RESEARCHERID
THOMSON REUTERS

[Ashfaque et al., 8(8), July 2023]

ISSN : 2455-9679
SJIF Impact Factor : 6.008

ijrtsm

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"FLUID FLOW AND TRANSIT HEAT ANALYSIS OF A SOLAR HEATER DUCT ENGRAVED WITH NOVEL RIBS AND NANOPARTICLES USING CFD"

Ashfaque Alam [1]**,** ***Pushkar Dwivedi*** [2]

[1] *M.Tech Scholar, Department of Mechanical Engineering, School of Research and Technology Bhopal, India*

[2] *Assistant Professor, Department of Mechanical Engineering , School of Research and Technology, Bhopal, India*

ABSTRACT

The term solar air heating is a technology in which the radiant energy emitted by the sun is captured in an absorber and is used for space heating. Needless to say it is a renewable and pollution free method to produce space heating and when is used in commercial buildings or industries could be very cost effective.It is observed that the 2D analysis model itself yields results, which are closer to the experimental ones as compared to 3D models. The 3D model requires much higher memory and computational time compared to 2D ones. It may be because of negligible effect of secondary flow in transverse ribbed duct surface. Hence, it is sufficient to employ a simpler 2D model which being more economical with the memory and computational time requirement.

Keyword*:* *Solar, heating, 2D model, absorber, radiant energy*

I. INTRODUCTION

Artificial roughness up to laminar sub-layer to enhance heat transfer coefficient is used in various applications like solar air heaters, heat exchangers, nuclear reactors and gas turbine blade cooling channels. A number of experimental studies in this area have been carried out but very few attempts of numerical investigation have been made so far due to complexity of flow pattern and computational limitations. In this work, an attempt is made to predict numerically the details of both the velocity and temperature fields responsible for heat transfer enhancement. The presence of rib may enhance heat transfer because of interruption of the viscous sub layer, which yields flow turbulence, separation and reattachment leading to a higher heat transfer coefficient. The enhancement of heat transfer by flow separation and reattachment caused by ribs is significantly higher compared to that by the increased heat transfer area due to ribs (fin-effect). The heat transfer measurements results for six different rib spacing, p/e 5, 10,12,15,18 and 20, indicate the importance of roughness geometry have performed both the numerical analysis and experimental study to investigate the heat transfer and fluid flow behavior in a rectangular channel flow with stream wise periodic ribs mounted on one of the principal walls. They have concluded that the flow acceleration and the turbulence intensity are two major factors influencing the heat transfer coefficient. The combined effect is found to be optimum for the pitch to rib height ratio approximately equal to 10, which results in the maximum value of average heat transfer coefficient. Hence, these investigations reveal that not only the rib geometry but also its geometrical arrangement play a vital role in enhancing the heat transfer coefficient. Karwa has reported an experimental investigation for the same configuration for the Reynolds number range of 4000–16,000. Tanda [16] has carried out experimental investigation of heat transfer in a rectangular channel with transverse and V-shaped broken ribs using liquid crystal thermography. He concluded that features of the inter-rib distributions of the heat transfer coefficient are strongly related to rib shape and geometry; a relative maximum is typically attained downstream of each rib for continuous transverse ribs (due to flow reattachment).

ISSN : 2455-9679
SJIF Impact Factor : 6.008

The main aim of the present analysis is to investigate the flow and heat transfer characteristics of a two-dimensional rib roughened rectangular duct with only one principal (broad) wall subjected to uniform heat flux by making use of computer simulation. The ribs are provided only on the heated wall. The other three walls are smooth (without ribs) and insulated. Such a case is encountered in solar air heaters with artificially roughened absorber plate. The following section presents the selection and validation of model and detailed analysis using selected model followed by results and discussion.

Energy in various forms has played an increasingly important role in world wide economic progress and industrialization. In view of the world's depleting fossil fuel reserves, which provide the major source of energy, the development of non-conventional renewable energy sources has received an impetus. Sunlight available freely as a direct and conventional source of energy provides a non-polluting reservoir of fuel. The simplest and the most efficient way to utilize solar energy is to convert it into thermal energy for heating applications by using solar collectors.

Solar air heaters, because of their inherent simplicity are cheap and most widely used collection devices. The main applications of solar air heaters are space heating; seasoning of timber, curing of industrial products, and these can also be effectively used for curing/drying of concrete/clay building components. The solar air heater occupies an important place among solar heating system because of minimal use of materials and cost. The thermal efficiency of solar air heaters in comparison of solar water heaters has been found to be generally poor because of their inherently low heat transfer capability between the absorber plate and air flowing in the duct. In order to make the solar air heaters economically viable, their thermal efficiency needs to be improved by enhancing the heat transfer coefficient. There are two basic methods for improving the heat transfer coefficient between the absorber plate and air. The first method involves increasing the area of heat transfer by using corrugated surfaces or extended surfaces called fins without affecting the convective heat transfer coefficient. The second method involves increasing the convective heat transfer by creating turbulence at the heat-transferring surface. This can be achieved by providing artificial roughness on the underside of absorber plate. Many investigators have attempted to design a roughness element, which can enhance convective heat transfer with minimum increase in friction losses.

