CFD ANALYSIS OF CONVEX SHAPE SOLAR AIR HEATER WITH QUARTER CIRCULAR SHAPE RIBS

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***Abstract*: For the increment of heat transfer from solar air heater, since last many decades' researcher is optimizing the different parameters and also using the different mechanisms to enhance the heat transfer from heat sink. In the same order heat this work effect of use of quarter circular shape rib inside the convex shape solar air heater was performed. The thermo-hydraulic analysis of convex shape solar heater with different pitch and arrangement of quarter circular ribs was analysed. Here in this work first the CFD analysis of convex solar air heater was performed and validated with the previous published experimental data. After validating the CFD model of solar heater, effect of different pitch in between quarter circular shape ribs was analysed. For analysing the effect of different pitch in between the ribs four different pitch was considered that is 50, 60 70 and 80 mm. In each case of analysis Nusselt number, pressure variation, velocity variation throughout the duct and Heat transfer enhancement factor was calculated.**

***Keywords*: Solar air heater, ribs, quarter circular shape, performance, Heat transfer enhancement factor**

1. Introduction

Air heating of solar defined as thermal tools from solar in which the potential starting to the stellar, insolation, has been arrested through a fascinating path that is utilized to warmth air. Stellar air warming is a potential of environment warming tools utilized to warmth as well as circumstance of air for constructions or development of hotness submissions. It is characteristically the maximum charge operative from each of the stellar tools, particularly in profitable with engineering requests, as it reports the prime practice of constructing potential in warming weathers, which is like heating of planes with method warming of the firms. Air radiators of solar are methods that assemble stellar dynamism with transfers the warmth to transient air, which is moreover deposited as well utilized for portions reheating. The accumulators were repeatedly gloomy to engross extra stellar drive with a resistive substance, a lot of material, turns likewise exchanger of heat. There have been several altered projects with structures might comprises blowers to upsurge the stream amount of air. For enhancing the heat transfer from convex shape solar air heater, here in this work quarter circular shape of ribs was placed on the absorber plate. In this work effect of different pitch in between ribs was analysed, for that it considered four different pitches that is 50, 60, 70 and 80 mm. It also analysed the effect of different set of arrangement of ribs inside the solar duct on the performance of solar air heater. For that is considered four different arrangements during the CFD analysis of solar heater at constant pitch. For each case of CFD analysis in this work it calculates the value of Nusselt number and heat transfer enhancement factor. It also analysed the velocity and pressure variation for different geometries of solar heater at different heat flux. For analysing the effect of different heat flux, it considered five different heat flux that are 500, 600, 700, 800, 900, 1000 and 1100 W/m^2. 5 mm radius quarter circular was considered as a rib in this work.

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.1 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.

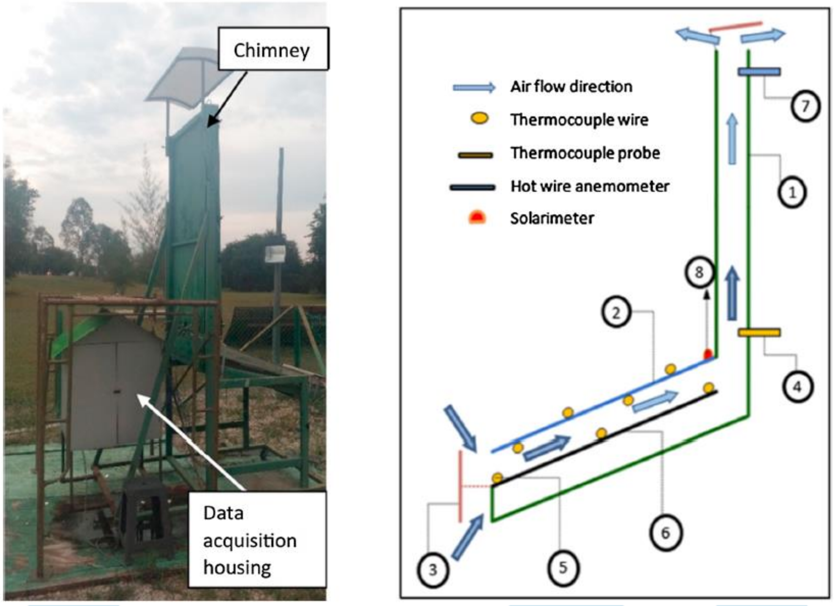


Fig.2 Experimental setup used by Gilani et al. (5)

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 discretize 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 belowFig.4.3 Mesh of flat inclined plate solar air heater.

