Asian Journal of Applied Science and Technology (AJAST)
(Open Access Quarterly International Journal) Volume 2, Issue 3, Pages 127-134, July-September 2018

CFD Study of Solar Air Heater Roughened With Broken Arc Shaped and Broken S Shaped Ribs

Shivam Haldia[1], Vijay Singh Bisht[2] and Sumit Kumar[3]

[1]shivam4haldia@gmail.com, Department of thermal engineering, Faculty of Technology, UTU, Dehradun, India.
[2]vsinghbisht5@gmail.com, Department of thermal engineering, Faculty of Technology, UTU, Dehradun, India.
[3]sumit.pce90@gmail.com, Department of thermal engineering, Faculty of Technology, UTU, Dehradun, India.

Article Received: 20 April 2018 *Article Accepted: 29 July 2018* *Article Published: 24 August 2018*

ABSTRACT

Using the roughness n the rectangular duct with combination of broken arc shaped and broken S shaped ribs. The numerical and CFD probe analysis of the working model of the solar air heater is examined. Reynolds are in the range of 2000 to 22000. Therefore, it is mandatory to check that thee smooth hose and numerical analysis are compared with the Dittus-Boelter equation at the time of geometry, certain points are taken equal heat flow q=1200w/m2. The maximum Nusselt number is observed Nu = 350.2253 when the gap g = 0.9 mm is given in s-shape roughness and at some fixed values like pitch space P = 25 mm, relative roughness pitch p/e = 17.85, relative gap width g/e = 0.64, Reynolds number Re = 22000. The highest thermal hydraulic performance obtained η = 4.010806892 when the gap g = 0.9 mm is given in the s-shape roughness, at relative roughness pitch p/e = 17.85, pitch space p = 25 mm, at Reynolds number Re = 22000.

1. INTRODUCTION

Solar Energy

Energy produces sun energy by using solar energy collector panels so that conditions can be created which can then be converted into a type of power. Solar energy is a sustainable source of energy that cab ne utilized for Solar heating, cooling, electricity and lighting. There are many devices like solar water heater [1-2] and solar air heater [3-4] that utilize the solar energy. Lot of researchers have conducted theoretical study of solar air heater [5-9]. CFD is a important tool to analyze thermal systems [10-11]. Kumar et.al[12] conducted 3D CFD investigation of solar air heater using broken curved ribs and concluded that these ribs augmented thermo-hydraulic performance. Gupta and Varshney [13] conducted CFD study of solar air heater, they reported that by use of sectioned tapered rib performance of solar air heater could be enhances. Gupta et.al [14] reported that transverse ribs enhance the heat transfer rate of air flowing in solar air heater duct.

2. METHODOLOGY

The methodology of the working model of the solar air heater presented as Rectangular air heat roughened with combination of broken S-shaped and broken arc-shaped ribs with different gaps. The methodology of the model designed is helped to examine solar energy efficiency and also used to analysis the energy of the solar air heater by use of roughness in the rectangular duct.

Ansys is a software design process which analysis of the rectangular duct by the help of Computational fluid dynamics (CFD) and the design is taken in the form of 3-Dimensional CFD which is also known as Ansys fluent. The study of the model created to maintain fluid flow as air and heat transfer enhance characteristics in a rectangular duct with different types of S-shaped and broken arc shaped with gap ribs roughness of variation in flow direction and CFD k- e turbulence model is used.

