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CFD Analysis of Solar Air Heater by Using Combination of Triangular and Pentagon Ribs on the Absorber

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Abstract: ***Solar air heater are used to heat up the air and supply it to the place which is to be kept hot. In present work, a 3-dimensional CFD analysis has been carried out to study heat transfer and fluid flow behavior in a rectangular duct of a solar air heater with one roughened wall having combination of circular and square transverse wire rib roughness. The effect of Reynolds number, roughness height, roughness pitch, relative roughness pitch and relative roughness height on the heat transfer coefficient and friction factor have been studied. The main objectives of this work is to investigate the effect of flow and roughness parameters on average heat transfer and flow friction characteristics of an artificially roughened solar air heater having the combination of triangular and pentagon ribs on the absorber plate, to find out optimal configuration of triangular and pentagon sectioned transverse rib for heat transfer enhancement. And investigate the effect of roughness parameters on various thermal properties of SAH like Reynolds number, Nusselt number, heat transfer coefficient and friction factor in flow and compare the result with smooth plate***

Keywords: CFD Analysis, Absorber plate, Reynolds's No., Nusselt No

1. Introduction

Solar air heater is one of the basic equipment through which solar energy is converted into thermal energy. Solar air heaters, because of their simple designing, are cheap and most widely used as a collection devices of solar energy. The main applications of solar air heater are space heating, seasoning of timber, curing of industrial products and these can also be effectively used for curing or drying of concrete or clay building components. A conventional solar air heater generally consists of an absorber plate, a rear plate, insulation below the rear plate, transparent cover on the exposed side, and the air flows between the absorbing plate and rear plate. A solar air heater is simple in design and requires little maintenance. However, the value of the heat transfer coefficient between the absorber plate and air is low and this result in lower efficiency. For this reason, the surfaces are sometime roughened in the air flow passage.

Heat transfer enhancement is a subject of considerable interest to researchers as it leads to saving in energy and cost. Because of the rapid increase in energy demand in all over the world, both reducing energy lost related with ineffective use and enhancement of energy in the meaning of heat have become an increasingly significance task for design and operation engineers for many system. In the past few decades numerous researches have been performed on heat transfer enhancement.

2. Literature Review

Anil Singh Yadav and J.L.bhagoriya (2015) numerically analysed twelve different configurations of the two-dimensional incompressible Navier–Stokes flows through the artificially roughened solar air heater. MM Sahu, JL Bhagoria (2005) carried out an experimental investigation to study the heat transfer coefficient on absorber plate of a solar air heater. Jitesh Rana, Anshuman Silori, Rohan Ramola (2016) analysed solar air heater using artificial roughness. Ajeet Singh Kushawaha and Ravi Vishwakarma (2015) used CFD for studying heat transfer and fluid flow processes in an artificially roughened solar air heater. Prasad and Saini (1988) developed the relations to calculate the average friction factor and Stanton- number for the artificial roughness of absorber plate Many authors have worked for enhancement of efficiency of solar air heater. CFD is one of the best way to perform the detailed flow analysis of Solar air heaters.

3. Geometric Modeling and Meshing

A 3-dimensional model of the shape of a rectangular duct is developed for analysis of solar air heater. The geometry is created using ANSYS DESIGN MODELER. The physical dimension set to be 640 mm length, 100mm width, and 20mm height.

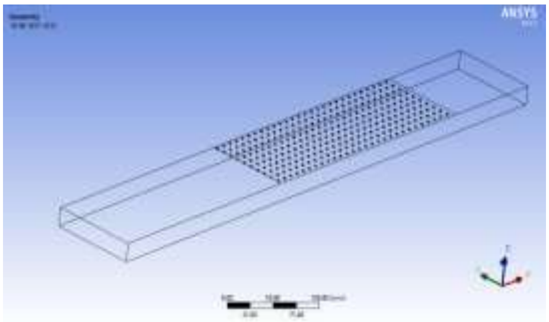

Figure 1: 3-D Domain SAH DUCT with combination of triangular and pentagon ribs on the absorber plate with P = 10mm

