Analysis of Solar Air Heater by using RIBS

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Abstract: Solar air heater is mainly used to utilized solar energy, with the used of solar energy air or water was heated. For increasing the heat transfer rate different design of solar air heater was developed. For further improvement of heat transfer from convex shapes solar air heater, here in this work ribs were places inside the convex shape solar air heater. For analyzing the effect of different pitch ratio, four different pitch ratio geometry was analyzed numerically using Ansys fluent. Through CFD analysis 25 mm pitch ratio shows the maximum heat transfer as compared to other pitch ratio. Effect of different shapes of ribs on heat transfer was also analyzed, for those 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.

Keywords: Solar, Air Heater, Ansys, CHD.

***How to cite this article**: Ravi Kumar and Mahendra Prajapati, "Analysis of Solar Air Heater by using RIBS", Published in International Journal of Scientific Modern Research and Technology (IJSMRT), ISSN: 2582-8150, Volume-16, Issue-2, Number-4, August- 2024, pp.14-19, URL: https://www.ijsmrt.com/wp-content/uploads/2024/10/IJSMRT-24160204.pdf*

IJSMRT-24160204

I. INTRODUCTION

Energy demand depends on five different factors, including country status, climate and year-round climate, population, energy and energy conversion technology. Rising global energy demand is being largely reduced by the habit of renewable energy resources such as fossil fuels (oil, gas and coal) and nuclear power. The use of these non-renewable energy resources contributes to environmental degradation such as acid rain, greenhouse gas emissions, global warming and depletion of natural resources. Global energy demand is strongly influenced by global population growth, estimated at 1.23% per year for 2000 to 2015 (World Bank 2017). This increased energy demand can be recognized by the growth of economic growth and modern luxury lifestyle among the population, as well as technological advances.

Energy Resources

We know that per capita energy consumption is considered a sign of prosperity for a country. Energy can be obtained from various resources, which can be confidential as under:

Based on Duration of Availability

Renewable Energy Resource: That resource which can be replenished in short period because of our utilization. E.g. solar energy, biomass energy, hydrogen energy, wind energy and geothermal energy etc.

Non-Renewable Energy Resource: After millions of years of geological processes these resources are formed, they are naturally replenished in vary long period.

Maximum requirement of energy is accomplished by nonrenewable sources, extracting them by refining process and is in common use like generating electricity production of fuels for automobiles. e.g. oil, coal, nuclear energy and natural gas.

II. LITERATURE REVIEW

Kabeel A.E. *et.al* (2024) Attempts to study the thermal characteristics of SS with flat and angular boards, with and without PCM as heat storage devices. In this study, he directly studied the SAA, with its flattened, flattened, and lettered SP shape, with HPS combined as the thermal energy of the storage material. SAH together with PCM is 12% higher than Paraguay, higher without PCM, it is also 15% higher and 21.3% higher than below value when flat plate is used with and without PCM when mass flow 0.062 kg. G / s respectively.

Patil *et.al* (2022) Conducts several studies to monitor the effects of different rough geometry on hydraulic thermal characteristics in SA networks. This work reviewed different studies in which different roughness elements were used to improve the low heat transfer coefficient. Correlations from other researchers were used to compare the thermal characteristics of the network.

Kaygusuz et.al (2021) Recognize that lack of energy can hinder the achievement of goals. This study shows that sustainable energy security and a sustainable environment require more efficient and economical use of clean energy technologies. He also noted that the lack of consumer awareness and indifference to clean energy equipment are barriers to using energy differently.

Driss et.al [2020] In this work, a numerical study was carried out to study the turbulent flow around the unusual wind turbine of Savannah. This study compares different rocket designs defined by blowing angles of 60 °, 75 °, 90 ° and 130 °, while other geometric parameters are kept constant. Under these conditions, the third case involves a normal wind turbine rotor. The results showed that the blower design had a direct effect on the local property. In particular, it is believed that the area of depression increases as the angle of the bucket nose increases.

