ANALYSIS OF SOLAR AIR HEATER HAVING DIFFERENT TYPES OF RIBS TO INCREASED HEAT TRANSFER INSIDE THE SOLAR DUCT

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***Abstract*: In order to increase the efficiency of the system or to increase the heat transfer inside the solar air heater, here in this work, experimental analysis of solar air heater was done and measure the value of temperature at different conditions after doing the experimental work on flat plate collector solar air heater. Different types of ribs were used inside the solar air heater to create turbulence near the absorber plate that is at the top face of solar air duct. For analyzing the effect of different shapes of ribs used inside the solar air heater, here in this work it considered four different types of ribs that are rectangular, triangular, circular and hexagonal. With each shape of ribs, effect of change in Reynolds number was also analyzed. For measuring the heat transfer enhancement here it calculates the value of Nusselt number and for pressure drop it calculates the friction factor. Ansys Fluent model was used to analyze the flow behavior of air inside the solar air heater and temperature distribution throughout the duct.**

***Keywords:* Solar air heater, heat transfer, ribs, Nusselt number and friction factor**

1. Introduction

Presently, solar thermal systems are the most economical solar utilization technologies on a large scale. Solar thermal collector or solar collectors is a device which is used for the utilizing the solar energy. Solar collector is special type of heat exchanger that converts the incoming solar flux into the internal energy of the fluid that is used as a transport medium. Solar collector is the main component of the any solar utilization system. In a solar collector, the incoming solar flux is absorbed by the absorber plate and converted into heat energy that is then next transferred to the circulating fluid (usually air or water). The circulating fluid flowing through the collector acts as a transport medium. The converted heat energy from the circulating fluid can be directly used to heat the water or space conditioning or it can be stored in a proper thermal storage tank from which it can be used in nights or during rainy or unclear days. Solar collectors can be broadly classified into two type's namely non-concentrating and concentrating collectors. A non-concentrating collector has same aperture area for receiving and absorbing solar flux, whereas in case of concentrating solar collector, concave aperture surface is used to receive and focus the solar flux to a smaller absorbing area, thereby increasing the amount of radiation for the same area of collector.

Solar air heater are basically used to utilized the solar energy, so in order to increases the efficiency and heat transfer rate of the system different types of geometrical modification was done by researchers. In order to further increase the efficiency of solar air duct, here in this work different types of ribs where used to increase the efficiency of the system. For analyzing the effect of different shapes of ribs, here in this work four different shapes (square, equi-triangular, hexagonal and circular) of ribs were used. For analyzing the effect of different shape of ribs it calculate the value of Nusselt number and friction factor for different ribs at different Reynolds numbers. After validating the CFD model of solar air heater, it analyzed the effect of different types of rib used in solar air heater. The CFD analysis of solar air heater for different ribs is shown in the below section.

2. Development of CFD model

In order to perform the CFD analysis of solar air heater, here in this work it first develops the CFD numerical model of solar air heater. For developing the CFD model following steps were taken out.

2.1 Development of solid model

First, it develops the solid model of solar air heater on the basis of geometric parameters given in the base paper.

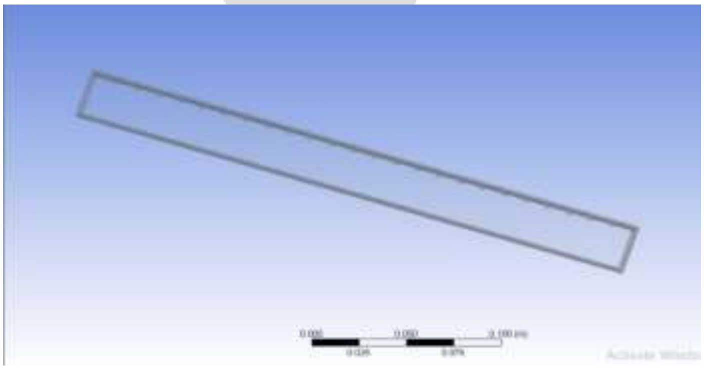


Fig. shows the solid model of solar air heater section used during numerical analysis

The geometric parameters used to develop the solid model of solar air heater is Length-1000 mm, Width-300 mm, height-25 mm, Roughness height of square ribs-2 mm, Roughness Width of square ribs- 2 mm. On the basis on above mention geometry solid model of solar air heat were developed. The solid model of solar air heater used for the numerical analysis is shown in the below fig.