2.1 GEOMETRICAL MODELING OF THE BROKEN S-SHAPED AND ARC SHAPED SOLAR RECTANGULAR DUCT

The parameters of the rectangular duct are taken review paper as length of the duct L = 2400 mm, height of the duct H = 25 mm, and width of the duct W = 300 mm. Now the typical geometry of the model is start after inserted the with combination of broken S-shaped and broken arc-shaped roughness in the smooth duct. So, it is compulsory for investigation the smooth duct and after that numerical analysis is compared with Dittus-Boelter equation. At the time of geometry some fixed points are taken like uniform heat flux q = 1200 w/m2 and heat flux is used for calculating the heat transfer rate amount of thermal energy carried away through average area per unit of time. The geometry also shows the thermal performance of the roughened solar air heater how can be increased without any loss of energy. Parameters are given to the geometry of the smooth rectangular with inserted obstacles as s-shape inserted parts with gap g = 0.3 mm, 0.5 mm, 0.7 mm and 0.9 mm but in the situation mass flow rate is required to check the geometry on the basic of Reynolds number Re = 2000, 6000, 10000, 14000, 18000, and 22000. The geometry of the designed solar rectangular duct with combination of broken S-shaped and broken arc-shaped with gap is shown in the below figures:-

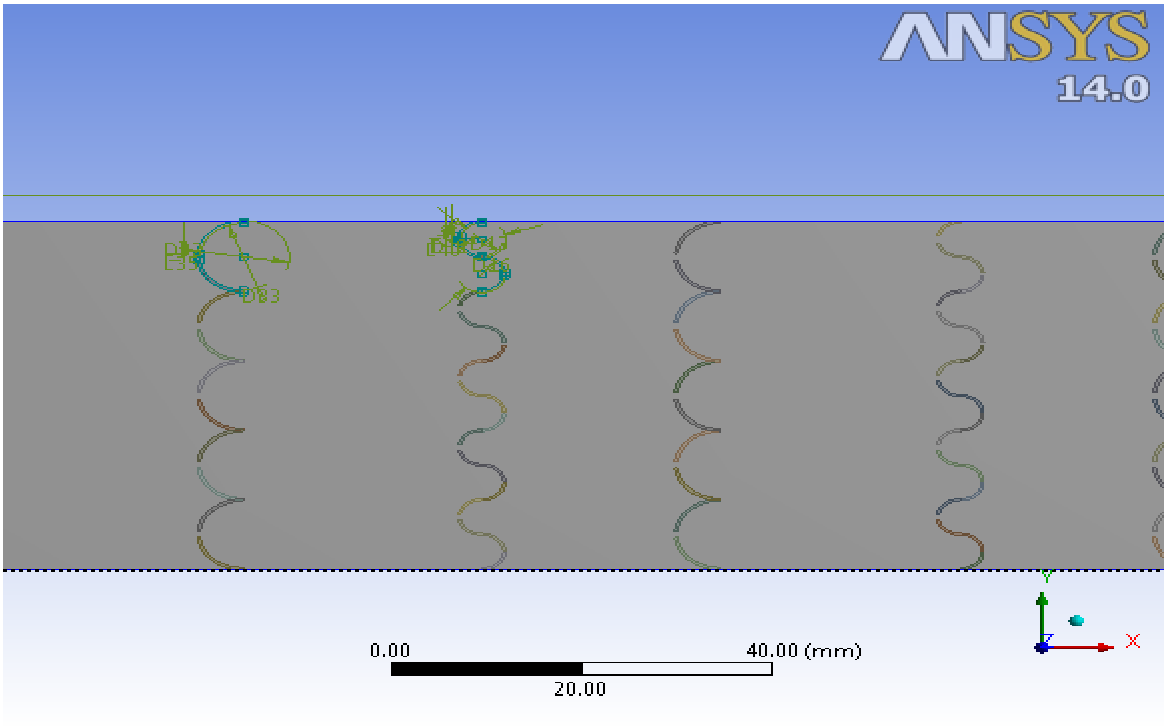

Figure 1

ASSUMPTION: - Following assumptions have been considered during the numerical simulation of the continuous Combination of broken S-shaped and broken arc-shaped solar rectangular duct.

(1) Steady flows

(2) Pressure variation in y direction is zero.

(3) Shear force in y direction is zero.

(4) Body force due to gravity has been neglected.

(5) Incompressible flow.

(6) At the inlet of test section, the flow has been fully developed flow.

(7) The axial heat conduction in the fluid was negligible.

(8) The properties of air constant at atmospheric pressure and temperature.