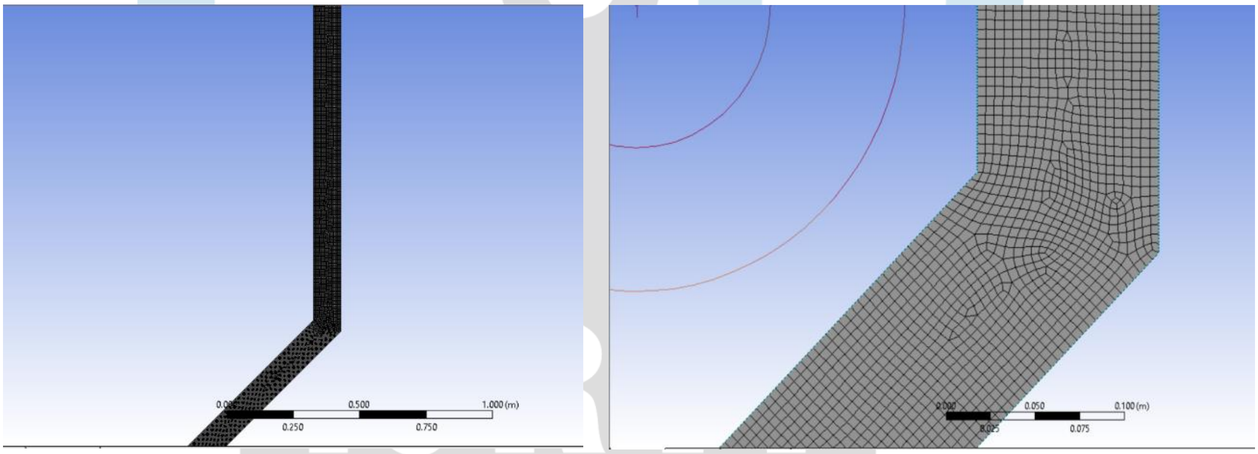


Fig.3 Shows the mesh of solar air heater.

Above meshing conditions was used for validating the CFD model of flat inclined plate solar air heater 32457 number of elements was considered during the analysis. For applying the different boundary conditions at different components of the system, name selection of different components of solar air heater was done.

Validation of CFD analysis for Convex shaped solar air heater:

For constructing the solid model of convex shape solar heater, 50-degree curvature radius of convex shape profile was considered as considered by Singh et.al. Singh et.al analyzed the effect of convex and concave shape of solar air heater at different curvature radius and found that convex profile having 50-degree curvature shows the maximum heat transfer enhancement ratio. Due to this region 50-degree convex shape profile heater is used in this work. For validating the convex shape profile solar heater analysis, here it calculates the value of Nusselt number at different heat flux and then it is compared with the values of Nusselt number obtained by Singh et.al at same heat flux. The solid model of solar heater with convex shape profile is shown in the below fig.