2.2 Meshing

During meshing, the complete solid model of solar air heater gets discretized in to different number of nodes and element. In order to obtain optimum level of number of nodes and elements, solar air heater were discretized with different number of nodes and elements and for each case it calculates the value of Nusselt number. Meshing of solar air heater is shown in below figures.

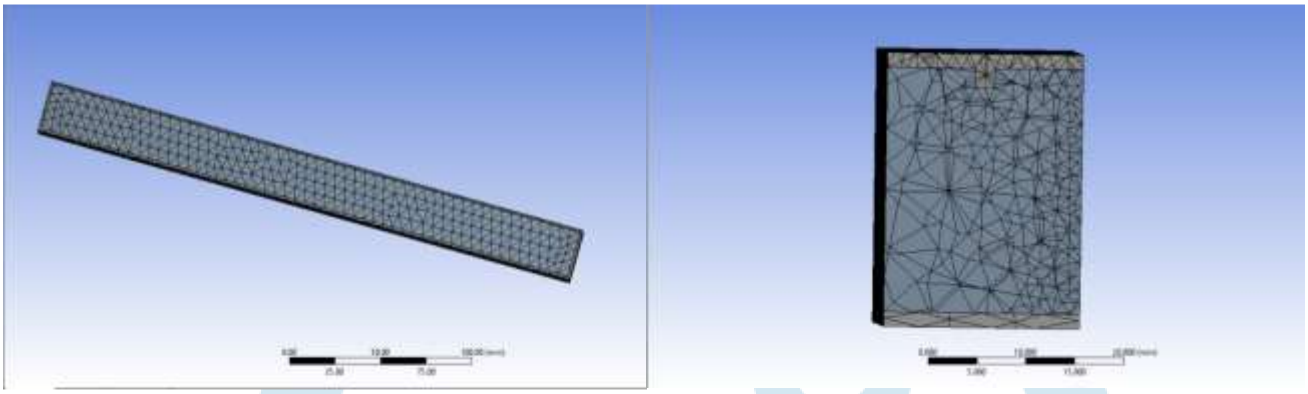


Fig. Meshing of solar air heater

2.3 Boundary Condition

Initially for validating the CFD model of solar air heater with the base paper same boundary conditions were applied. Here in this analysis five different Reynolds number were used to analyze the effect of change in velocity of air on heat transfer. For analyzing the effect of change in velocity it considered 3000, 6000, 9000, 12000 and 15000 Reynolds number and measure value of Nusselt number. 1000 W/m^2 heat flux is applied on the roof top surface of solar air heater and other side of solar heater is considered as a thermal insulator.

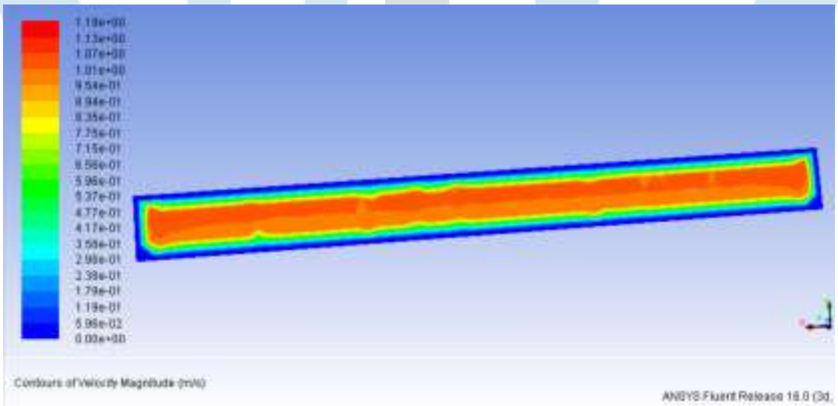


Fig. Velocity contours for Re = 3000

3. Validation of Numerical Model

For validation of CFD model of solar air heater, value of Nusselt number for different Reynolds number calculated through CFD analysis were compared with the value of nusselt number obtained from base paper at same Reynolds number.

