Enhancement of heat transfer in the convex shape roughened absorber of solar air heater duct

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***Abstract*: In this work ribs were places inside the convex shape solar air heater. For analysing the effect of different pitch ratio, four different pitch geometry was analysed numerically using ANSYS Fluent. Through CFD analysis 30 mm pitch shows the maximum heat transfer as compared to other pitch. Effect of different shapes of ribs on heat transfer was also analysed, for that four different shapes of ribs was considered. Rectangular, triangular, right angle triangular and trapezoidal shapes of ribs was considered during the CFD numerical analysis. In the triangular shape of ribs shows the maximum heat transfer rate. It also analysed the effect of change in heat flux on absorber plate and measure the value of Nusselt number and heat transfer enhancement factor for each case in each type of solar air heater design.**

***Keywords*: solar air heater, ribs, pitch, thermal performance**

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 air heaters are basically used to utilized the solar energy in different application. Since last two decades immense research is going on to enhance the performance of solar air heater. Convex and concave shapes solar air heater is the new concept for enhance the performance of solar heater. Very few works are carried out in this area so far, some of the researcher have done work on natural convection at different inclination angle of convex and concave shape profiles. In natural convection solar air heater, heat transfer mainly due to convection whereas heat transfer through radiation is avoided. With the used of chimney effect natural convection solar air heater performance get increase. Up to our knowledge nobody has done the forced convection study on convex solar air heater. Here in this work, it studied the performance of convex shape solar air heater under forced convection. To study the behavior of flow and heat transfer with respect to change in Reynolds number inside the heater four different Reynolds number was considered during the analysis that is 2000, 3000, 4000 and 5000.

For further improvement of solar air heater in forced convection ribs were placed on absorber plate to modify the flow behavior of air so that heat transfer inside the solar air heater get enhanced. Here in this work four different pitches were considered to analyzed the effect of change in pitch on heat transfer during forced convection. After analyzing the effect of change in pitch, effect of different shapes of ribs were also study under forced convection. For studying the effect of change in shape of ribs four different shapes of ribs was considered during the work that is rectangular, triangular, right angle triangle and trapezoidal.

2. Solid Model of Solar Air Heater

As inclined flat plate collector solar air heater was considered first, solid model of flat solar air heater was made fist. The geometric conditions that are used for the construction of solid model is mention in the below table.

Table.3.4: Geometric parameters of flat solar air heater

Geometric parameters	Value
Absorber plate length (mm)	1100
Chimney height (mm)	2000
Width of chimney (mm)	102
Gap in between absorber plate and glass sheet (mm)	102
Inclination angle (degree)	45

Base on the geometric conditions mention in the above table, solid model of solar air heater was made. He schematic diagram of flat inclined plate solar air heater is mention in the below fig. schematic diagram shows the inlet and outlet conditions of air. It also shows the absorber and glass sheet plate.

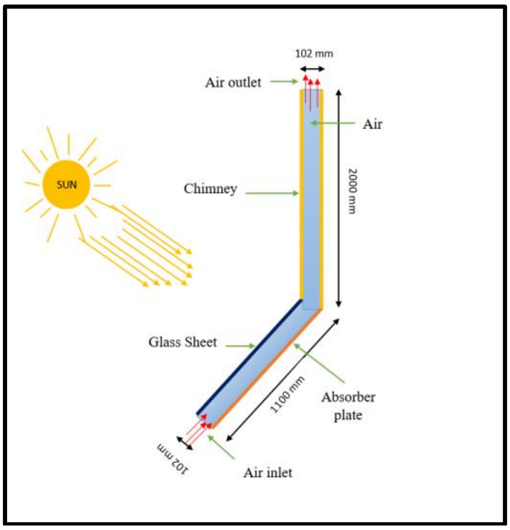

Fig: Shows the schematic of flat inclined plate solar air heater

3. Meshing

After developing the solid model of solar air heater, discretization of solid model is done. For performing the numerical analysis of solar heater, it is necessary to discretized the complete body in to number of nodes and elements. For finding the optimum value of number of nodes and elements, solid model of solar heater is discretized with different numbers of node and elements using different tools. The mesh used during the numerical analysis and validation of flat inclined plate solar air heater is shown in the below fig.