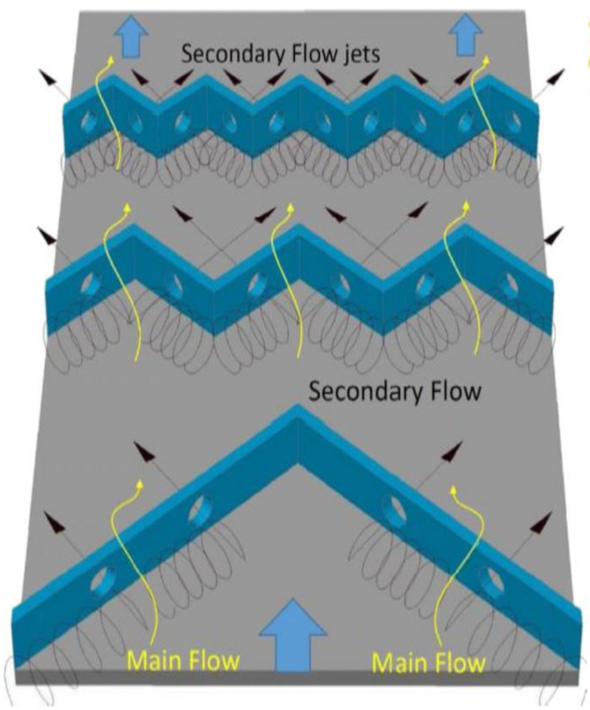


Figure.1 Solar ribs

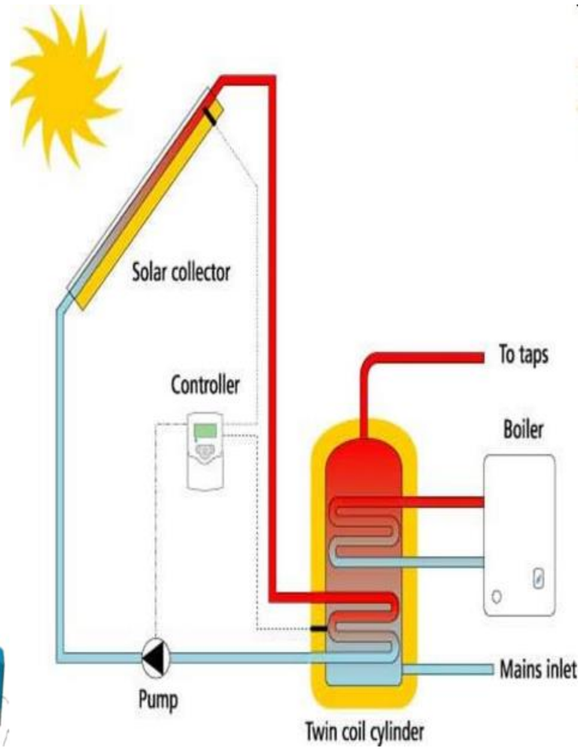


Figure 2. Solar Energy System [19]

ISSN : 2455-9679
SJIF Impact Factor : 6.008

II. Methodology

Once you have determined the important features of the problem you want to solve, you will follow the basic procedural steps shown below.

1. Create the model geometry and grid.
2. Start the appropriate solver for 2D or 3D modeling.
3. Import the grid.
4. Check the grid.
5. Select the solver formulation.
6. Choose the basic equations to be solved laminar or turbulent (or Inviscid), chemical species or reaction, heat transfer models, etc. Identify additional models needed: fans, heat exchangers, porous media, etc.
7. Specify material properties.
8. Specify the boundary conditions.
9. Adjust the solution control parameters.
10. Initialize the flow field.
11. Calculate a solution.
12. Examine the results.
13. Save the results.
14. If necessary, refine the grid or consider revisions to the numerical or physical model.