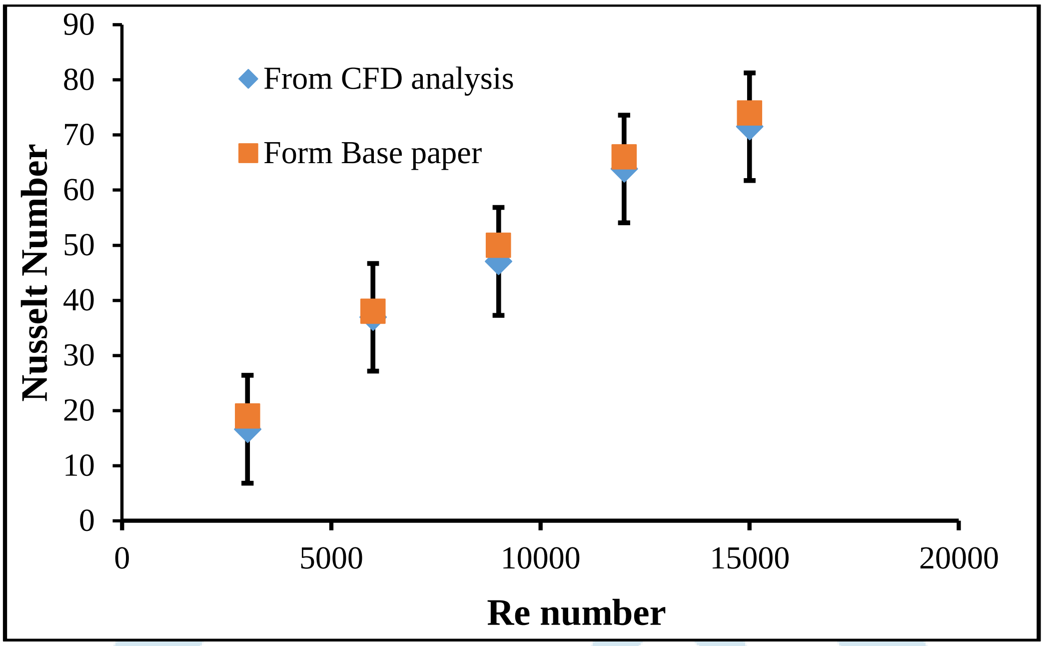


Fig. shows the comparison of value of Nusselt number for different Reynolds number

For calculating the friction factor for solar duct having different roughness following mathematical relation where use. For examine the value of Darcy friction factor (f) following mathematical calculation where used. The mathematical equation used for calculating friction factor

$$f = \frac{2\,\Delta P\, D_H}{L\,\rho\, u^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where ΔP is the pressure difference at the inlet and outlet of the solar duct, D_H is the hydraulic mean diameter, L is the length of solar duct computational zone, ρ density of air and u is the velocity of air at inlet. With the support of eq. 1 we can calculate the value of friction factor for different Re numbers. For validating the CFD analysis of solar air heater having the square rib, it calculates the value of friction factor, for calculating the friction factor for different Reynolds number first it calculates the value of Pressure drop inside the solar duct through CFD analysis and then analytically calculates the value of friction factor.