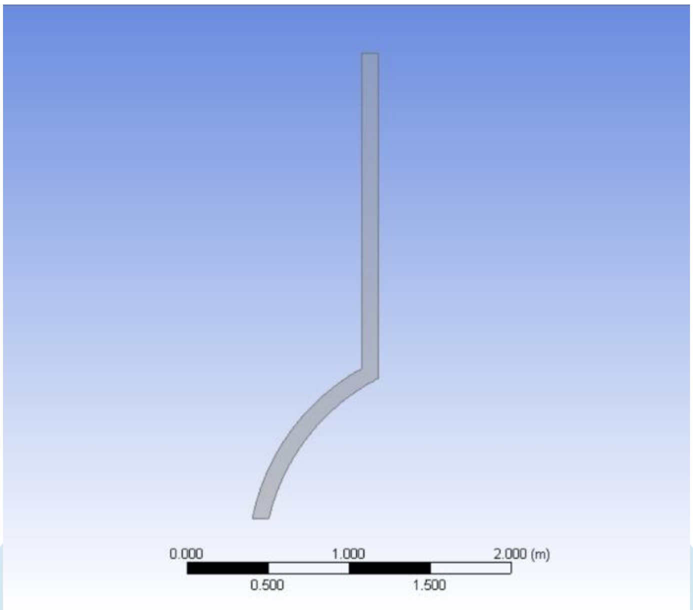
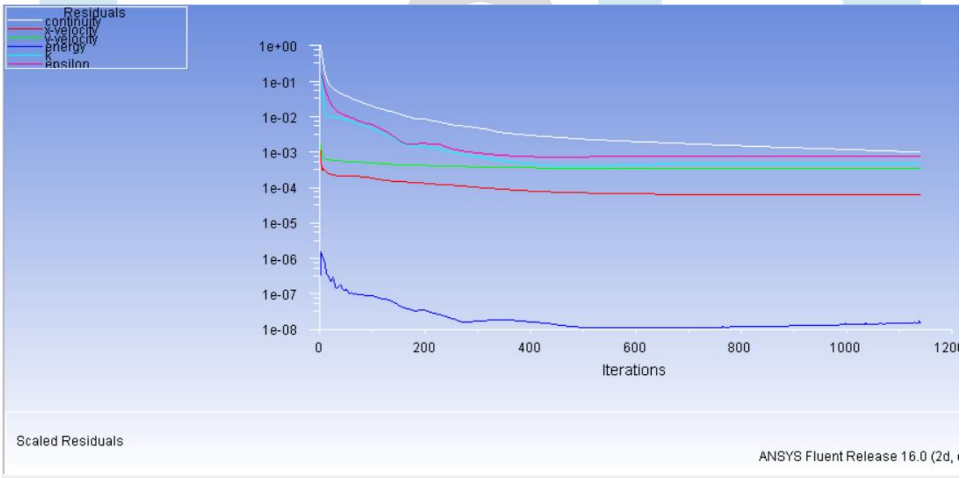


Fig.4 Solid model of solar heater with convex profile.

For 500 W/m² heat flux on the convex shape solar heater

Here in this case 500 W/m² heat flux was applied on the absorber plate and other boundary conditions will remain same as considered during the analysis of inclined flat plate collector.

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  1140  1.0006e-03  6.3165e-05  3.4873e-04  1.5873e-08  4.8095e-04  7.8742e-04  0:01:55  660
! 1141 solution is converged
  1141  9.9897e-04  6.3172e-05  3.4873e-04  1.5462e-08  4.8095e-04  7.8741e-04  0:03:44  659

                Average of Facet Values
                 Surface Nusselt Number
-------------------------------- --------------------
                  absorber_plate            1342.6005
                             air            24.751569
                       air_inlet                    0
                      air_outlet                    0
                     glass_sheet           -220.36876
           interior-surface_body                    0
                            wall                    0
               wall-surface_body                    0
                ---------------- --------------------
                             Net            16.137425
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Fig.5 Value of Nusselt number for convex shape profile at 500 W/m² heat flux