3. RESULTS AND DISCUSSION

The results of the inserted part with variation in the gap show the low reduction of the energy. The results are carried out from the use of combination of broken S-shaped and broken arc-shaped roughness in solar air heater to gain the heat transfer characteristics, friction factors coefficient, temperature gradient, and conversion of natural energy. The designed S-shaped and broken arc-shaped roughness with gap solar air heater has a motive to use natural energy for collecting and absorbing the maximum heating source. The design also used for conversion of solar energy to thermal energy of the fluid.

3.1 COMPARISON BETWEEN THE SMOOTH RECTANGULAR DUCT AND DITTUS-BOELTER.

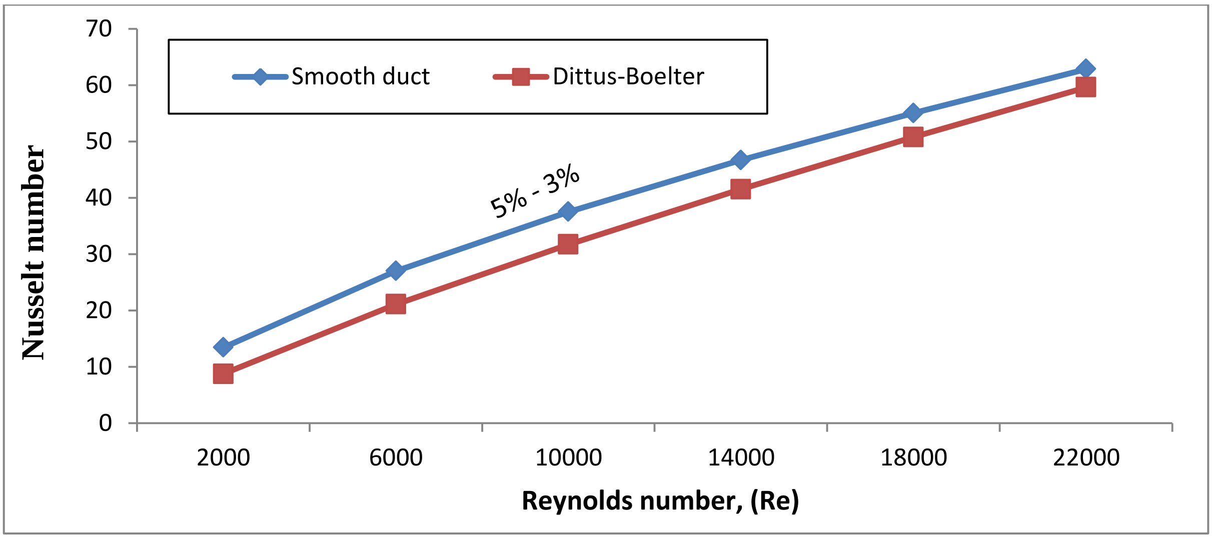

Figure 2

The comparison between the smooth duct and Dittus-Boelter equation. There is small variation (5% - 3%) between the smooth duct and Dittus-Boelter equation[15]. the maximum Nusselt number of the smooth duct is Nu = 62.85528 and maximum Nusselt number of the Dittus-Boelter equation is Nu = 59.62573508 at Reynolds number Re = 22000. The correlations satisfied the experimental work as CFD.

3.2 COMPARISON BETWEEN THE SMOOTH DUCT AND BLASIUS FRICTION FACTOR EQUATION

The minimum friction factor is obtained Fr = 0.003308179 in smooth tube and in case of Blasius friction factor equation, the friction factor is obtained Fr = 0.006494875.