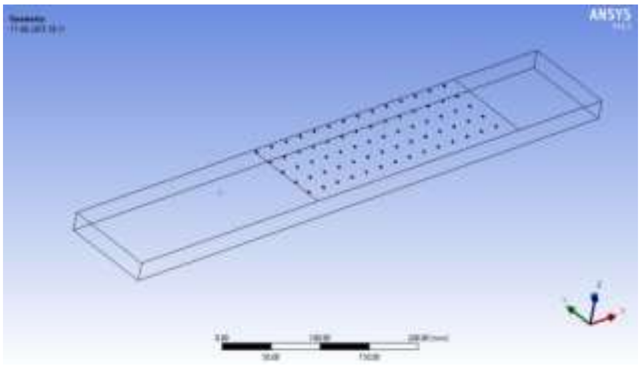

Figure 2: 3-D domain SAH DUCT with combination of triangular and pentagon ribs on the absorber plate with P = 20mm

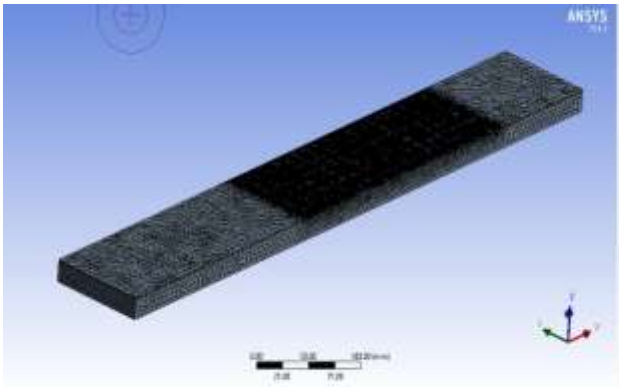

Figure 3: Plate-Triangular -Pentagon-e=2- , P=15

Table 1: Mesh Details

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

4. Results and Discussion

Airflow velocity, pressure and temperature profiles during forced-air flow over rib geometry in the duct which were obtained using CFD Post. The CFD analysis has been performed for combination of triangular and pentagon ribs on the absorber plate of SAH and result has been compared with the case of smooth duct operating under the same condition to evaluate the enhancement in heat transfer.

The analysis have been done using ANSYS FLUENT 14.5.

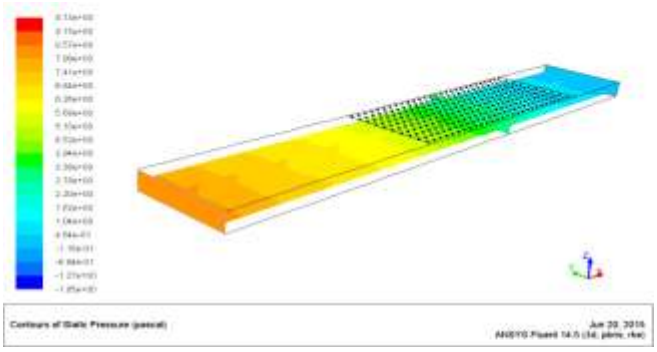

Figure 4: Plate-triangular-pentagon ribs-e=2-p=10-re-8000-pressure of the absorber plate

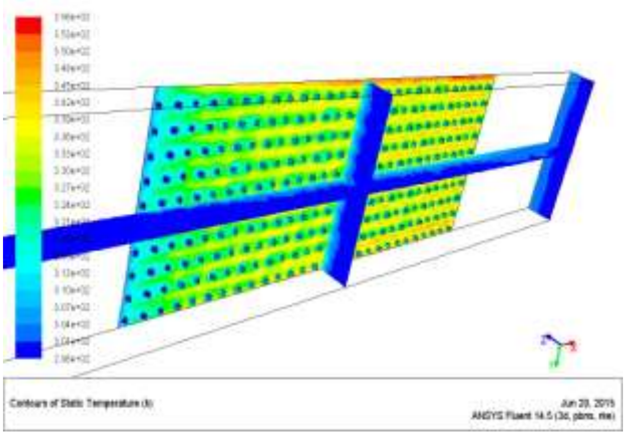

Figure 5: Plate-triangular-pentagon ribs-e=2-p=10-re-8000-temperature of the absorber plate

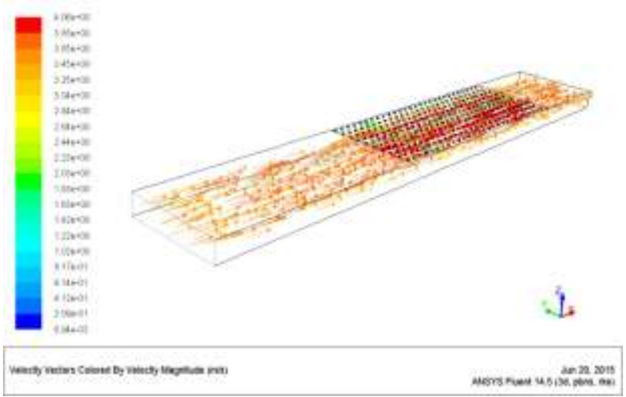

Figure 6: Plate-triangular-pentagon-e=2-p=10-re-8000 velocity -vector of the absorber plate

Higher pressure is observed at inlet of the domain. The pressure reduces gradually till the exit of the domain as seen in Fig. 4. The reason for this can be change of pressure head into velocity head. The temperature of the absorber plate increases from inlet to outlet for down side of plate also, as the air flows over it.