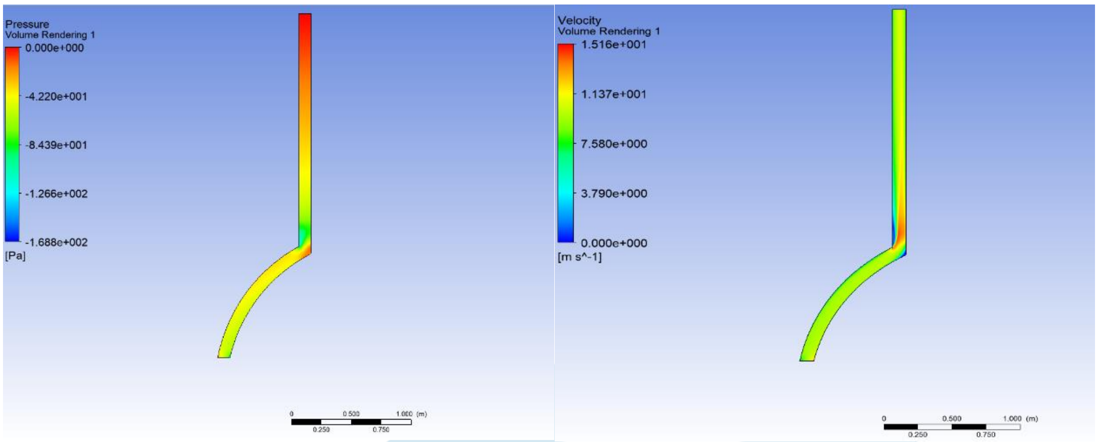

Fig.6 Shows the pressure and velocity variation inside the solar air heater.

From above graph it is found that the value of Nusselt number calculated through CFD analysis for convex shaped solar air heater is close to the value calculated by Singh et.al. The percentage error is also under permissible limit. Hence it can say that the CFD analysis of convex shaped solar air heater is correct. So, after validating the numerical model for inclined and convex shaped solar air heater, effect of different pitch ratio and different shape of ribs was analyzed and calculated the heat transfer enchantment factor for each case of analysis.