Inderjeet Singh *et.al* (2018) computationally investigated the heat transfer and fluid flow analysis for non-uniform cross-section transverse rib of square wave profile (using ANSYS fluent).

Pandey *et.al* (2016) The thermal characteristics of the roughened elements of the absorbing plate were analyzed. The findings based on the results show a good increase of the nucleation when using this type of rough configuration. The maximum gain obtained at Nu and f is 5.85 and 4.96, respectively. The maximum gain for ny is found at the Reynolds numerical value of 21000 for the geometric configuration (g / e = 1, d / x = 0.65, W / w = 5, e / D = 0.044, P / e =.8 and α = 60 equator A statistical equation for the nucleus and the coefficient of friction as a function of various geometric and flow parameters is established.

Azawie et.al [2014] In this work, the conversion capabilities of six different raw materials available in Malaysia were investigated experimentally and numerically. Experimental equipment for recording measurement data was constructed. In the FLUENT software office, digital models are designed to model and simulate power conversion processes. Selected materials include ceramics, black chalk, scotch, black wood (DGPS), sand and gravel.

Yadav et.al (2013) Advantages - A study of the heat transfer in the rectangular shape of the triangular beam at the edge of the absorber plate using CFDs. The ANSYS 12U Limited Commercial Package is used to analyze and visualize the nature of the flow through solar panels. The results of the CFD simulation agree well with the experimental results and the standard theoretical methods. Nusselt's numbers were found to increase as Randall rose.

III. RESEARCH OBJECTIVES

1. Performing the CFD analysis of solar air heater having flat incline and curved shape collector plate.

2. Evaluating the effect of different shapes of ribs on the heat transfer enhancement of convex shape solar air heater.

3. Also evaluating the effect of different heat flux at absorber plate on the performance of solar air heater during different geometric conditions.

IV. METHODOLOGY

Materials Used

Here in this work, air is used as a working fluid which is flowing inside the solar air heater. Absorber plate of solar air heart is made from aluminum and solar chimney is also made from the same, whereas the upper sheet of solar heater is made from transparent glass. The properties of different materials that are used during the numerical analysis of solar air heater is mention in the below table.

Air – it is considered as a working fluid, which is flowing inside the solar air heater. The properties of air remain constant throughout the simulation

Aluminum- it is used for the manufacturing of solar chimney wall and absorber plate. The properties of aluminum will also remain constant throughout the numerical analysis and material of absorber plate will remain same for different shapes of solar heater.

Glass – The top surface on which solar irradiation is falling is made off from transparent solar air heater. Heat transfer from the glass through radiation is not considered is this work, only heat transfer through convection is considered during the analysis and 5.7 heat transfer coefficient was considered on glass surface.

Validation of CFD Model

Here in this work, first numerical analysis of flat inclined plate solar air heater was analyzed using Ansys fluent, the value of Nusselt number at different heat flux was calculated and compare with the experimental result performed. After validating the CFD analysis of flat solar air heater, convex shape curved solar air heater was analyzed.

For this 50-degree curvature radius convex shape solar plate profile was considered as considered. Singh analyzed the effect of concave and convex shape solar air heater with chimney at different curvature radius and find that convex shaped profile with 50-degree curvature shows the maximum heat transfer.

So here in this work, for enhancing the heat transfer capacity of convex shape profile by using ribs, 50-degree curvature radius profile was considered for each case of analysis.

Table 1: Geometric parameters of flat solar air heater

Geometric parameters	Value
Absorber plate length (mm)	1000
Chimney height (mm)	2000
Width of chimney (mm)	100
Gap in between absorber plate and glass sheet (mm)	100
Inclination angle (degree)	45

Model Selection and Boundary Condition

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.

Validation of CFD model of Convex shaped solar air heater

For validating the CFD analysis Convex shaped solar air heater, same boundary conditions were considered during the numerical analysis was considered 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.

