CFD Investigation on Dimpled Fins With Parameter Variation for Heat Transfer Augmentation

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Abstract - Computational Fluid dynamics in this paper predicts the flow of air over the dimpled fins and the heat transfer due to forced convection. Dimpled fins are modeled and made using variation in parametric dimensional. We consider three parameters Diameter, Depth and Pitch of dimples. Design of experiment is done and L9 model was used for solving this experiment. Analysis is done for three different Reynolds number (Re) 6500, 8000 and 10000. For the purpose of validation we have also performed experimentation. Calculating the heat transfer coefficient of the results obtained from CFD we found the percentage contribution of each parameter and proposed an optimum combination

Keywords – Dimple fins, heat transfer coefficient

1.0 INTRODUCTION

The science and engineering of heat transfer for forced convection plays a critical role in the design of heat exchangers. This research investigates fin topologies with heat transfer characteristics that shall surpass conventional fin, where the aim is to increase the heat transfer rate of the fin surface while keeping an acceptable pressure drop penalty. Boundary layer regeneration and enhanced flow mixing are the main techniques used to increase the overall heat transfer coefficient (h) of the surface. Surface roughness is usually applied to smooth surfaces to promote flow mixing and initiate turbulence in the flow. Dimples have shown good heat transfer characteristics when used as surface roughness, in this work we investigate the dimensional variations of continuous surfaces with dimples and protrusions on opposite sides for heat augmentation. In this paper we calculate heat transfer Coefficient (h), Nusselt Number (Nu), friction Factor (fr), for various Reynolds number (Re)

2.0 ANALYSIS TECHNIQUE

3D model of experiment was made using Pro-E and then imported to Ansys ICEM software. The assembly consists of duct, heat source and fins. This assembly was then meshed using tetrahedron elements (Patch dependent robust octree) and 4 layers of prism elements on the fin surfaces for proper convective results.

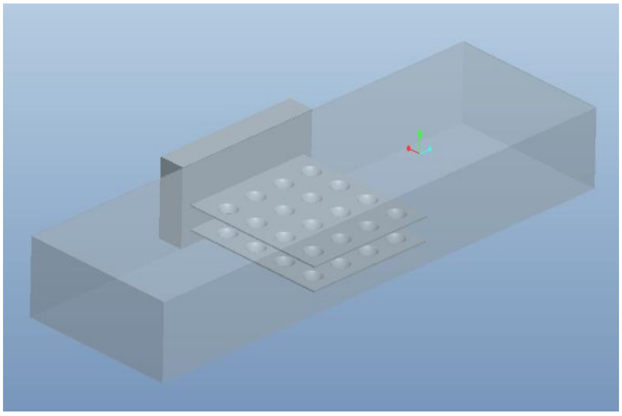

Fig 1: 3D model of the Duct, Base plate and Dimpled Fins

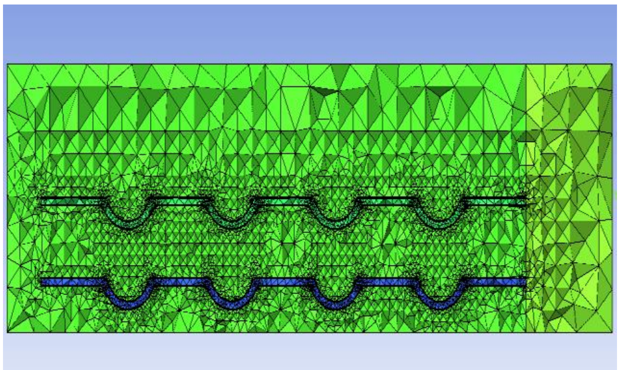

Fig 2: Cross section of Meshed model.

Results obtained after importing the mesh file to ICEM and analyzing by applying boundary conditions. This model is to be mirrored for results as the model made was half from symmetry axis.

3.0 DESIGN OF EXPERIMENT

For the experimental purpose, Three parameters and three levels were used for Taguchi method by careful understanding the levels taken for the factors. The factors to be studied are Diameter, Depth and Pitch. Before selecting an orthogonal array, the minimum number of experiments to be conducted can be decided by using the following relation,

Table 1 – Control Parameters and Levels

Control Parameter	Level 1	Level 2	Level 3
Dimple Diameter	10	15	20
Dimple Depth	3.5	4	4.5
Pitch	28	30	32

$$N_{Taguchi} = 1 + NV\,(L - 1)$$

where

$N_{Taguchi}$ = number of experiments to be conducted

NV = number of variables = 3

L = number of levels. = 3.

Table 2 - Orthogonal array for L9 design

L9	Level 1	Level 2	Level 3
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

4.0 RESULTS AND DISCUSSION

The study of results from CFD showed that heat transfer coefficient increases for dimple as compared to plain fin. Vortex are created due to dimple as shown in fig:4 and this breaks the boundary layer and heat transfer augmentation is seen.