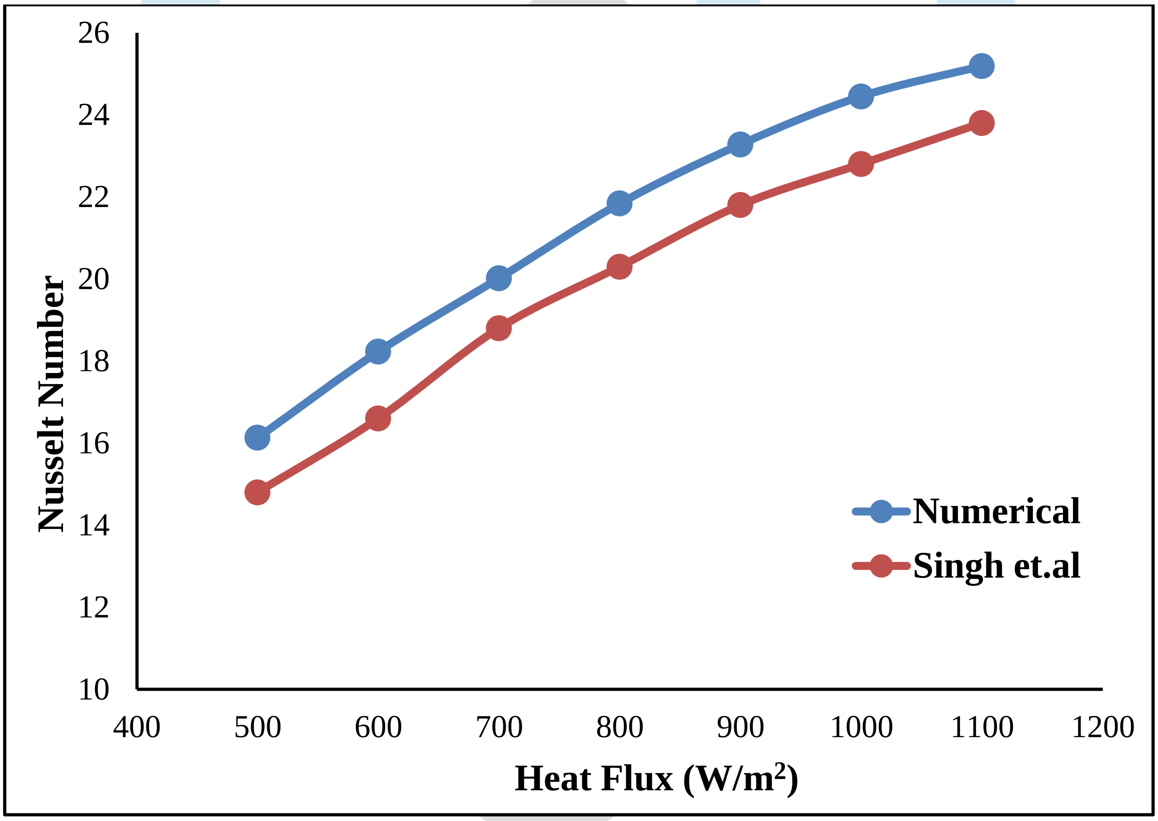

Fig.7 Comparison of value of Nusselt number for convex shape solar air heater.

The value of maximum velocity that achieved during the simulation for the flat and convex shape solar air heater is mention in the below table.

Effect of quarter circular ribs on convex shape solar air heater

For quarter circular shape of ribs, the circular radius was considered as 5 mm. The in-between gaps of two ribs were varied according to the cases. Four different pitch was considered during this work that is 50, 60, 70 and 80 mm. Another dimension of the solar heater will remain constant.

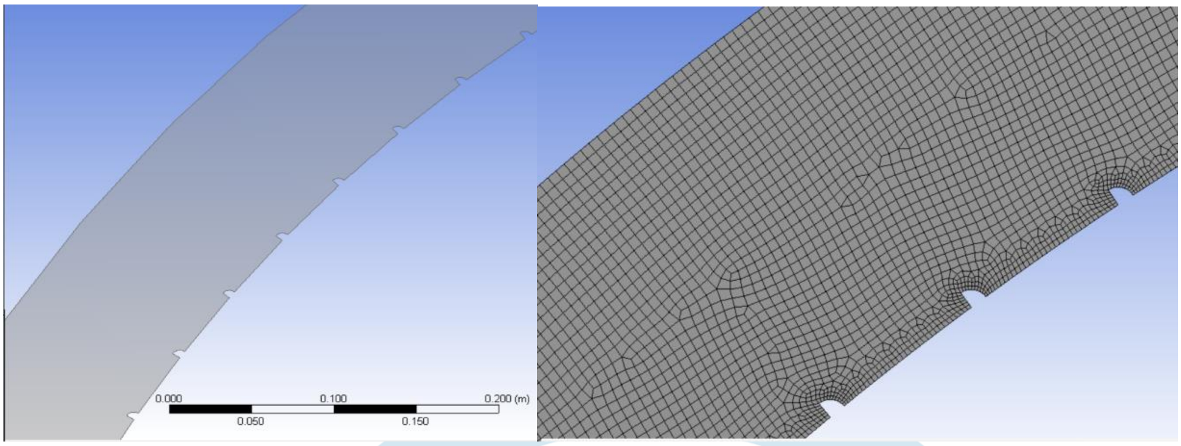

Fig.8 Solid model and mesh of solar air heater with 50 mm pitch quarter circular ribs.

4. Comparison of different pitch of quarter circular shape ribs solar heater:

After calculating the value of Nusselt number for different pitch of quarter circular shape ribs, comparison was done. The comparison of value of Nusselt number for different pitch was mention in the below figure.