As seen in Fig. 5, higher value of temperature is observed in the zone having triangular pentagon ribs. The lower portion transfers heat at higher rate as compared to upper region.

Highest velocity vector is observed near the zones of triangular pentagon ribs which is also for velocity. The flow restriction leads to increase in the velocity vector of working fluid as seen in Fig.6..

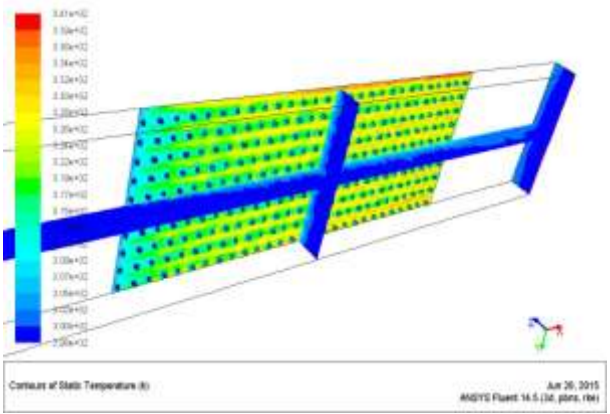

Figure 7: Plate-triangular-pentagon-e=2-p=10-re-12000 temperature of the absorber plate

As seen from Fig. 7, the temperature at top of the absorber plate increases from inlet to outlet. The temperature difference between inlet and outlet decreases with increase in Reynold's number. The reason for this is that air with high discharge takes away heat with it.

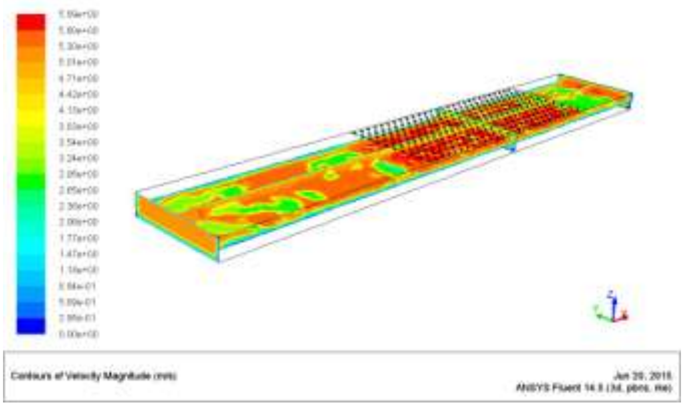

Figure 8: Plate-triangular-pentagon-e=2-p=10-re-12000-velocity of the absorber plate

Highest velocity of wind is observed in the zones of ribs because of restriction in the flow passage as seen in Fig. 8. Higher wind velocity magnitude is observed in all the zones.

With the further increase in Reynold's number, it is observed that the temperature difference further reduces. Static temperature increases from inlet to outlet as seen in Fig. 9.

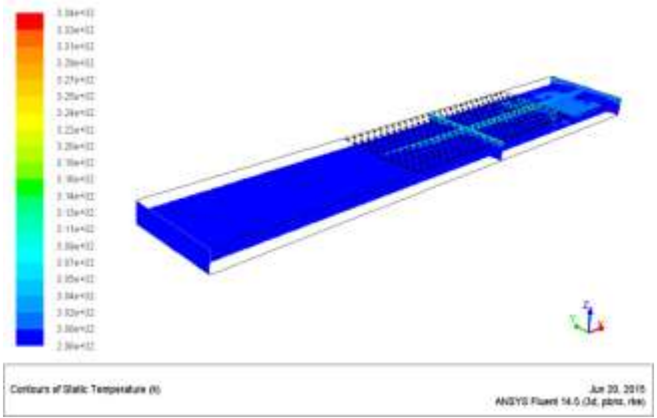

Figure 9: Plate-triangular-pentagon-e=2-p=10-re-15000 temperature of the absorber plate