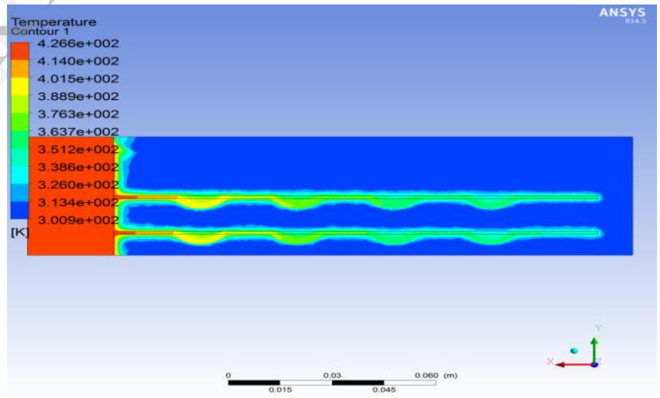

Fig 3: Temperature contour

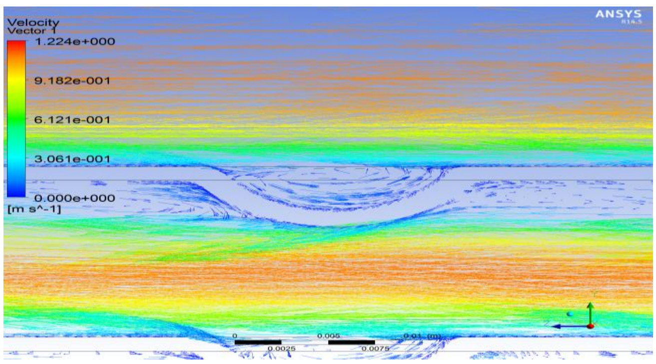

Fig 4: Velocity Vectors

We determine the main effects of the working parameters of dimpled fins, to perform the analysis of variance (ANOVA). The main effects of dimpled fins analysis are used to study the effects of each of the factors. The performances of the fins (ANOVA-significant factor) can be calculated for each experiment of the L9 by using the observed values of the heat transfer coefficient from Table 3. Table 4 lists the ANOVA test results for heat transfer coefficient for Re 6500, 8000 and 10000 respectively.

We plot a graph of Reynolds Number vs Nusselt Number for all the experiments. Also we plot a graph of Reynolds Number vs Friction factor shown below.

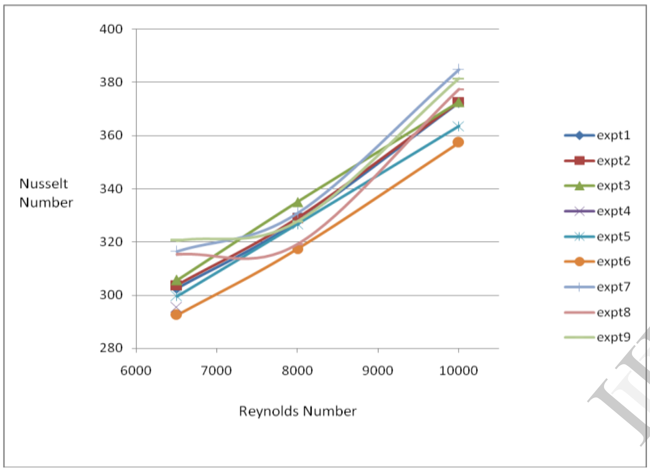

Fig No – 5: Nu vs Re for all experiments

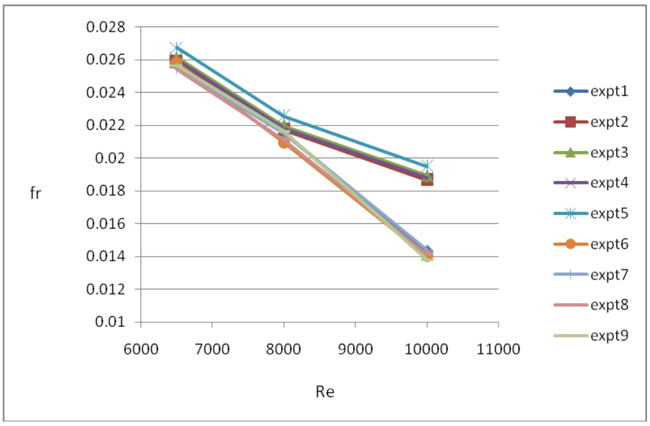

Fig No – 6: Friction factor vs Re

Table No – 3 – Results for parameter contribution

Re	Para meter	I Mean	II Mean	III Mean	SS	% Contrib ution	F ratio
10000	Dia.	74.27	71.78	76.80	32.72	72.99%	44.7
	Pitch	74.35	72.51	75.80	0.163	5.156%	0.74
	Depth	75.29	71.71	76.08	3.523	20.9%	16.6
8000	Dia.	65.73	64.00	66.41	11.79	71.63%	68.7
	Pitch	65.82	64.52	66.38	0.662	5.2%	3.8
	Depth	66.56	64.71	66.38	5.013	22.19%	29.2
6500	Dia.	60.12	59.11	63.58	36.90	78.99%	48.0
	Pitch	61.03	59.56	63.11	0.649	6.08%	3.23
	Depth	61.18	58.80	63.72	2.956	14.32%	13.1