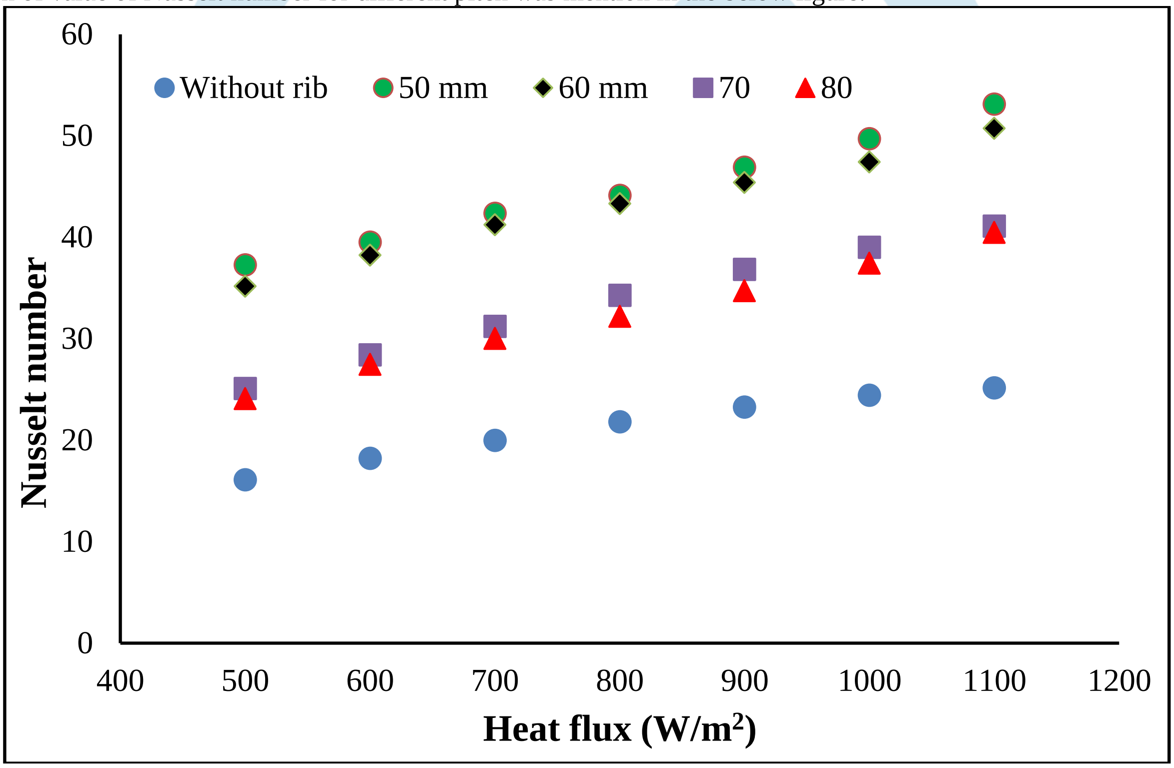

Fig.9 Comparison of value of Nusselt number for different pitch

5. Heat transfer enhancement factor (HTEF):

After calculating the value of Nusselt number for different pitch of quarter circular shapes of ribs. Effectiveness of heat transfer for convex shape solar air heater with quarter circular shape of ribs as compared to simple convex shape solar air heater. For calculating the value of HTEF for different pitch value following relation was considered.

$$HTEF = \frac{Nu_{Ribs}}{Nu_{Simple}} \quad \ldots\ldots\ldots\ldots\ (1)$$

Nu_{Ribs} is the value of Nusselt number with ribs, whereas Nu_{Simple} is the Value of Nusselt for simple convex shape solar heater.

Value of HTEF for different pitch of quarter circular shape convex shape solar air heater with respect to simple convex shape solar air heater