Convex Shaped Solar Air Heater

After validating the CFD model of flat plate incline solar air heater, numerical analysis of curved shape solar air heater was performed. 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.

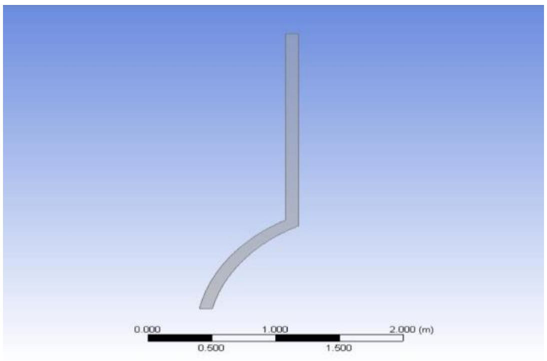

Figure 1: Solid model of solar heater with convex profile

For 500 W/m^2 Heat Flux

Here in this case 500 W/m^2 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. The value of Nusselt number and contours for this case is mention in the below figs.

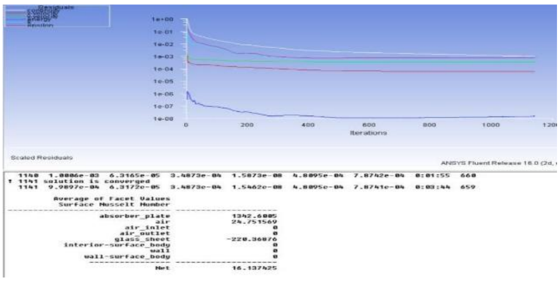

Figure 2: Value of Nusselt number for convex shape profile at 500 W/m^2 heat flux

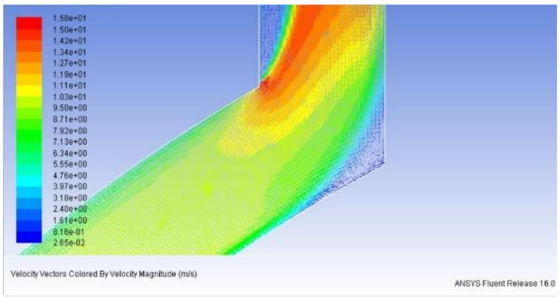

Figure 3: Shows the velocity vector at 500 W/m^2 heat flux

Above fig. shows the variation of velocity inside the solar heater channel, through contours it is found that there is a constant and linear variation of velocity. While moving away from the absorber plate velocity of air get increases which is mainly due to natural convection. Air coming inside the solar heater and gain energy from the absorber plate and mode towards the chimney. The variation of pressure inside the solar air heater

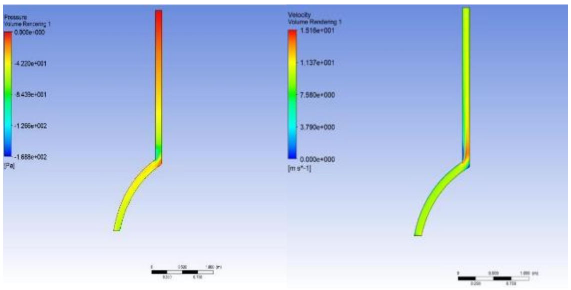

Figure 4: Shows the pressure and velocity variation inside the solar air heater.

Effect of Different Shapes of RIBS

Effect of different shapes of ribs was analyzed. 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 Rectangular Shapes of RIBS

Solar air heater having rectangular ribs with 25 mm pitch ratio will analyzing in the above cases the value of Nusselt number for different heat flux was mention in the below table.

Table 2: Value of Nusselt number for rectangular ribs with 25 mm pitch ratio solar heater

SN	Heat flux (W/m^2)	Nusselt number
1	500	79.42
2	700	82.29
3	900	86.14
4	1100	88.5

For Triangular RIBS`

In this case of analysis, triangular shape of ribs was used inside the solar air heater to increase the heat transfer rate. The solid model of solar air heater with triangular ribs is shown in the below fig.