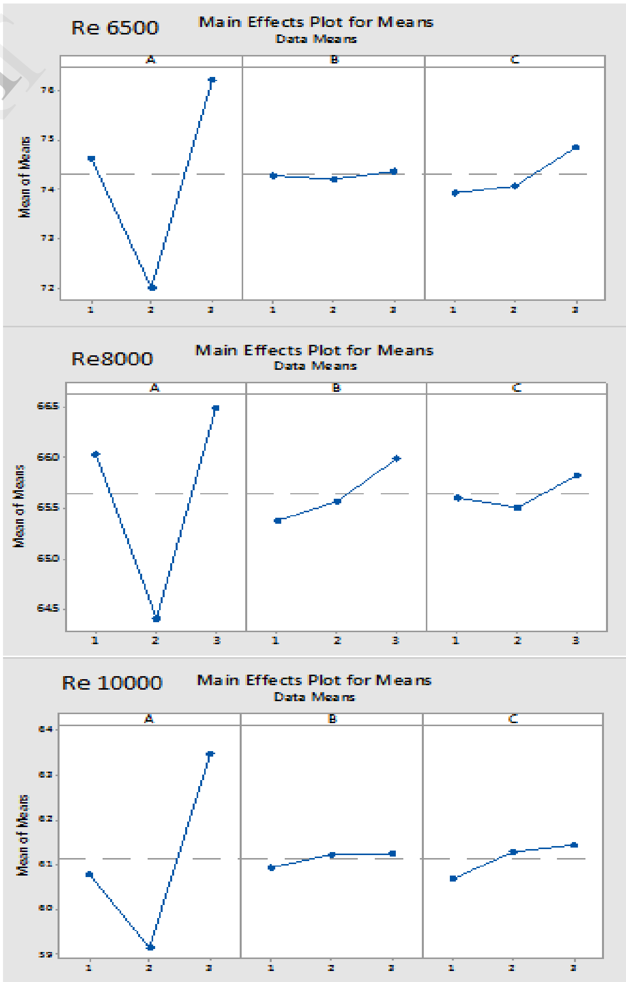

Fig. No – 7 – Effect of Parameters

As per table 3 and graphs plotted we can see the contribution of diameter is higher then depth and pitch. Pitch value is very small and is least affective parameter in these three parameters.

Table No – 4 - Optimum working parameters

Parameter	6500	8000	10000
Diameter	20	20	20
Pitch	32	32	32
Depth	4.5	4.5	4.5

After achieving the optimum working parameters of fins using Taguchi methodology, the experiments were conducted and their values are displayed in the Table No - 5. The experimental results give the optimum performance of fins at various Reynolds number and these values are found to be better than the previous observations.

Table No –5– Results for Optimum working parameters

Parameter	Re 6500	Re 8000	Re10000
Heat transfer coefficient	64.94750	67.8236	77.4644

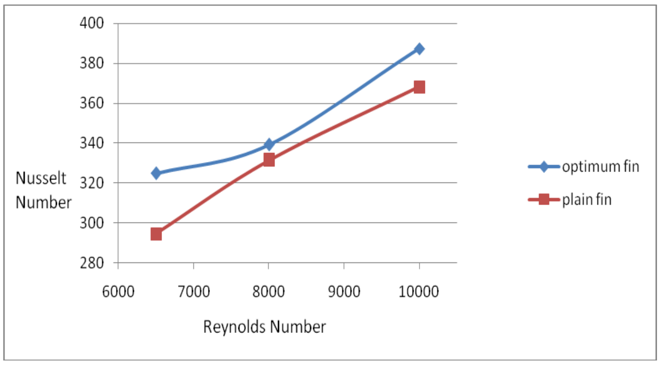

Fig No – 7 (Nu vs Re for Plain and optimum fin)

5.0 CONCLUSION

This project was carried out with the aim of investing the parameters of dimpled fins for heat transfer coefficient. Comparing all the nine dimpled fin channel configurations, the convective heat transfer coefficients shows considerable variations. With the varying dimple depth, dimple pitch and dimple diameter it is concluded that The rate of increase for the Heat transfer coefficient is higher for Diameter when compared with the Pitch and Depth. But the rate of increase for the Heat transfer coefficient is very low for pitch variation, thus combination with the maximum diameter, depth shows best convective heat transfer coefficients.. There is a considerable increase in the value of Nusselt number in the dimpled configurations as compared to plain fins. The friction factor decreases with the increase in the Reynolds number.

Taguchi optimal solutions gave better results for Dimpled fins and it also reduces the number of experiments that were required for finding its performance metrics.

As per the velocity vectors seen in the results vortex are created due dimples. This vortex leads to break in boundary layers and leads the heat transfer enhancement.

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