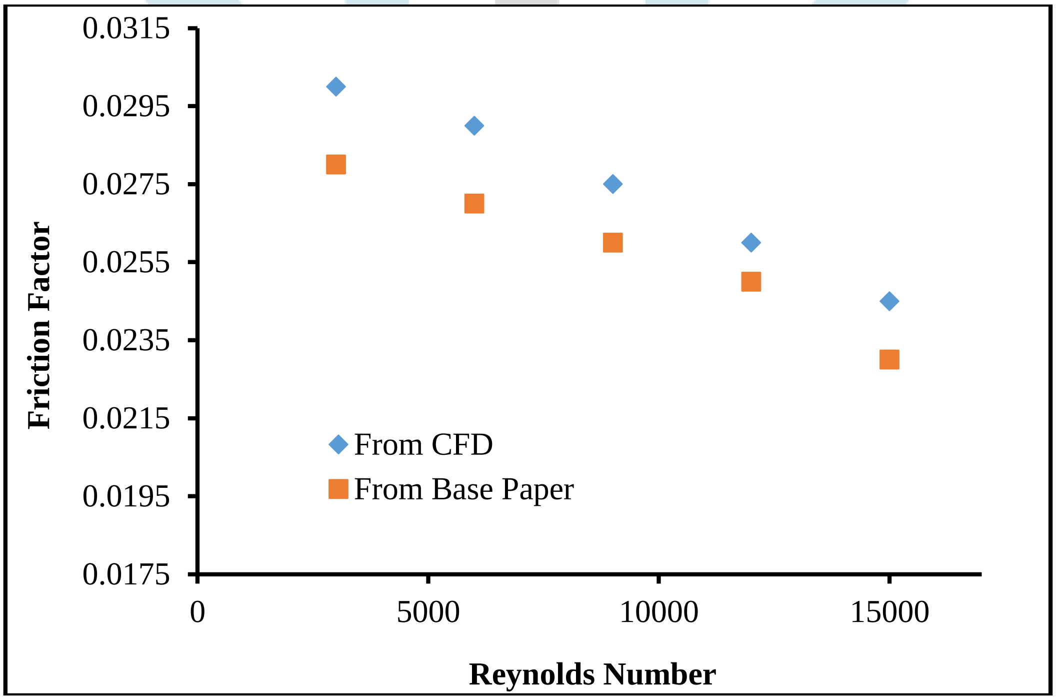


Fig. Comparison of friction factor for different Reynolds number

4. Effect of different shapes of ribs

In order to increase the heat transfer rate from solar air heater different shapes of ribs used inside the solar air duct and calculates the value of Nusselt number and friction factor. Equi-triangular ribs are used for increasing the efficiency of the solar air heater.

The cross sectional of triangular ribs is same as of square ribs. The solid model of solar air heater having triangular ribs is shown in the below fig.