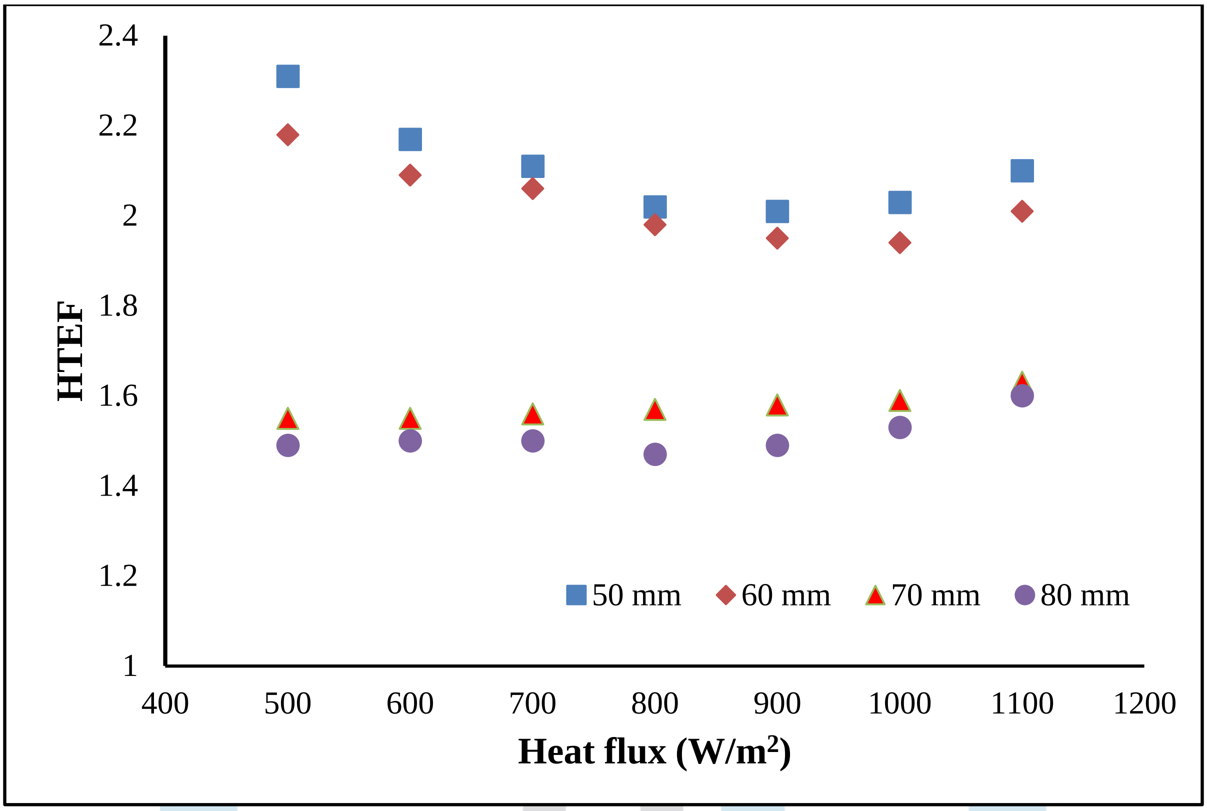

Fig.10 Comparison of value of HTEF for different pitch of quarter circular ribs with respect to simple convex shapes solar air heater.

From graph it is found that with quarter circular ribs the heat transfer for different pitch is more as compared to without ribs convex solar air heater. With 50 mm pitch the heat transfer get almost double for all the heat flux value. Which shoes the effectiveness of ribs inside the solar air heater. The analysis also that even though there is a buoyancy driven force if ribs were placed inside the solar heat absorber plate the heat transfer get enhanced. After comparing with the simple convex shape solar heater, it is also compared with the flat plate solar air heater.

6. Conclusion

CFD analysis of convex shape solar air heater was performed through Ansys Fluent. The validation of CGD analysis of convex shape solar air heater was done successfully with the previous reported data. For the further enhancement of heat transfer from convex shape solar air heater, quarter circular shape ribs were used inside the solar duct. Through analysis it was found that with the use of quarter shape ribs the Nusselt number of convex shape solar air heater get enhanced as compared to without ribs solar heater. With change in pitch, in between two ribs the performance of solar air heater get change. Due to quarter circular ribs the performance of solar heater gets near about double for 50- and 60-mm pitch, whereas with 70- and 80-mm pitch it increases near about 50 % more than the convex solar air heater without ribs. From comparison graph it was found that with 50 mm pitch the value of heat transfer from convex shape solar heater is more as compared to other pitch geometry.

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