACH

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Abstract

Thermo-Hydraulic Performance ("THP", η) waspredicted using an ANN model for a fixed channel with the turbulators fixed at 90 degrees and compared by CFD analysis conducted by applying the Taguchi approach.The ribs were arranged in a straight line alternately, and the numerical values of the coefficient of friction and the coefficient of convective heat transfer were evaluated. The L_{16} orthogonal array was adopted to evaluate the thermal performance. The relative rib pitch to height (p / e) varies from 3 to 12 in steps of three. The rib vertical angle converges from the plane of the square ribs (i.e. 90°) 80°, 70° to 65° (trapezoidal ribs). Heat transfer & friction coefficient aredetermined using Reynolds numbers of 4000, 8000, 12000, 16000. The ANN model predicted the values close to the CFD Analysis and it was found that Equilateral triangular ribs with $(\alpha)_1(Re)_1(p / e)_3$have the best THP.

Keywords: ANN, Taguchi, Thermo- Hyrdraulic Performance, CFD

1. INTRODUCTION

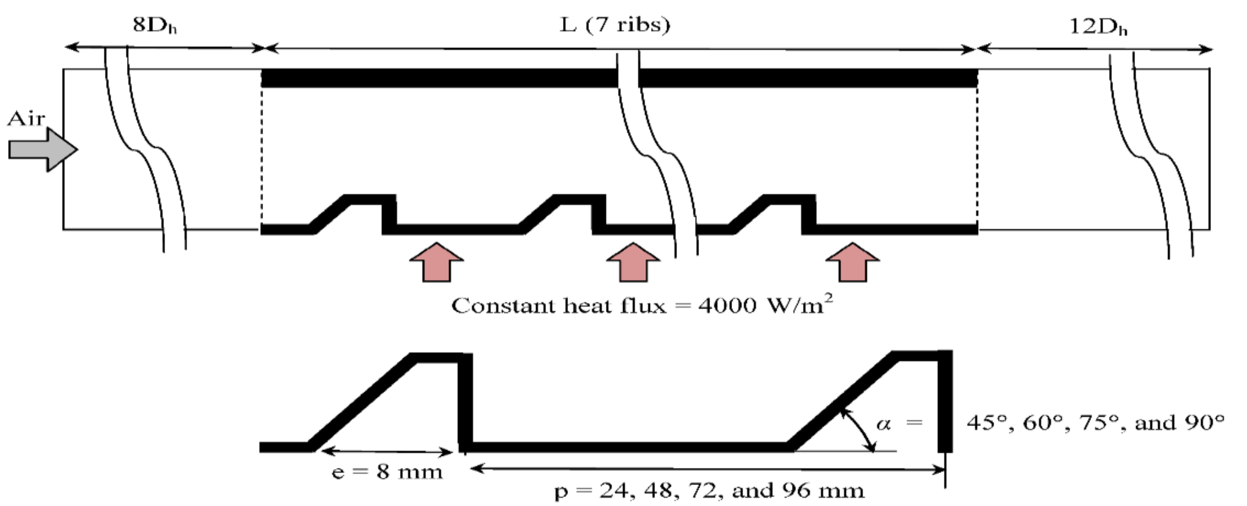
Thermal applications in Industries employ Heat exchangers and major design challenge in a heat exchanger is to make compact, high heat transfer rate equipment using minimum power[1]. To improve heat transfer performance in ducts, Channels and other heat transfer applications, techniques like fin, protrusion, dimple , vortex generators, groove and ribs are used [2]. Heat transfer and friction coefficientsof rectangular channel having inclined ribs were discretized throughgeneration of not inline gaps [3]. Different cross sections air flow paths at sides of parallel pass in the absorber plates are roughened with inclined shape ribs [4]. Significant output parameters like Nu, friction coefficient and thermal parameters like Re,P/e and e/Dh was analyzed for T shaped Ribs [5]. The THP of triangular duct with ribs of varying inclination in turbulent flow fieldhas been studied [6]. Computational Fluid Dynamics along with Taguchi design has been performed for investigation of thermo-hydraulic performance [7].The Fluid Dynamics can be performed with the help of input images[8]. The cubic Interpolation method can be used for Images to investigate Thermo -hydraulic[9].Thermal Application can be employed with self compacting concrete methods[10].