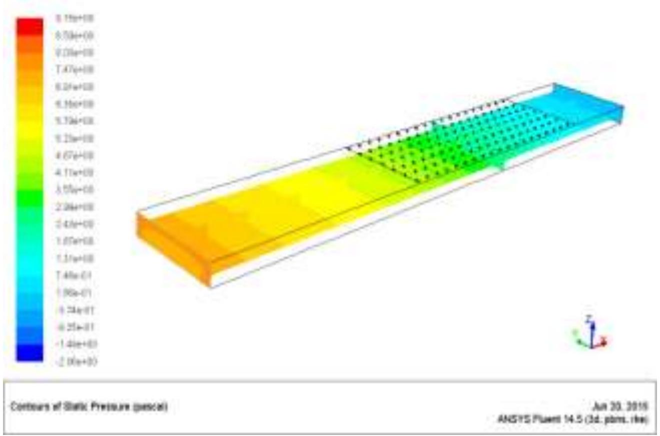

Figure 10: Plate-triangular-pentagon-e=2-p=15-re-8000-pressure of the absorber plate

As seen in Fig. 10, pressure decreases from inlet to outlet of the absorber plate. Variation in larger in the region of the ribs. Not much variation is observed on either sides of the ribs.With increase in roughness, pressure drop increases but the difference is little.

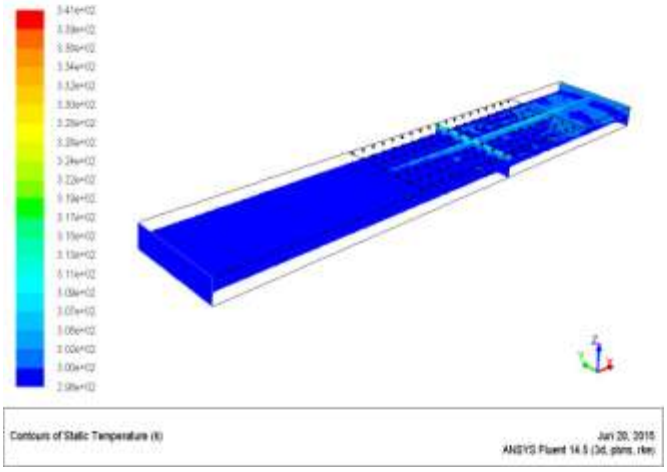

Figure 11: Plate-triangular-pentagon-e=2-p=15-re-12000-temperature of the absorber plate

As seen from Fig. 11 and 12, it is seen that the temperature drop decreases with increase in Reynold's number. But there is no temperature difference on increase in roughness of plate.

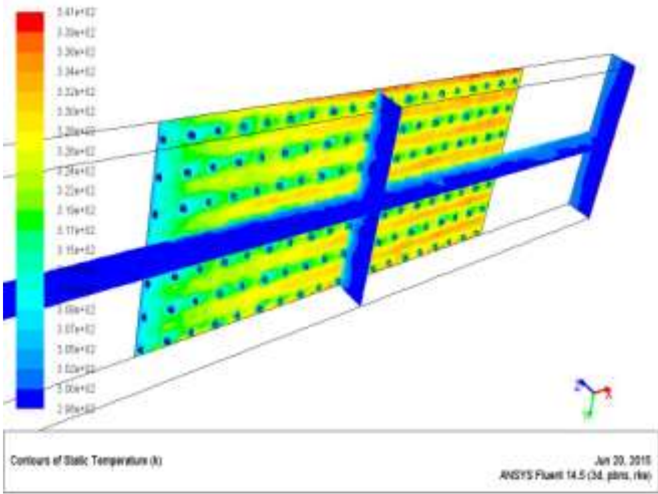

Figure 12: Plate-triangular-pentagon-e=2-p=15-re-12000-temperature of the absorber plate

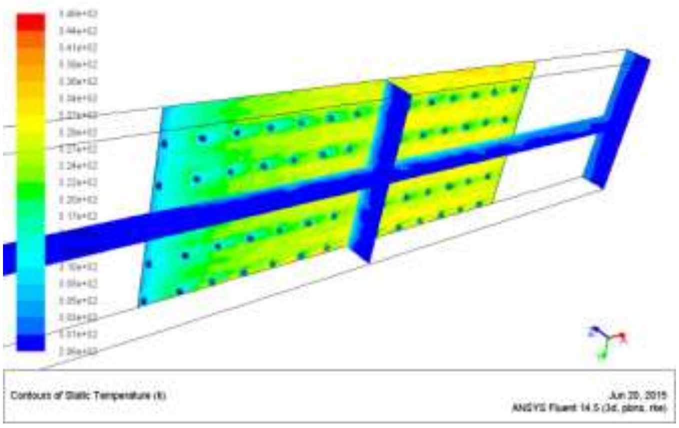

Figure 13: Plate-triangular-pentagon-e=2-p=20-re-12000-temperature of the absorber plate