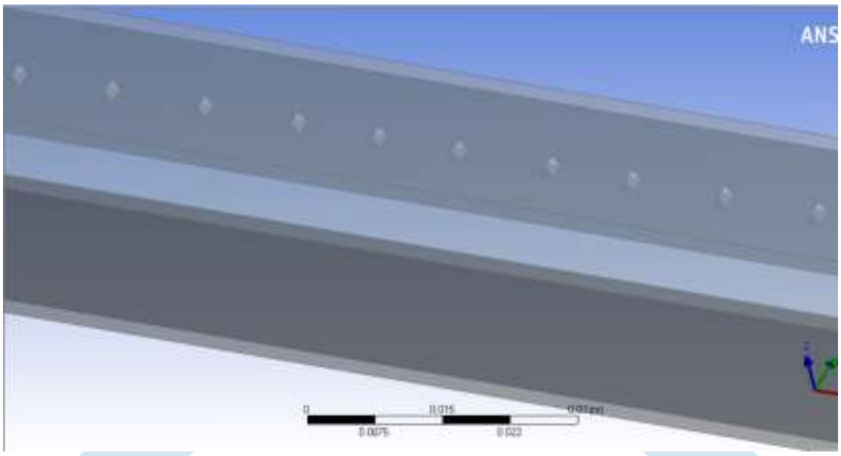


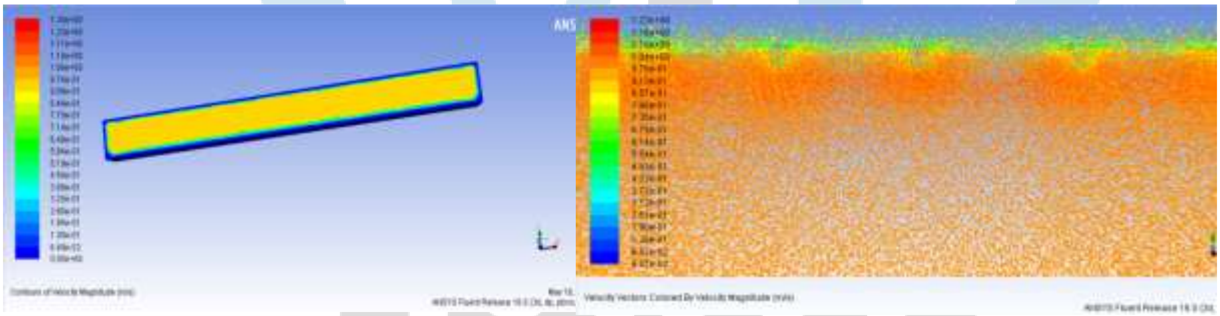
Fig. close view of solid model of solar heat exchanger having triangular ribs

For performing the CFD analysis of solar air heater having triangular ribs the geometrical dimension of solar heater is remain same as considered for solar heater with square rib. The boundary conditions were also remaining same and it calculates the value of Nu and friction factor for different Reynolds number. After applying the different boundary condition are calculates the value of Nu number numerically. The velocity magnitude contour for 3000 Re number is shown in the below fig.

Fig. velocity contour of solar air heater having triangular ribs

5. Comparison of Different Ribs

For analyzing the performance of solar air heater having different shapes of ribs here it compare the value of Nu number and friction factor for different ribs at different Re numbers. The comparison of different types of rib used in solar air on the basis of Nusselt number is shown in the below table.



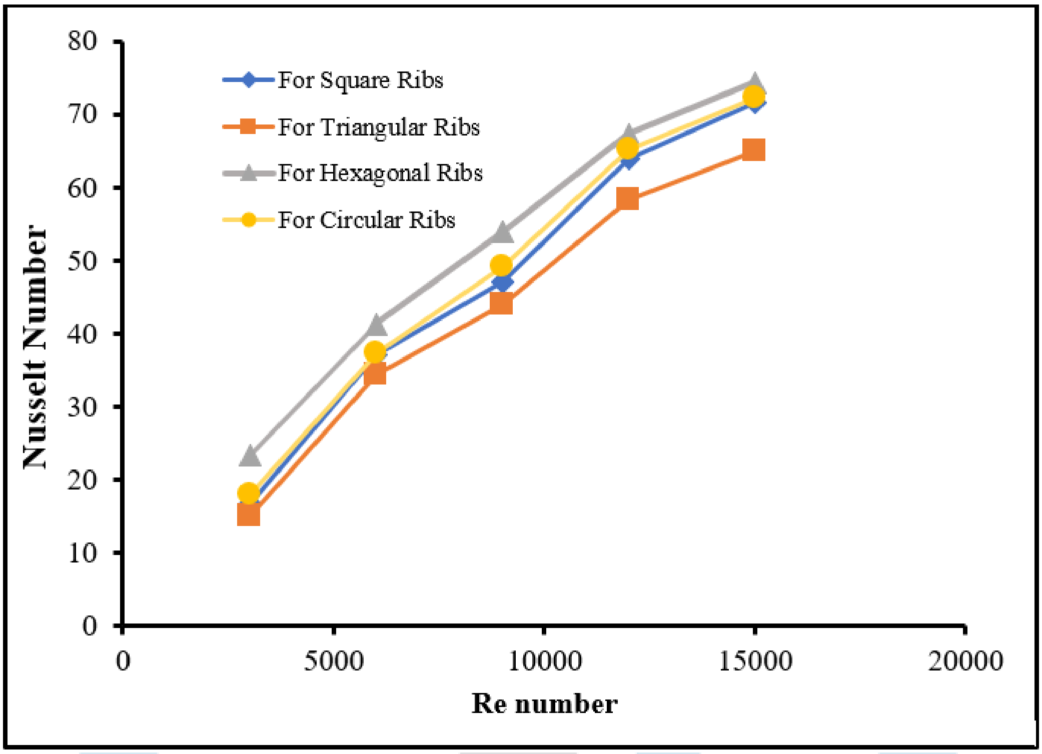


Fig. Comparison of Nu number for different shapes of ribs at different Re numbers

After comparing the value of Nu number for different shapes of ribs used in solar air heater, it also compares the value of friction factor for different Reynolds number. The comparison of friction factor values for different ribs are mention in the below table.