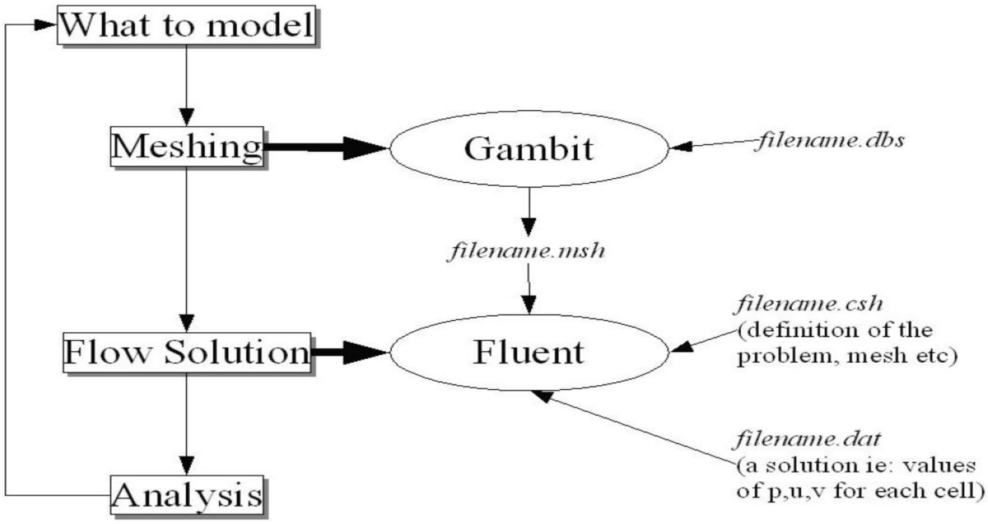
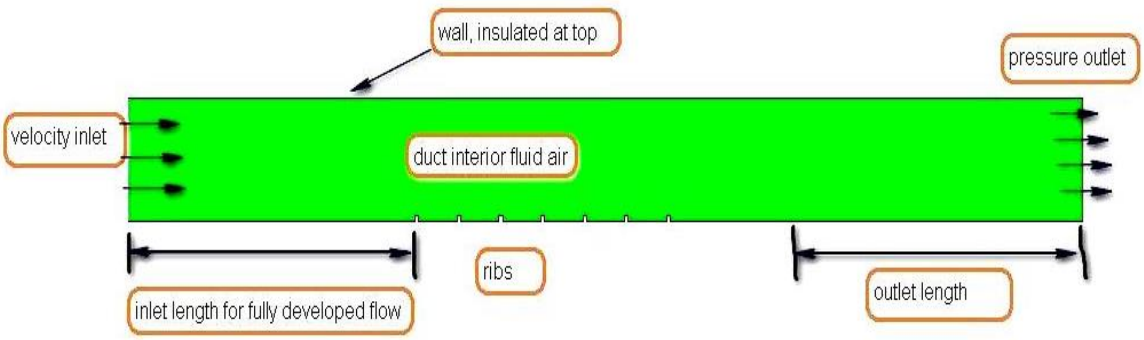


Figure 2.1 Working steps in Gambit and Fluent Solver

III. Simulation

Define Boundary Conditions



ISSN : 2455-9679
SJIF Impact Factor : 6.008

HEAT TRANSFER IN ROUGHENED DUCT

The flow and heat transfer characteristics get affected in the flow direction due to rib provided in the form of artificial roughness. In the vicinity of the rib the values of Nusselt number has been found to be low. The reason may be that heat transfer takes place around the rib due to conduction only. The values of Nusselt number have been observed to attain very high value upstream and downstream of the rib. Nusselt number starts decreasing as the flow approaches the rib and near rib region it drops down to lower value. However, as the flow past the rib in the downstream, the Nusselt number increases. The increase in Nusselt is attributed to the variation in flow parameters downstream of the rib. The presence of rib along the flow direction creates vortices just downstream of the rib and the fluid also separates from the wall. Separation of flow decreases heat transfer whereas vortices make fluid to mix thus increasing heat transfer. Downstream of the rib in its vicinity, vortices effect will be predominant than flow separation effect, thus values of Nusselt number increases in this region As Reynolds number increases, Nusselt number also increases in inter-rib regions.

CFD results have critically analyzed the flow separation and reattachment to explain other related phenomenon such as increase in Nusselt number for different roughness parameters.

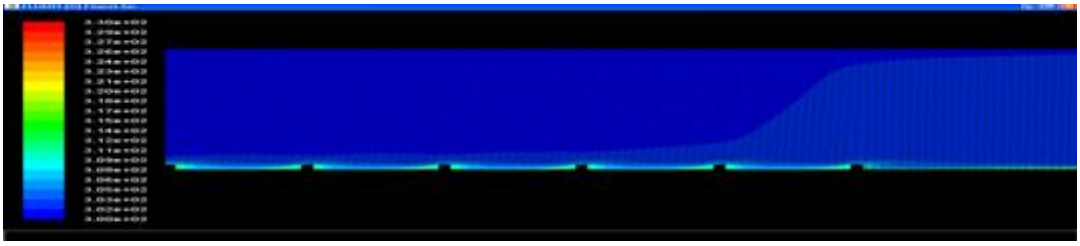


Figure 3.1 Temperature profile for Square ribs (a)