2. METHODS AND METHODOLOGY

In the present study, a double walled duct with upper wall insulated and lower wall with a series of Trapezoidal ribs (with equilateral angle varying from 65˚, 70˚, 80˚ and 90˚) and other input parameters are taken as shown in table 1..The totallength of the duct was taken 1500mm, entry length of 320 mm, test length of 700mm,exit length of 480mm,duct width(W) of 160 mm, duct height, (H) 40mm, hydraulic diameter (D_h) of 64mm, uniform heat flux (I) and Prandtl Number (Pr.) of 4000 W/$m^2$and 0.707 respectively.

Table 1.Input parameters and investigated geometry of ribbed channel

Parameters Symbol	p/e	α	Re
Range of values	3 – 12 (step size of 3)	65˚, 70˚, 80˚, 90˚	4000 – 16000 (step size of 4000)



2.1. ANN Modelling

The modelling for input and output was done through ANN toolbox through MATLAB software. The simulated MLFF-ANN architecture consisting 3 neurons in input layer one for each considered process inputs and the output layer comprising of 3 neurons foreach output characteristics. Table 2. Shows the CFD analysis results along with ANN predictions.

Table 2. Main Experimental Table with ANN Modelling

S.No.	**Input Parameters**			**CFD Analysis**			**ANN Predictions**		
	Re	**P/e**	**A**	**Nu**	**F**	**η**	**Nu**	**f**	**η**
1	4000	3	65°	43.35	0.0104947	2.73717	43.3	0.011	2.7223
2	4000	6	70°	40.48	0.0132207	2.36649	40.52	0.0135	2.3354
3	4000	9	80°	40.97	0.0153632	2.27790	41.02	0.01501	2.1223

4	4000	12	90°	41.01	0.0175015	2.18363	40.98	0.01657	2.1789
5	8000	3	70°	62.24	0.0099913	2.16550	62.26	0.0103	2.1872
6	8000	6	65°	65.53	0.0112298	2.19283	65.43	0.01212	2.2020
7	8000	9	90°	65.44	0.0118445	2.15129	65.32	0.011527	2.65
8	8000	12	80°	67.44	0.0141818	2.08784	67.58	0.019654	2.39
9	12000	3	80°	74.19	0.0086417	1.89350	74.41	0.008268	1.59
10	12000	6	90°	76.58	0.0101059	1.85531	76.68	0.009085	1.37
11	12000	9	65°	95.51	0.0122588	2.16949	99.45	0.0.12310	2.73
12	12000	12	70°	91.67	0.0129090	2.04672	93.24	0.012782	2.22
13	16000	3	90°	83.63	0.0082362	1.68231	83.45	0.008685	1.52
14	16000	6	80°	96.67	0.0099908	1.82340	93.71	0.0099	1.72
15	16000	9	70°	113.59	0.0120500	2.01278	114.11	0.12380	2.08
16	16000	12	65°	113.09	0.0125956	1.97456	115.07	.013056	1.91

3. RESULT AND DISCUSSION

The current investigation data is presented in terms of contour/vector plots of velocity distribution superposed with mean streamlines in the inter-rib region. The streamline patterns superposed on dimensionless mean streamwise velocity are shown in Fig1.for rib p/e ratio varying from 3 to 12. It is observed that the flow characteristics in the inter-rib regions after 3rd rib are matching well irrespective of p/e, and therefore, the flow can be considered as periodic.