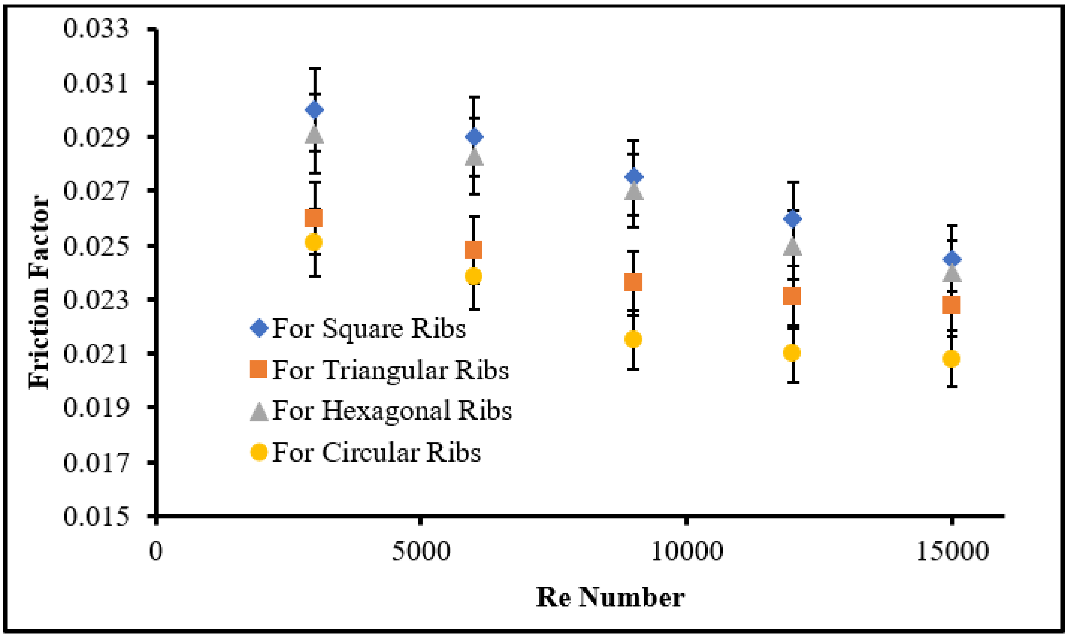


Fig. Value of friction factor for different Reynolds number

From above graph it is found that square shape ribs shows the maximum pressure drop inside the duct, which means that it is having higher friction drop as compare to other ribs. For hexagonal ribs the pressure drop is less as compare to square ribs and higher as compare to triangular and circular ribs. Though the pressure inside the solar air heater for hexagonal is higher as compare to circular and triangular ribs, but heat transfer inside the solar duct is also much higher for hexagonal shape ribs as compare to other ribs. Due to turbulence the heat transfer from solar duct to air get increased. With hexagonal ribs inside the solar air heater, it is found that near ribs there is lot of velocity variation in air, which means that there is turbulence near the ribs. Due to high turbulence inside the duct with hexagonal ribs, Nusselt number inside the duct is higher which means that heat transfer get enhance. As compared to all ribs hexagonal ribs shows the maximum heat transfer inside the solar duct.

6. Conclusion

Through analysis it is found that, ribs inside the solar air heater generates turbulence neat to the upper absorber plate of solar air heater on which solar radiation is falling. For solar air heater it is also necessary to have less pressure drop inside the duct, so the friction factor inside the duct must be measured for each rib at different Reynolds number. The pressure drop inside the duct is much higher for rectangular ribs as compared to other ribs, whereas hexagonal ribs shows less pressure drop inside the duct. Though the pressure drop for hexagonal ribs is higher for hexagonal ribs, but as compared to pressure drop heat transfer is much higher for hexagonal ribs.

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