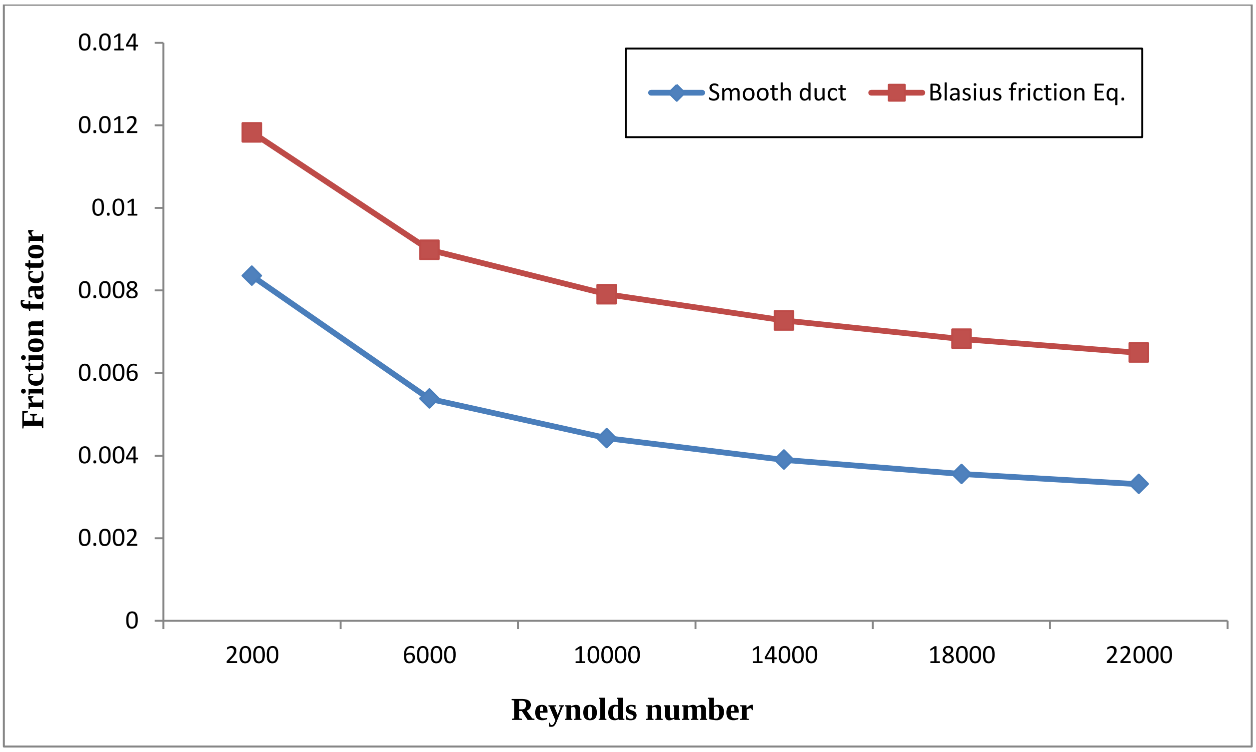

Figure 3

The results of the s-shape solar air heater are effective when the number of gaps were used between the s-shape roughness in solar air heater. When the air passes over the one side of the s-shape roughness absorber plate, the air gets warm from conduction process or property of the material and convective process of the working fluid. The air gets high velocity when passes from the gap between the s-shape.

At high velocity of the air, the convective energy of the solar air heater increased that is enough way to increase the thermal energy. because variation in the gaps g = 0.3 mm, 0.5 mm, 0.7 mm and 0.9 mm work nozzle for velocity of the fluid. These gaps between the s-shape roughness presented more affection on the solar air heater when pitch space between the s-shape series used. the variation in the pitch space P = 15 mm, 20 mm, 25 mm used for circulating the warm air around the surface, temperature difference. The examined results and discussion are shown in number of figure and terms like velocity contour, temperature contour, Nusselt number, friction factor, turbulent kinetic energy, and thermal hydraulic performance of the solar air heater.

3.3 VELOCITY CONTOURS

The variation in the velocity contour with respect to the Reynolds number Re = 2000 – 22000 at pitch space between the s-shape series roughness P = 25 mm when gap between the combination of broken S-shaped and broken arc-shaped roughness is used g = 0.9 mm. the gap is more effective for improving the thermal performance of the solar air heater because at these parameters solar air heater obtained maximum velocity of the fluid v = 64.56 m/s.