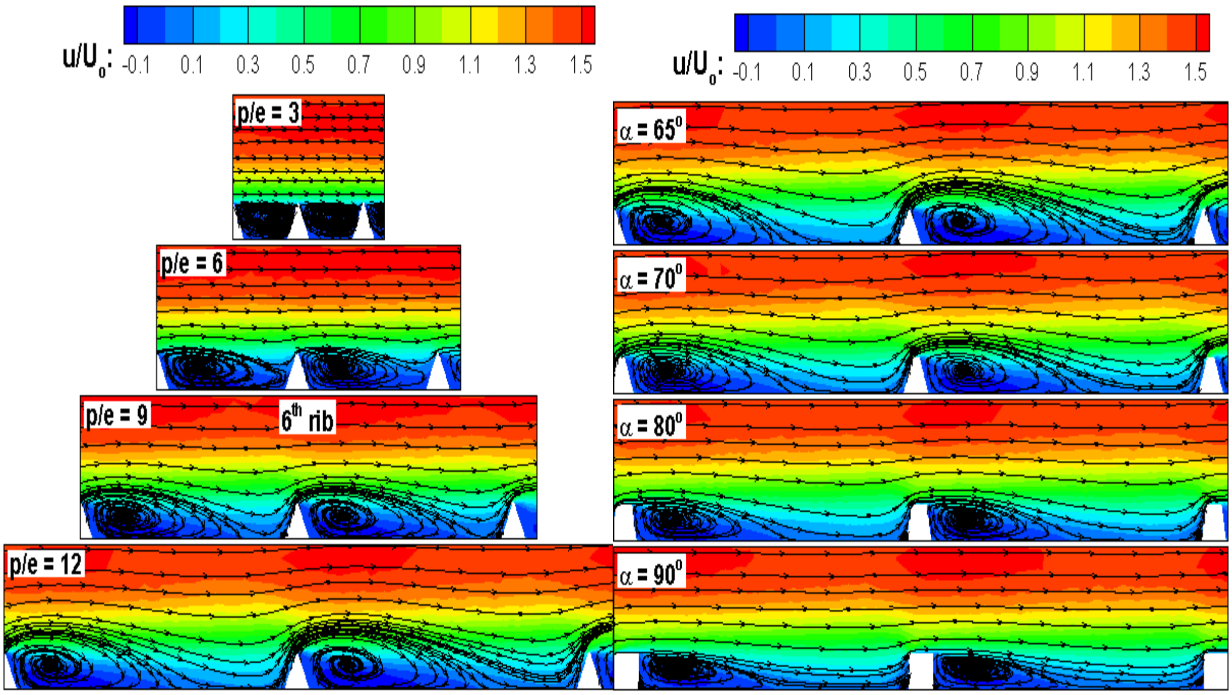


Fig.1. Effect of rib p/e ratio on flow structures and Effect of rib geometry on flow structures

Table 3. Signal to Noise ratio for Nu, f and THP(η)

Input Parameters			**CFD Analysis**			**Signal to Noise Ratio**		
Re	**P/e**	**A**	**Nu**	**f**	**η**	**Nu**	**f**	**η**
4000	3	65°	43.35	0.0104947	2.73717	32.74	39.5806	8.75
4000	6	70°	40.48	0.0132207	2.36649	32.15	37.5749	7.48
4000	9	80°	40.97	0.0153632	2.27790	32.25	36.2704	7.15
4000	12	90°	41.01	0.0175015	2.18363	32.26	35.1385	6.78
8000	3	70°	62.24	0.0099913	2.16550	35.88	40.0075	6.71
8000	6	65°	65.53	0.0112298	2.19283	36.33	38.9925	6.82
8000	9	90°	65.44	0.0118445	2.15129	36.32	38.5297	6.65
8000	12	80°	67.44	0.0141818	2.08784	36.58	36.9654	6.39
12000	3	80°	74.19	0.0086417	1.89350	37.41	41.2680	5.55
12000	6	90°	76.58	0.0101059	1.85531	37.68	39.9085	5.37
12000	9	65°	95.51	0.0122588	2.16949	39.60	38.2310	6.73

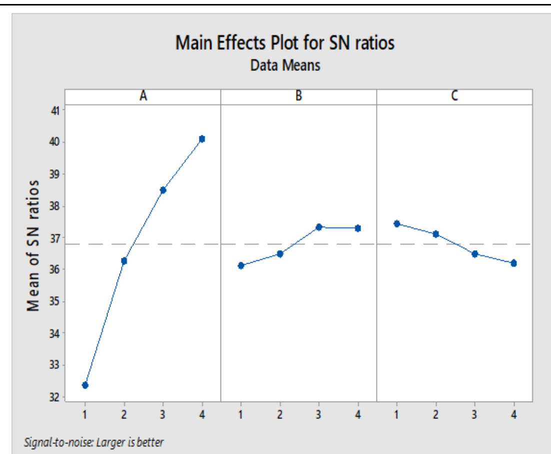
12000	12	70°	91.67	0.0129090	2.04672	39.24	37.7821	6.22
16000	3	90°	83.63	0.0082362	1.68231	38.45	41.6854	4.52
16000	6	80°	96.67	0.0099908	1.82340	39.71	40.0080	5.22
16000	9	70°	113.59	0.0120500	2.01278	41.11	38.3802	6.08
16000	12	65°	113.09	0.0125956	1.97456	41.07	37.9956	5.91