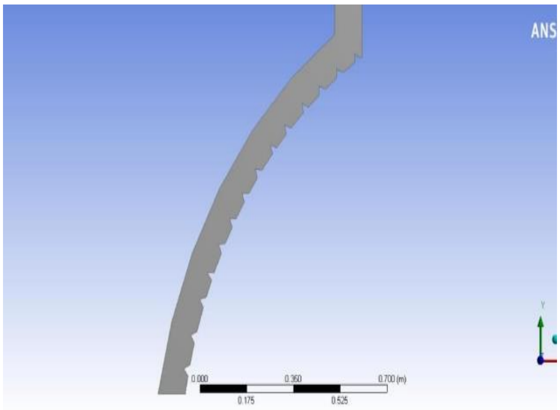

Figure 5: Solid Model of Solar Air Heater with Rectangular RIBS

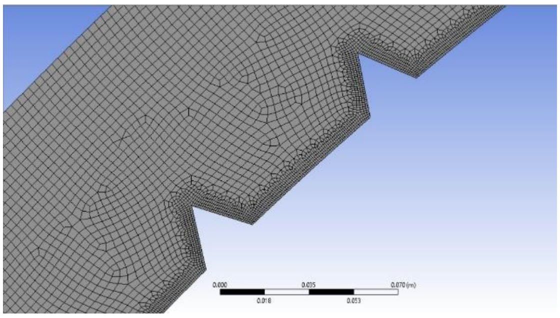

Figure 6: Mesh of Solid Model

For 500 W/m²

In this case, 500 W/m² heat flux was applied on the absorber plate and other boundary conditions will remain same as considered for the other cases. The value of Nusselt number and contours plot for this case is shown in the below figs.

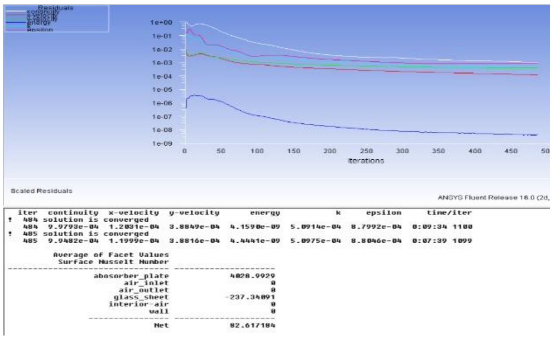

Figure 7: Value of Nusselt Number for 500 W/m² Heat Flux

Comparison of Different Shapes of RIBS

Different shape of ribs, comparison was done on the basis of Nusselt number at different heat flux. The value of Nusselt number for different shapes of ribs was mention in the below table.

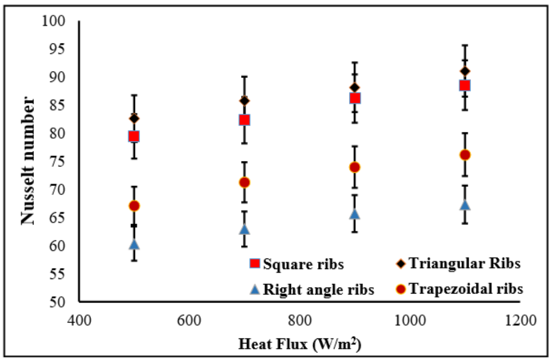

Figure 7: Shows the Comparison of Value of Nusselt Number for Different Shapes of RIBS

On the basis of above mention formula value of heat transfer enhancement factor (HTEF) was calculated with respect to simple convex shape solar air heater. The value of HTEF for different shapes of ribs is mention in the below table.

