CFD Analysis for the Effect of Triangular and Pentagonal Ribs on Performance of Solar Air Heater

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Abstract— Solar energy can be converted effectively using Solar Air Heater. And the effectiveness of Solar Air Heater can be increased by using better and rough absorber plate. Roughness on the absorber plate lead to increase in turbulence and increase in air travel length, leading to increase in the performance of Solar Air Heater. Computational Fluid Dynamics is one of the best tools to find out the effect of any parameter of equipments in design phase only. In the present paper, 3-D CFD analysis of a solar air heater with triangular and pentagonal ribs has been done to study heat transfer and fluid flow behaviour. Effect of various roughness parameters such as heat transfer coefficient, Reynolds number, Nusselt number has also been covered.

Keywords: Solar Air Heater, Ribs, Turbulence Model, CFD Analysis, Absorber Plate

I. INTRODUCTION

Solar radiation can be converted into thermal energy using Solar Air Heater. This thermal energy is cheap and can be used for many applications including food industry, buildings, for industrial products, etc. An absorber plate, a rear plate, insulation and transparent cover are the basic components of the solar air heater.

To increase the performance of Solar Air Heater, heating capacity of absorber plate needs to be increased. The present research paper presents the effect of flow and roughness parameters on heat transfer and flow friction characteristics of an artificially roughened solar air heater with triangular and pentagon ribs on the absorber plate. The effect on thermal properties has also been covered such as Reynolds number, Nusselts number and heat transfer coefficient. The results are also compared with that for a flat plate.

II. LITERATURE REVIEW

Singh et al., 2012, confirmed that artificially rib roughened solar air heaters have higher efficiency than the conventional flat-plate solar air heater Yadav, et al., 2013 and Lahori et al, 2016 presented review of the literature covering the application of CFD for design of solar air heaters. Hu et al, 2013, developed a numerical model for predicting internal flow and heat transfer characteristics for solar air heater. Boulemtafes-Boukadoum et al, 2014, presented numerical analysis for heat transfer enhancement in solar air heaters with artificially roughened absorber plate. Lahori et al, 2016 emphasised on increasing air travel length for increasing performance of solar air heater. Kumar et al., 2017, used FLUENT software for simulating 2 D flow for solar air heater. Prasad et. al., 2017, presented mathematical and numerical analysis for solar air heater. Manjunath et. al., 2017, discussed the effect of turbulence of flat plate solar air heater. Abhay et al, 2018, used artificial roughness to increase the heat transfer rate for indirect type solar air heater. Salih et. al., 2019, investigated the thermal performance of a double-pass solar air heater. Raj et. al, 2019, experimented on a double-pass solar air heater system.

III. GEOMETRIC MODELING

The geometry of Solar Air Heater was modelled in ANSYS Design Modeler with dimensions given in Table 1.

L_1 (mm)	L_2 (mm)	L_3 (mm)	W (mm)	H (mm)	D (mm)	E (mm)	P (mm)
245	280	115	100	20	33.33	2	10, 15, 20, 25

Table 1: Geometric parameters of Solar air Heater with ribs

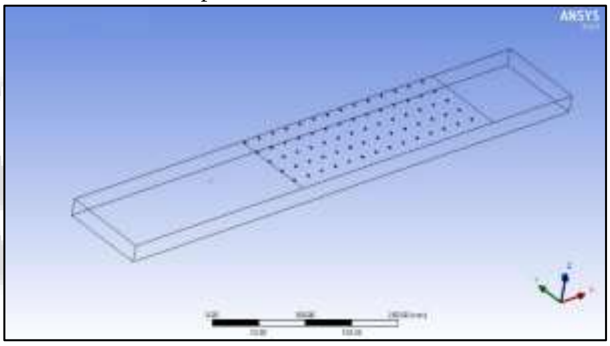

Fig. 1: Solar Air Heater with triangular and pentagon ribs on the absorber plate with 20 mm pitch value

IV. MESHING

The geometry is descritised into small elements as per specified in Table 2.

Rib pitch (P)	No. of nodes	No. of element
10	71932	185110
15	52315	136258
20	38379	101371
25	32573	87532

Table 2: Meshing details

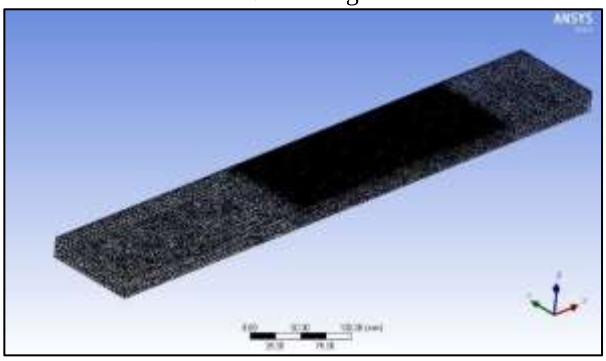

Fig. 2: Meshing of the Solar Air Heater

V. INPUT PARAMETERS AND BOUNDARY CONDITIONS

The range of operating parameters were specified as input parameters and boundary conditions as given in Table 3.

Operating parameters	Range
Uniform heat flux, 'q'	1000 w/m^2
Reynolds number, 'Re'	8000, 1200, 15000
Prandtl number, 'Pr'	0.71
Relative roughness pitch, 'P/e'	5, 7.5, 10, 12.5
Relative roughness height, 'e/D'	0.060
Duct aspect ratio, 'W/H'	5

Table 3: Range of operating parameter

VI. RESULTS AND DISCUSSIONS

ANSYS Fluent was used for analysis. Following temperature contours were obtained.