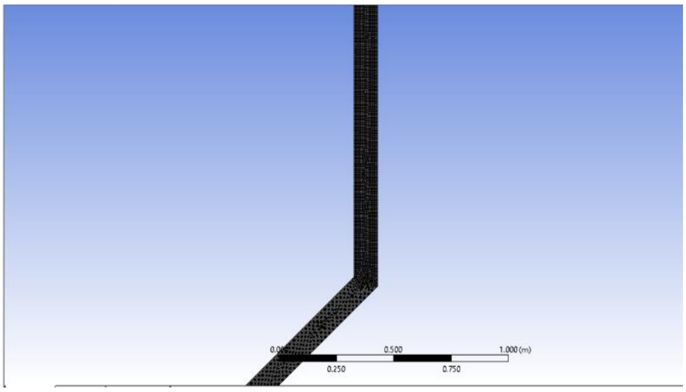

Fig. Mesh of flat inclined plate solar air heater

4. Boundary conditions

For performing the CFD analysis of solar air heater K-epsilon standard wall function model was considered. Same model of analysis was also considered by singh et.al. As natural convection is responsible for the flow of air, so at the inlet of air pressure inlet condition was given. At the outlt of solar heat exchanger pressure outlet conditions was mention. Different heat flux was applied at the absorber plate of solar air heater, basically for analyzing the effect of different heat flux on absorber plate four different flux was considered that are 500, 700, 900 and 1100 W/m^2. Through glass sheet heat transfer form the system was considered only through natural convection and 5.7 heat transfer coefficient was applied on the glass sheet.

5. Validation of CFD

For validating the CFD analysis of incline flat plate solar air heater, same boundary conditions were considered during the numerical analysis was considered by Gilani et.al [1] and calculates the value of Nusselt number at different heat flux. Compare the value of Nusselt number with the value obtained through experimental analysis done by Gilani et.al [1]. The value of nusselt number and velocity-pressure contours at different heat flux for flat inclined solar heater is shown in the below fig.