Table 3: Shows the value of heat transfer enhancement ratio (HTER) for different shapes of RIBS

SN	Heat flux (W/m²)	HTER for rectangular	HTER for Triangular	HTER for Trapezoidal	HTER for Right angle triangle
1	500	4.92	5.12	4.15	3.73
2	700	4.12	4.28	3.55	3.14
3	900	3.7	3.78	3.17	2.82
4	1100	3.52	3.61	3.02	2.67

V. CONCLUSIONS

- From numerical analysis variation of velocity and pressure inside the solar air heater was analyzed and also analyzed the flow behavior of air.
- Through analysis it is found that value of Nusselt number increases marginally for convex shape as compared to flat plane inclined solar air heater.
- For further improvement of heat transfer from solar air heater, ribs are used inside the solar duct.
- Through CFD analysis it is found that heat transfer increases significantly while using ribs as compared to simple convex shape solar air heater.
- With 25 mm pitch ratio value of heater transfer and HTEF is maximum as compared to other pitch ratio.

REFERENCES

[1] M.I Carretero, G. Lagaly, Appl. Clay Sci. 36, 2007, 1.
[2] C.H. Zhou, D.S. Tong, M.H. Bao, Top. Catal. 39, 2006, 213.
[3] S.G. Adoor, M. Sairam, L.S. Manjeshwar, J. Membr. Sci. 285, 2006,182.
[4] F. Bergaya, G. Lagaly, *General Introduction: Clays, Clay Minerals, and Clay Science*. 2006.
[5] M.F. Brigatti, E. Galan, B.K.G. Theng, *Structures and Mineralogy of Clay Minerals*. 2006.

[6] Y. Kim, J.S. Lee, C.H. Rhee, H.K.Kim, *J. Power Sources* 162, 2006,180.
[7] J.P.G. Villaluenga, M. Khayet, J.L. Valentin, *Eur. Polym. J*. 43, 2007,1132.
[8] R.Y. Lin, B.S. Chen, G.L. Chen, S.Y. Suen, *J. Membr. Sci*. 326, 2009,117.
[9] R. Bhadoria, B.K. Singh, R. Tomar, *Desalination*, 254, 2010,192.
[10] D. W. Breck, Zeolite Molecular Sieves: Structure, Chemistry, and Use; *Wiley-Interscience: New York*. 1974.
[11] B. K. Marcus, W. E. Cormier, Going green with zeolites. *Chem.Eng. Prog*., 1999, 47.
[12] W.J Paulus, S. Komarneni, R. Roy, Bulk synthesis and selective exchange of strontium ions in $Na_4Mg_6Al_4Si_4O_{20}F_4$ mica. *Nature* 357, 1992, 571.
[13] S.C. Larsen, *J. Phys. Chem*.111, 2007,18464.
[14] Pankaj Sharma, Gurpreet Singh, Radha Tomar, Journal of Colloid and Interface Science, 332, 2009, 298.
[15] S.K. Singh, S.S. Tomar, Radha Tomar, J. Indian Chem. Soc., 86, 2009, 866.
[16] S. A. Ansari, P.K.Mohapatra and V. Manchanda, *Talanta*, 73, 2007,878.
[17] B.K. Singh, Radha Tomar, Sumit Kumar, Aishwarya Jain, B.S. Tomar and V. K. Manchanda, *Journal of Hazardous Materials*, 178, 2010, 776.
[18] M. Williams, *Env. Geology*, 40, 2001, 278.
[19] V. Barron and J.Torrent, Surface *Journal of Colloid and Interface Science*. 177, 1996, 407.
[20] A.E. Blum and A.C. Lasaga, *Geochimica et Cosmochimica Acta*. 55, 2006, 2193.
[21] A.M. Yousof, M.N. Mahat and A.K.H. Wood, *J. Anal. Sci.*, 2, 1996, 327
[22] H.E. Allen, R.H. Hall and T.D. Brisbin, *Environmental Science and Technology*. 14, 1980, 441.