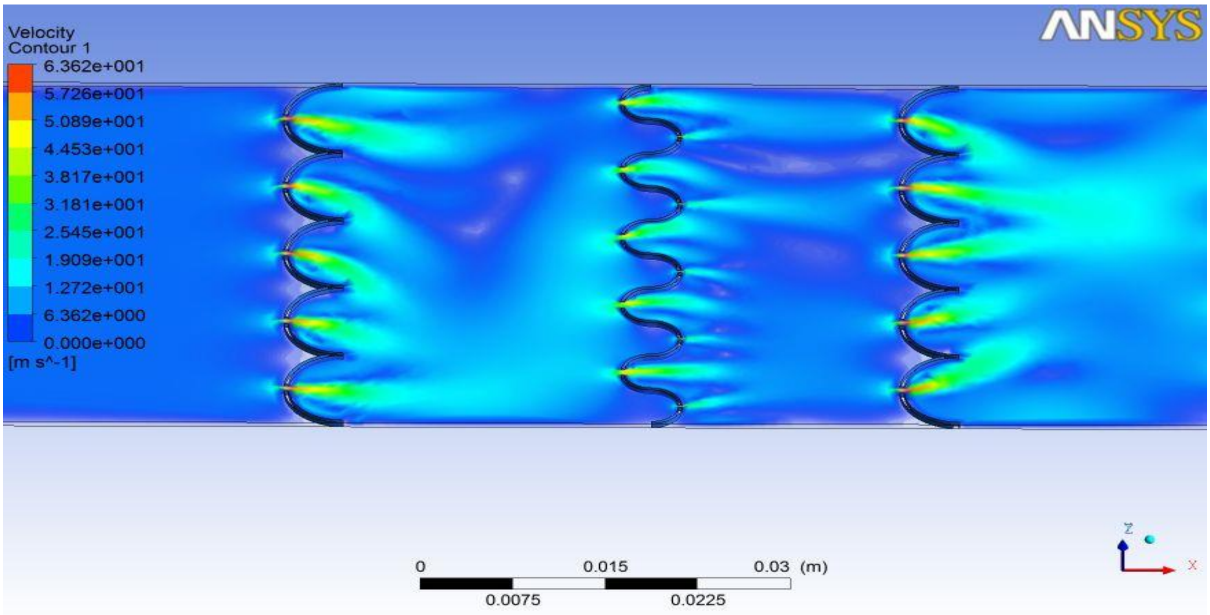

Figure 4

Figure shows the variation in the velocity contour with respect to the Reynolds number Re = 2000 – 22000 at s-shape roughness with gap = 0.9 mm

3.4 EFFECT OF REYNOLDS NUMBER AND RELATIVE ROUGHNESS PITCH ON THE FLUID FLOW AND HEAT TRANSFER CHARACTERISTIC IN COMBINATION OF BROKEN S-SHAPED AND BROKEN ARC-SHAPED WITH GAP SOLAR AIR HEATER

The comparison between the Nusselt number and Reynolds number Re = 2000 – 22000 with respect to the number of variations in the gap g = 0.3 mm, 0.5 mm, 0.7 mm, 0.9 mm between the combination of broken S-shaped and broken arc-shaped roughness when used in the smooth tube. The heat transfer increasing at some fixed values like relative roughness pitch p/e = 17.85, pitch space P = 25 mm, relative roughness height e/Dh = 0.030. In the figure, the maximum heat transfer as Nusselt number obtained Nu = 350.2253 when the gap g = 0.9 mm is used between the combination of broken S-shaped and broken arc-shaped roughness and pitch space P = 25 mm.

The solar air heater observed maximum Nusselt number obtained because the air accelerated with high turbulent velocity at this gap and air circulated with large reattachment around the surface area. When the gap is used g = 0.3 mm Nusselt number is Nu = 165.1391, at g = 0.5 mm the Nusselt number is Nu = 267.2994, at gap g = 0.7 mm the Nusselt number is Nu = 310.91802. The figure shows the increasing in the heat transfer rate with increasing in the gap between the s-shape roughness and increasing in Reynolds number Re 2000, 6000, 10000, 14000, 18000, 22000. All the results are compared with the smooth duct to check the effect of combination of broken S-shaped and broken arc-shaped roughness with gap and maximum Nusselt number Nu = 62.85528 smooth duct.