After conducting the CFD analysis based on the recommended experiment set by Taguchi orthogonal array the results of signal-to-noise ratio (S/N) were analyzed. Signal and noise depicts controllable and noncontrollable variables in aphenomenon. Assigned implementations with their corresponding S/N values for Nur, f and THPare presented in Table 3.

Table 4. Response table of S/N ratios & Main effects plot for S/N ratio of Nusselt number (a), Friction Factor (b) and Thermo-Hydraulic performance (c)

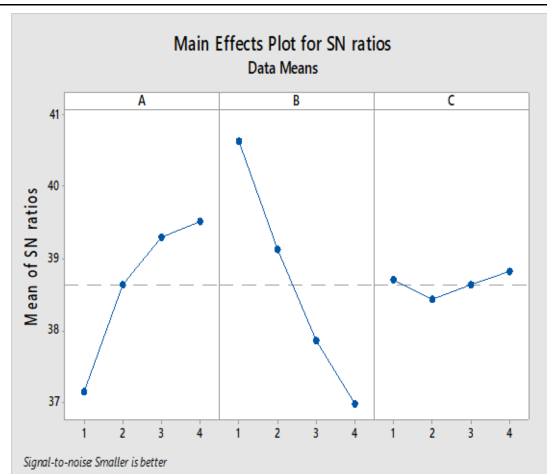
(a)

Level	Re	p/e	α
1	32.35	36.12	37.43
2	36.28	36.47	37.09
3	38.48	37.32	36.48
4	40.08	37.29	36.18
Delta	7.73	1.2	1.26
Rank	1	3	2
CR, (%)	75.86	11.78	12.37



(b)

Level	Re	p/e	α
1	37.14	40.64	38.7
2	38.62	39.12	38.44
3	39.3	37.85	38.63
4	39.52	36.97	38.82
Delta	2.38	3.66	0.38
Rank	2	1	3
CR, (%)	37.07	57.01	5.92



(c)

Level	Re	p/e	α

1	7.541	6.38	7.051	
2	6.645	6.222	6.623	
3	5.965	6.652	6.077	
4	5.43	6.327	5.831	
Delta	2.11	0.43	1.22	
Rank	1	3	2	
CR, (%)	56.12	11.44	32.45	

The difference in Max and Min S/N ratio is Delta while the ratios of these Delta indicatesthe contribution of each of the parameter under investigation which are being represented in Table 4. along with the Main effects plot for S/N ratios for output characteristics under investigation. Nusselt number andthermohydraulic performance follows larger SNR is better, whereas Friction Factorfollows smaller SNR is better. the Nu increases as Re increases, with increasing p/e, as the flow reattaches resulting inincreased heat transfer. Whereas itdecreases as α increases. It is alsoobserved thatf increases asRe increase and decrease p/e increases. The values of 'f' slightly decreaseas α increases.

4. CONCLUSIONS

The THPwas computed for stationary channels with ribs and four levels of the three input parameters.From the CFD analysis based onL_{16} orthogonal array of Taguchi approach. The subsequent conclusions have been drawn:

1. Nu increased with p/e ratio having optimum value at $Re_4p/e_3\alpha_1$ the outcomes indicates that major contributor was Reynold Number (Re).
2. p/e ratio is major contributor for Friction and optimum parameters Friction factor are at $Re_4p/e_1\alpha_4$.
3. Overall THP decreases with increase in Re values and are almost unaffected by change in p/e values and decreases as α increases. Overall maximum performance was obtained at $Re_1p/e_3\ \alpha_1$.
4. It was also observed that the ANN model predicted the values close to those of the CFD investigation.

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