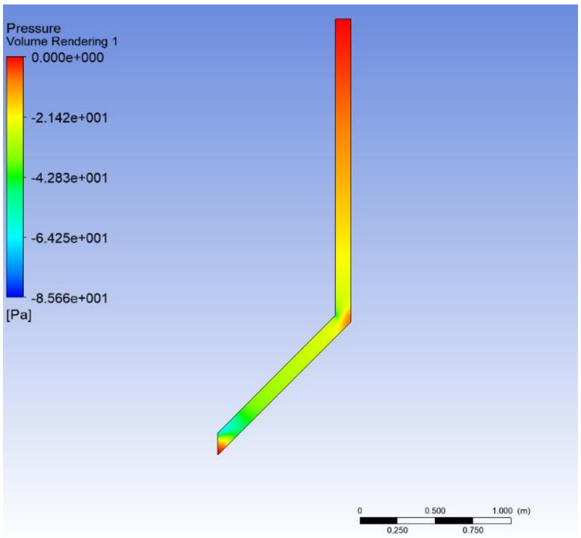

Fig. Pressure variation inside the solar duct at 500 W/m^2 heat flux condition

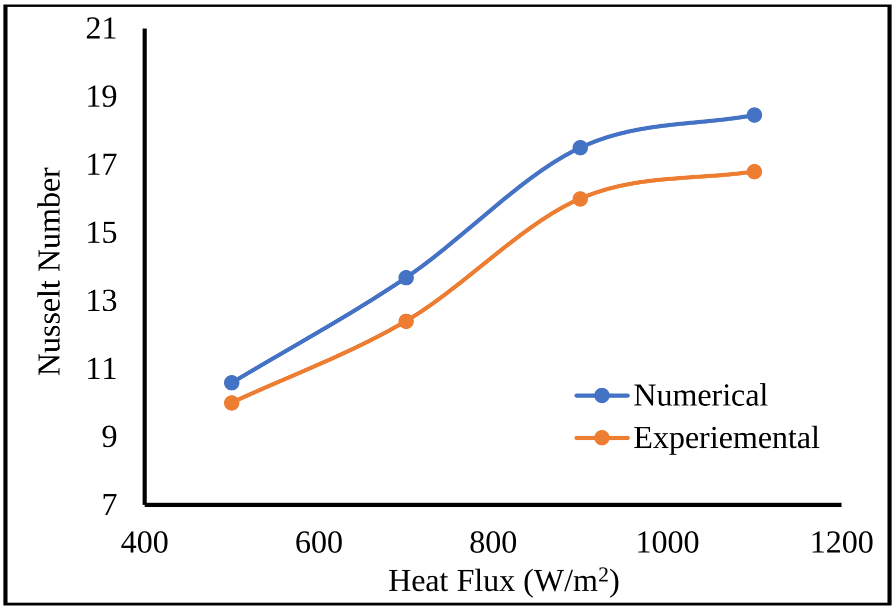

Fig. Comparison of value of Nusselt number for flat incline solar air heater

From the above graph, it is found that the value of Nusselt number calculated from the numerical analysis at different heat flux is close to the value of Nusselt number obtained through experimental analysis performed by Gilani et.al. hence the numerical analysis of flat inclined plate solar air heater is correct.

6. Effect of different shapes of ribs

For analyzing the effect of different shapes of ribs, four different shapes of ribs were analyzed in this work. In each case of shapes of ribs effect of different heat flux was also analyzed and measure the value of Nusselt number for each case. Boundary conditions were remained same for each case of analysis as considered in the above cases. For analyzing the effect of different shapes of ribs on solar air heater 30 mm pitch was considered for all the geometries.

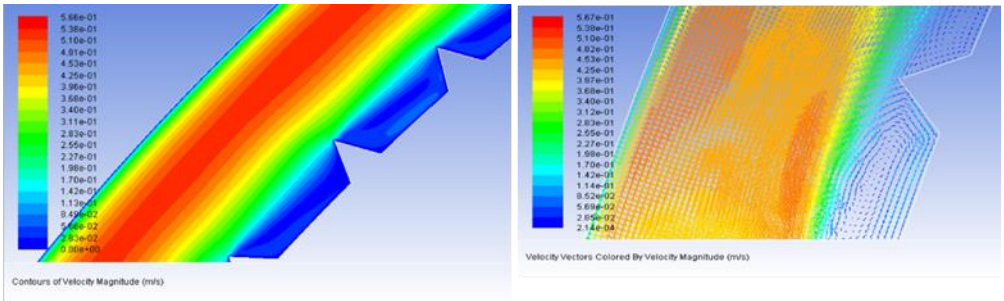

Fig. Shows the velocity vector for triangular ribs

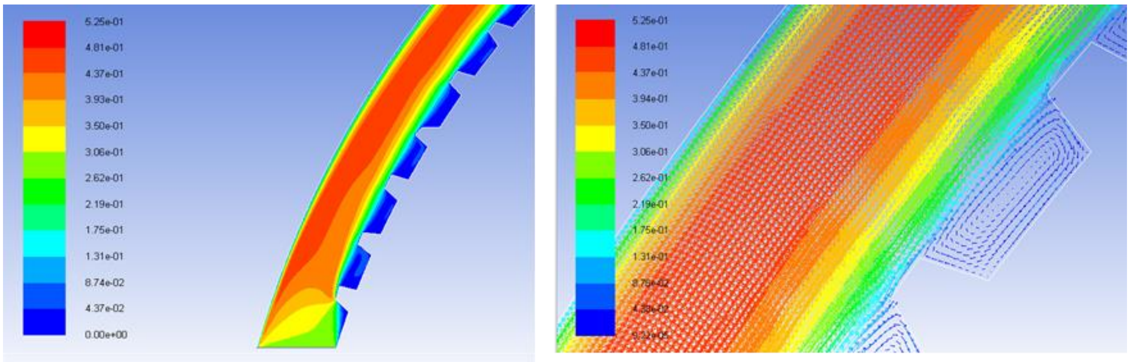

Fig. Shows the velocity vectors variation inside the solar air heater with trapezoidal shape of ribs