It is observed that air leaving the domain has higher value than that at inlet. Temperature increases gradually. On increasing Reynold's number, the value of maximum temperature reduces because air takes away heat with it

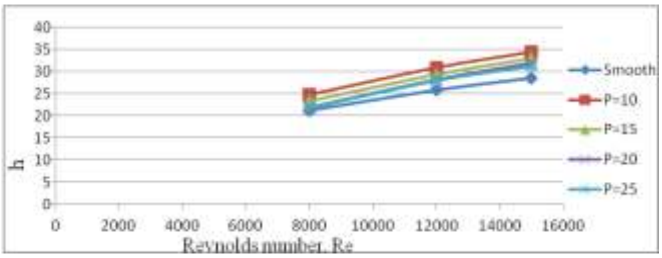

Figure 14: Re vs h

From Fig. 14 it is observed that for increasing roughness, heat transfer rate is high for same Reynold's number. For any specific roughness, heat transfer rate increases with increase in Reynold's number.

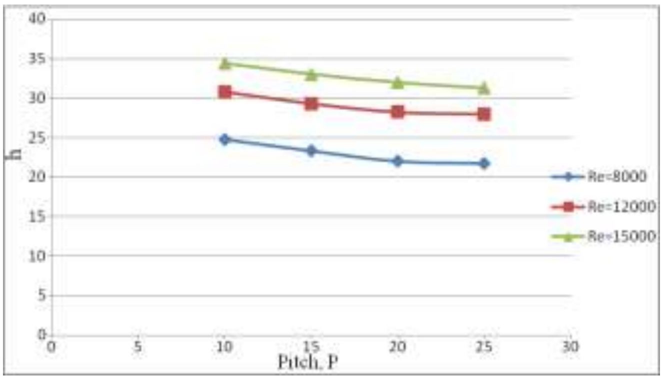

Figure 15: pitch vs h

It is observed from Fig. 15 that on increasing the pitch, heat transfer rate decreases for same Reynold's number.

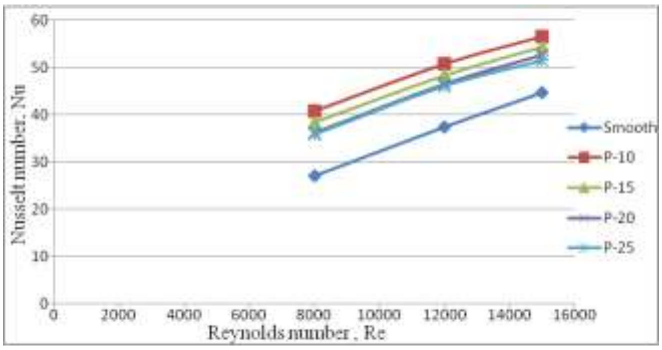

Figure 16: Re vs Nu

Table 2: Nusselt number enhancement ratio

e(mm)	*P(mm)*	*P/e(mm)*	*Re=8000*	*Re=12000*
2	10	5	1.163	1.193
2	15	7.5	1.096	1.135
2	20	10	1.034	1.092
2	25	12.5	1.022	1.083

The Nusselt number increases with increase in Reynolds number in all cases for fixed value of height. The Nusselt number decreases with increase in roughness pitch in all cases for fixed value of height. The friction factor decreases with increase in Reynolds number in all cases for fixed value of height. We can see maximum value of friction factor enhancement ratio has been found to be 1.872 times compared to smooth duct corresponds to height (e=2) and pitch (P=10, 15, 20, 25) at Reynolds number 8000 in the range of parameter investigated. The heat transfer decreases with increase in pitch in all cases for fixed value of height. Heat transfer increases with increase in Nusselt number and Reynolds number but decreases with increase in pitch.

It is also found out that maximum value of Nusselt number enhancement ratio is 1.5063 times as compared to smooth duct corresponds to pitch (P) of 10 at Reynolds number 15000 in the range of parameter investigated.

5. Conclusion

CFD is one of the best way to perform detailed flow analysis of solar air heater without preparing experimental setup. On increasing the roughness of the absorber plate, efficiency of solar air heater increases. On increasing the Reynold's Number, lesser temperature of absorber plate at exit is observed. Increase in pitch also leads to reduction in heat transfer.

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