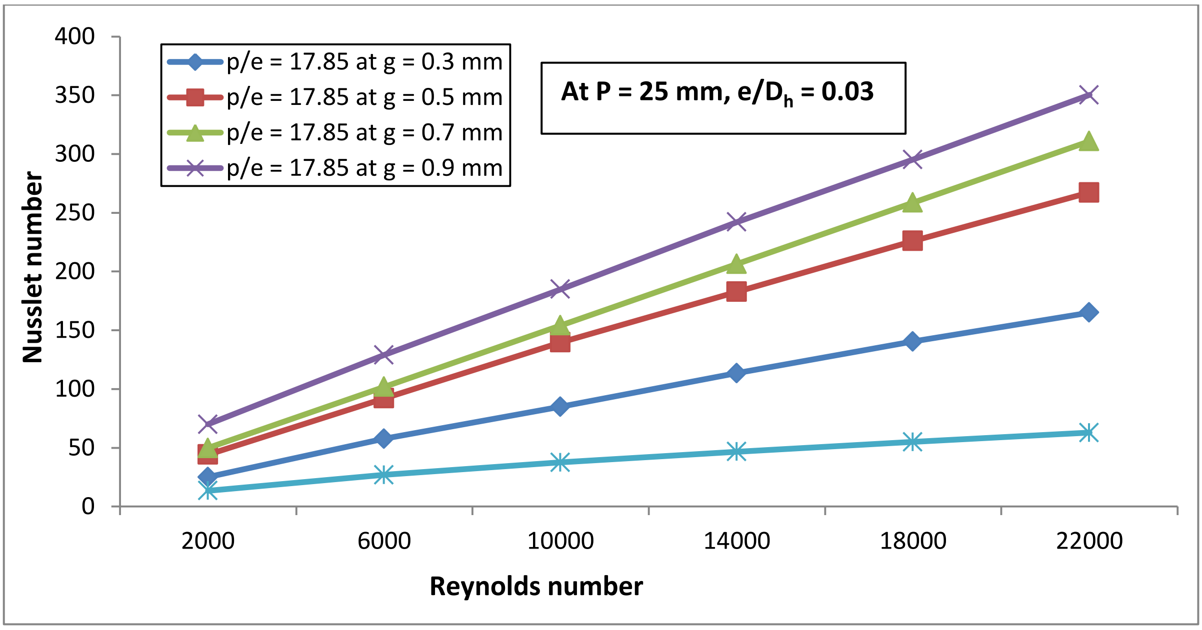

Figure 5

As we are decreasing the pitch value P the heat transfer rate decreasing. The heat transfer rate decreasing because turbulent flow decreasing in small gap, at P = 15 mm the Nusselt number has obtained Nu = 189.4631.The comparison between the Nusselt number and Reynolds number with respect the pitch space between the roughness with gap g = 0.9 mm.

