CHAPTER-6

CONCLUSION
6. CONCLUSIONS

Research work has been carried out using the model of a solar air heater with simulated atmospheric conditions in the laboratory. The triangular protrusions are provided over the surface of the absorber plate to act as artificial roughness which helps to enhance the overall performance of solar air heater. After validating the experimental setup by using smooth aluminum absorber plate experiment is repeated using the plates provided with artificial roughness elements. During the course three roughened absorber plates with varied apex angle of the triangular protrusions, i.e., 30°, 45°, 60°. It is observed that the thermo-hydraulic performance and the heat transfer rate of the apparatus are significantly improved when the plate with 45° triangular protrusions is used. The plate having protrusions with an apex angle of 60° is found to be yielding results less than the former by small amount, while the plate with protrusions having an apex angle of 30° yield the lowest values of heat transfer rate and thermo-hydraulic performance among all the three roughened plates. However, it can be noticed that the heat transfer rate and thermo-hydraulic performance has considerably been increased when roughened plates are used instead of smooth absorber plate. The conclusions drawn from the experimental results obtained are:

- The Nusselt number value increases with increase in Reynolds number. It can be noticed that maximum Nusselt number values are obtained for the plate with 45° apex angle protrusions at all
possible values of Reynolds number. For the $45^\circ$ plate, the maximum Nusslet number value is 109 and the average Nusselt number value is 102. The maximum Nusselt number is 42% higher than that of the smooth plate while the average value of the Nusselt number is 60% higher than that of the smooth plate. The maximum and average Nusselt number values for $30^\circ$ plate are 99 and 82 respectively and for the $60^\circ$ plate are 99 and 81 respectively.

- The Nusselt number is more for the roughened plates when compared to the smooth plate. This is because of the triangular protrusions. The triangular protrusions increase the turbulence of the air flowing inside the duct. Also the surface area of the roughened plate is more compared to smooth plate which helps in achieving more heat transfer. The reason why the $45^\circ$ roughness elements plate yield more heat transfer and thermo-hydraulic performance is due to the symmetry of the elements in alternate rows, which helps utilizing all the roughness elements to destroy the laminar sub layer effectively and create maximum turbulence inside the duct.

- It is observed that the friction factor value decreases with increase in Reynolds number. The value of the friction factor is observed to be almost the same for all the plates with different roughness elements used. But the friction factor value of the absorber plates with roughness elements is higher than the corresponding values
of the smooth plate. The maximum value of friction factor for the roughened absorber plate is $6.7 \times 10^{-3}$ which is obtained for the $45^0$ plate while the corresponding friction factor value of the smooth absorber plate is $5.4 \times 10^{-3}$.

- Friction factor is used to determine how good the artificial roughness elements provided on the surface of the absorber plate acting as roughness to create turbulence in the air flowing through the duct. The $45^0$ roughness elements are proved to be good in this case too. This is because the $60^0$ roughness elements when compared to the $45^0$ roughness elements provides less turbulence. The $30^0$ roughness elements are bigger than the $45^0$ roughness elements which results in decrease of mass flow rate when $30^0$ roughness elements plates are used. However, all the plates yield better friction factor value compared to the smooth plate which implies that the roughened plates have high heat transfer rate compared to the smooth plate.

- The thermo-hydraulic performance is observed for the $45^0$ absorber plate with a maximum value of 1.73 and an average of 1.51. The thermo-hydraulic performance is least for the $60^0$ absorber plate which has a maximum value of 1.2 and the average value is 1.17.

- From the above discussion, it can be inferred that, for every unit of friction factor for the roughness elements provided on the
absorber plate, the enhancement of heat transfer is maximum for the plate with 45° protrusions, provided that all other design parameters remain same for all the three types of roughness elements.

- Along with experiment, the apparatus is simulated in a virtual CFD environment to determine the temperature and velocity field to examine their distribution along the surface of the plate as well as the cross section of the duct. This may help in understanding the effect of providing protrusions in effecting the heat transfer at the flow of air.

- Using MATLAB software, Correlations have been determined to find out combined effect of various parameters on the Nusselt number and friction factor.

\[ \text{Nu} = (\text{Re})^{1.1853} (\text{Pr})^{19.3005} (\text{Tan } \alpha)^{-0.0955} \]

\[ f = (\text{Re})^{0.1961} (\text{Tan } \alpha)^{0.0040} \]

These correlations are the functional curves which aid in finding the Nusselt number and frictional factor for any values of independent parameters without doing the experiment.
Scope of Future Work

- The work can be extended by using protrusions having value of angle of attack other than 30°, 45°, 60°.
- The roughness on the plates can also be made by processes other than milling like cast elements, pressed elements, soldering extruded elements etc.
- The research can be done by varying parameters other than angle of attack like P/e Ratio, e/Dh, Ratio of triangular elements.
- The present work can be useful for research using elements similar to protrusions like pyramidal elements, tetrahedral elements, pin type conical elements etc.
- It is possible to use the experimental results of this work for Computational Fluid Dynamic simulation. CFD study makes the work simple and helps in studying the effect of change in any parameter used for design of triangular protrusions without physical models.
- Mathematical Correlations have been developed. These equations may be further modified using physical models of Triangular or other elements.