For calculating the HTEF (heat transfer enhancement factor) following calculation was done

$$HTER = \frac{Nu_{at\ different\ Pitch}}{Nu_{simple\ convex}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$Nu_{pitch\ ratio}$ is the Nusselt number for different pitch geometry under forced convection, whereas $Nu_{simple\ convex}$ is the value of Nusselt number for simple convex shapes solar air heater under forced convection condition.

7. Comparison of different shapes of ribs

After numerically analyzing the solar air heater having different shape of ribs, comparison was done on the basis of heat transfer enhancement factor (HTEF) at different heat flux. The value of HTEF for different shapes of ribs was shown in the figure.

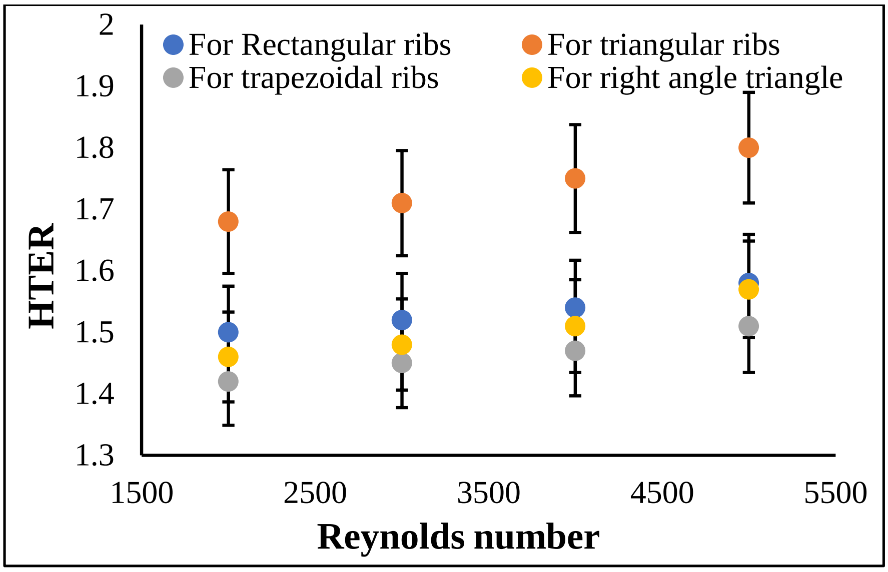

Fig. shows the enhancement of heat transfer for different shapes of ribs compared to simple convex solar heater under forced convection

From above fig. it is found that, solar air heater with triangular shape of ribs shows the maximum value of HTER, which means that it shows the maximum heat transfer capacity as compared to other shapes of ribs. Through CFD analysis of solar air heater it is found that under forced convection the performance of solar heater at different pitch and different shapes of ribs is much higher as compared to solar air heater under natural convection. From fig. it is also found that triangular and rectangular shapes of ribs show the marginal difference whereas trapezoidal, rectangular and right-angle triangular ribs show the large difference in terms of HTER and Nusselt number as compared to triangular shapes of ribs.

8. Conclusion

Convex shape solar heater having ribs inside the duct under forced convection shows significant improvement in heat transfer in each case of pitch as compared to simple convex shape solar air heater. It means that with the use of ribs the heat transfer from the duct is much higher than the without ribs duct. Solar air heater having 30 mm pitch shows the optimum condition for heat transfer. With 30 mm pitch, effect of different shapes of ribs was also analysed and it is found that convex shape solar air heater with each case of different shapes of ribs, heat transfer is more as comparted to without ribs solar air heater under forced convection. From analysis it is concluded that solar air heater having triangular ribs with 30 mm pitch shows the maximum heat transfer as compared to other geometric conditions.

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