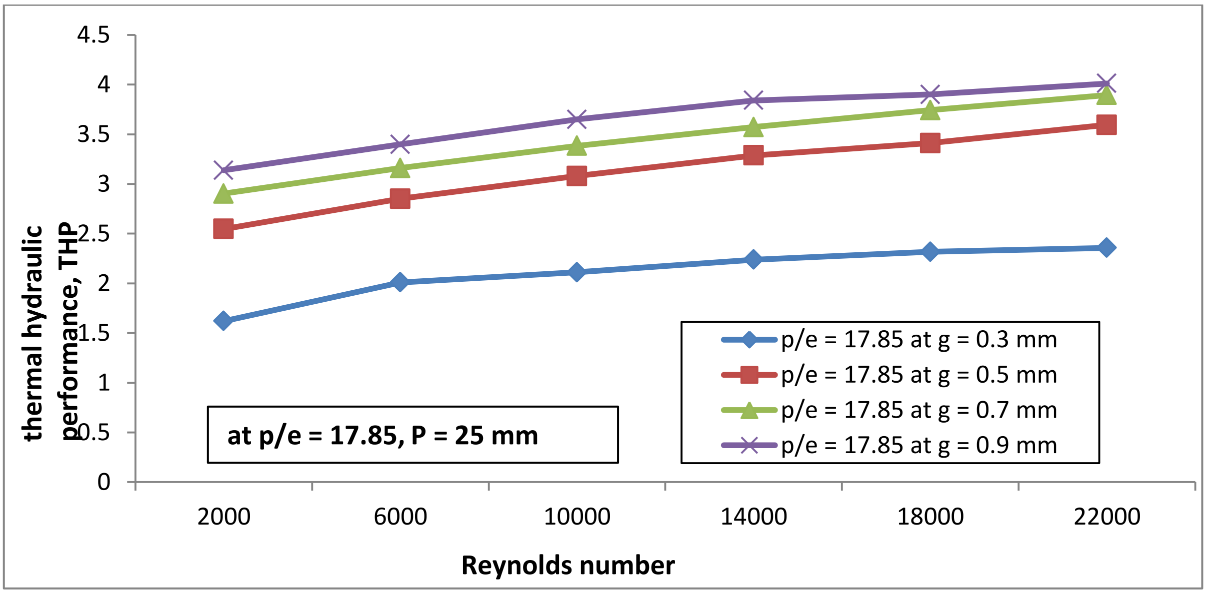

Figure 6

The maximum Nusselt number is Nu = 350.2253. This heat transfer is maximum for whole designed solar air heater at pitch space P = 25 mm, at relative gap width g/e = 0.64 and relative roughness pitch p/e = 17.85. When the pitch space given to the roughness P = 20 mm the Nusselt number is Nu = 289.0474, at P = 15 mm the Nusselt number observed Nu = 229.3941. All the results observed at Re = 22000, g/e = 0.64, p/e = 17.85, e/Dh = 0.030. The figure

4.25 shows the variation in the thermal hydraulic performance with respect to the Reynolds number Re = 2000 – 22000. The maximum thermal hydraulic performance observed ηmax = 4.010806892 when the gap g = 0.9 mm is given in the combination of broken S-shaped and broken arc-shaped roughness in the solar air heater, at gap g = 0.7 mm thermal hydraulic performance is 3.895751118, at g = 0.5 mm THP = 3.594554584, at g = 0.3 mm THP = 2.357847293. all the results are obtained at fixed various values p/e = 17.85, P = 25 mm, g/e = 0.64.

4. CONCLUSION

The conclusions of the model have been expressed by rate of heat transfer enhancement and friction factor characteristic. The heat transfer characteristics have been investigated by the help of Nusselt number, Friction factor coefficient, Turbulent kinetic energy, and Thermal hydraulic performance. The most important parts of the conclusion of the model is variation in the Reynolds number Re = 2000, 6000, 10000, 14000, 18000, 22000, and inserted obstacles as combination of broken S-shaped and broken arc-shaped roughness with gap g = 0.3 mm, 0.5 mm, 0.7 mm and 0.9 mm. the following conclusions are explained on the study of combination of broken S-shaped and broken arc-shaped solar rectangular duct.

The main conclusions calculated as follows factors given below:-

1. From the explanation of all results, it is clear that k-ε standard model could provide results with acceptable engineering accuracy for the analysis of flow and heat transfer patterns in rectangular duct with inserting the combination of broken S-shaped and broken arc-shaped roughness with gap.
2. The heat transfer increased, and friction factors decreased with respect to the increasing in the Reynolds number (Re) and variation in the parameters of the solar air heater.
3. The heat transfer increased as Nusselt number with increasing in the gap in s-shape roughness and friction factor decreased with decreasing in the gap in s-shape roughness.
4. The maximum Nusselt number is observed Nu = 350.2253 when the gap g = 0.9 mm is given in s-shape roughness and at some fixed values like pitch space P = 25 mm, relative roughness pitch p/e = 17.85, relative gap width g/e = 0.64, Reynolds number Re = 22000.
5. The highest thermal hydraulic performance obtained η = 4.010806892 when the gap g = 0.9 mm is given in the s-shape roughness, at relative roughness pitch p/e = 17.85, pitch space p = 25 mm, at Reynolds number Re = 22000.