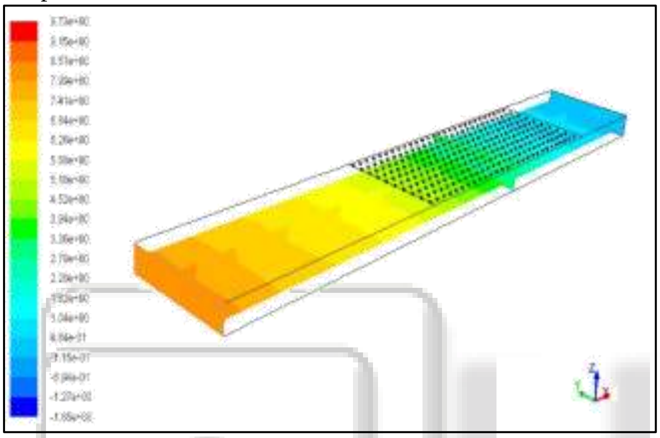

Fig. 3: Temperature contour for triangular-pentagon ribs for e=2, p=10, Re-8000-pressure of the absorber plate

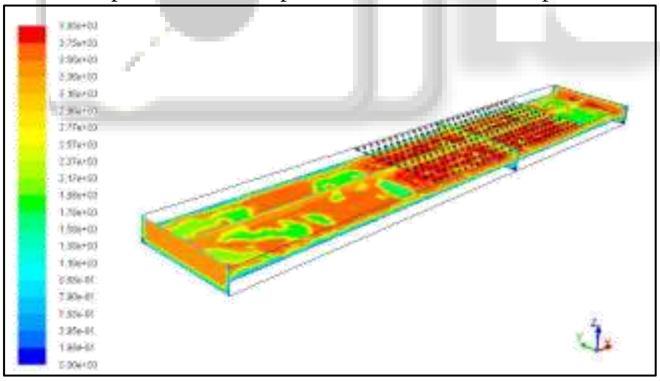

Fig. 4: Velocity of air at absorber plate for e=2, p=10, Re-8000

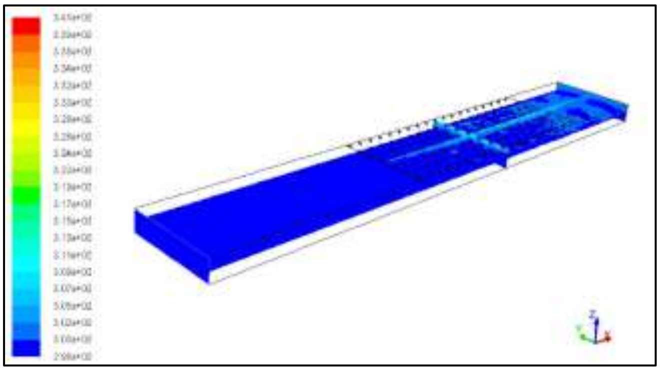

Fig. 5: Temperature of absorber plate for e=2, p=15 and Re-12000

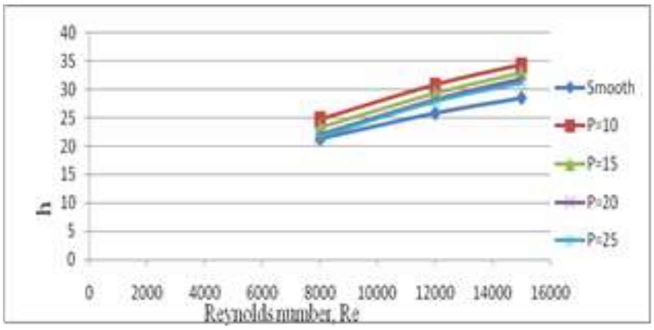

Fig. 6: Reynold's Number (Re) vs Heat Transfer Coefficient (h) plot

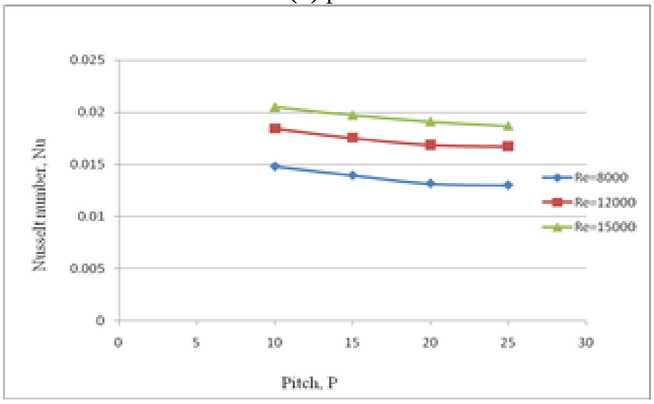

Fig. 7: Variation in Pitch (P) vs Nusselt's Number (Nu)

Nusselt number increases with increase in Reynolds number whereas it decreases with increase in roughness pitch. Friction factor decreases with increase in Reynolds number. The heat transfer decreases with increase in pitch and increases with increase in Nusselt number. Heat transfer increases with increase in Reynolds number and decreases with increase in pitch.

VII. CONCLUSIONS

A 3 D CFD analysis of solar air heater has been carried out to study the effect of roughness of absorber plate on its performance. The effect of parameters such as Reynolds's number, Nusselt number, roughness height, relative roughness pitch and roughness height have been studied for the performance prediction of solar air heater. The average Nusselt number increases with increase in Reynolds number. The average friction factor decreases with increase in relative Reynolds number.

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