REFERENCES

1. Prabhakar Bhandari, Lokesh Varshney, Vijay Singh Bisht. Numerical analysis of Hybrid Solar Water Heating System Using Wire Screen Packed Solar Air Heater. 1st International Conference on New Frontiers in Engineering, Science & Technology, vol 1,pp 415-422,2018.

2. L Varshney, Prabhakar Bhandari, Vijay Singh Bisht(2014).Performance Evaluation of Hybrid Solar Water Heating System Using Wire Screen Packed Solar Air Heater**.** Int. Journal of Engineering Research and Application (IJERA) 311-316.

3. Bisht, V. S., Patil, A. K., & Gupta, A. (2018). Review and performance evaluation of roughened solar air heaters. Renewable and Sustainable Energy Reviews, *81*, 954-977.

4. Gangwar,H.P,Rawat,K.S & Pratihar , A.K (2018).Heat Transfer Studies in an artificial roughened solar air heater having wire rib roughness. International journal of Pure AND APPLIED Mathematics, 119,1505-1509.

5. Ankit Kumar, Vijay Singh Bisht, Maneesh Khati, and Satish Kumar*(2017).*Numerical Study of a Roughened Solar Air Heater using Matlab,*IJIACE,4.*

6. Akbarzadeh, M., Rashidi, S., Karimi, N., & Ellahi, R. (2018). Convection of heat and thermodynamic irreversibilities in two-phase, turbulent nanofluid flows in solar heaters by corrugated absorber plates. Advanced Powder Technology**.**

7. Soi, A., Singh, R., & Bhushan, B. (2018). Heat transfer and friction characteristics of solar air heater duct having protruded roughness geometry on absorber plate. Experimental Heat Transfer, 1-15.

8. Singh, I., & Singh, S. (2018). CFD analysis of solar air heater duct having square wave profiled transverse ribs as roughness elements. Solar Energy, *162*, 442-453.

9. Rashidi, S., Javadi, P., & Esfahani, J. A. (2018). Second law of thermodynamics analysis for nanofluid turbulent flow inside a solar heater with the ribbed absorber plate. Journal of Thermal Analysis and Calorimetry, 1-13.

10. Akbarzadeh, M., Rashidi, S., Karimi, N., & Omar, N. (2018). First and second laws of thermodynamics analysis of nano fluid flow inside a heat exchanger duct with wavy walls and a porous insert. Journal of Thermal Analysis and Calorimetry, 1-18.

11. Kumar, S., & Bisht, V. S. (2018). 2D Modelling and Simulation of Heat Transfer in Blast Furnace Hearth Using ANSYS. In *Intelligent Communication, Control and Devices* (pp. 1051-1063). Springer, Singapore.

12. Kumar, K., Kaushik, S., & Bisht, V. S (2017). CFD Analysis on Solar Air Heater with Artificial Roughened Broken Curved Ribs,8,264-275.

13. Gupta, A. D., & Varshney, L. (2017). Performance prediction for solar air heater having rectangular sectioned tapered rib roughness using CFD. Thermal Science and Engineering Progress, *4*, 122-132.

14. Gupta, A. D., Varshney, L., & Pratihar, A. K. (2016). Heat Transfer and Pressure Drop Characteristics In A Duct With Roughened Absorber Plate Having Rectangular Transversed Rib Using ANSYS. Int. J. Sci. Eng. Res., 7, 252-26.

15. Rohsenow, W. M., & Cho, Y. I. (1998). *Handbook of heat transfer* (Vol. 3). J. P. Hartnett (Ed.). New York: McGraw-Hill.