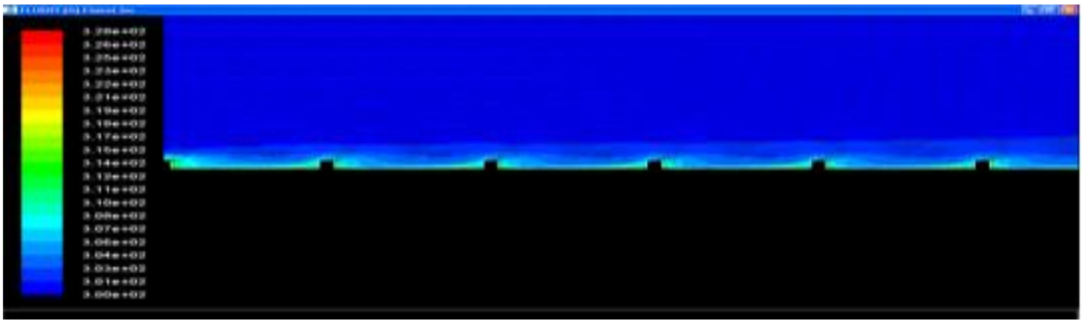


Figure 3.2 Temperature profile for Square rib (b)

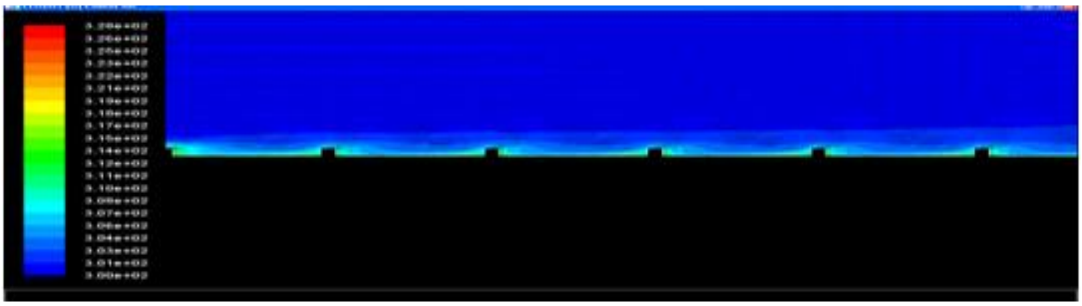


Figure 3.3 Temperature profile for semicircular rib

ISSN : 2455-9679
SJIF Impact Factor : 6.008

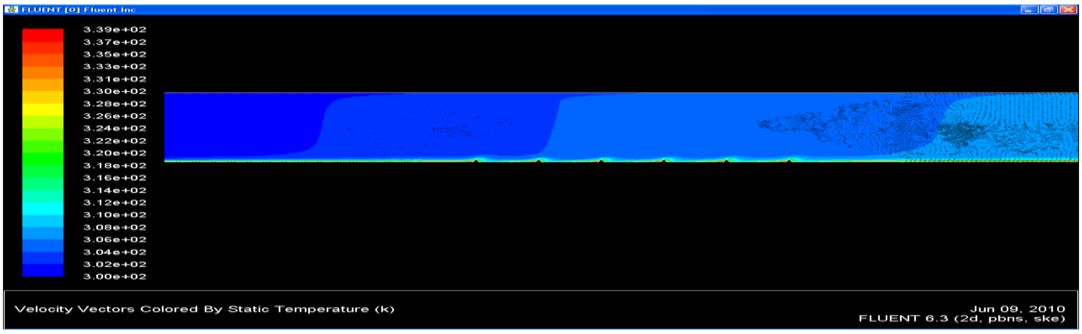


Figure 3.4 Temperature profile for Triangular ribs

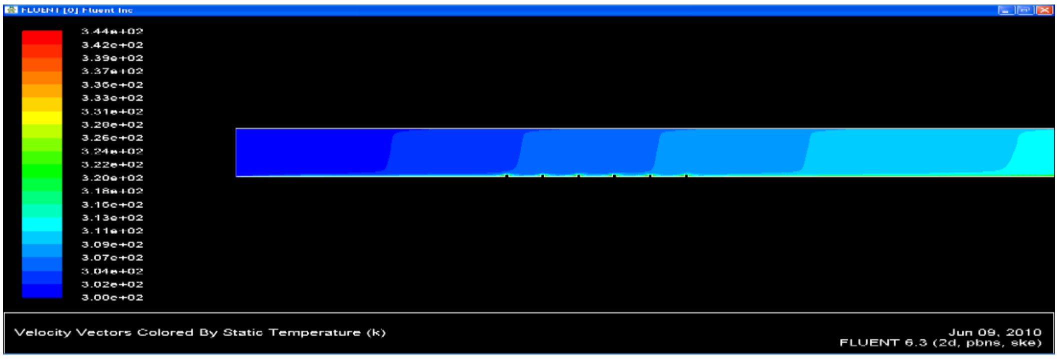


Figure 3.5 Temperature profile for semicircular ribs

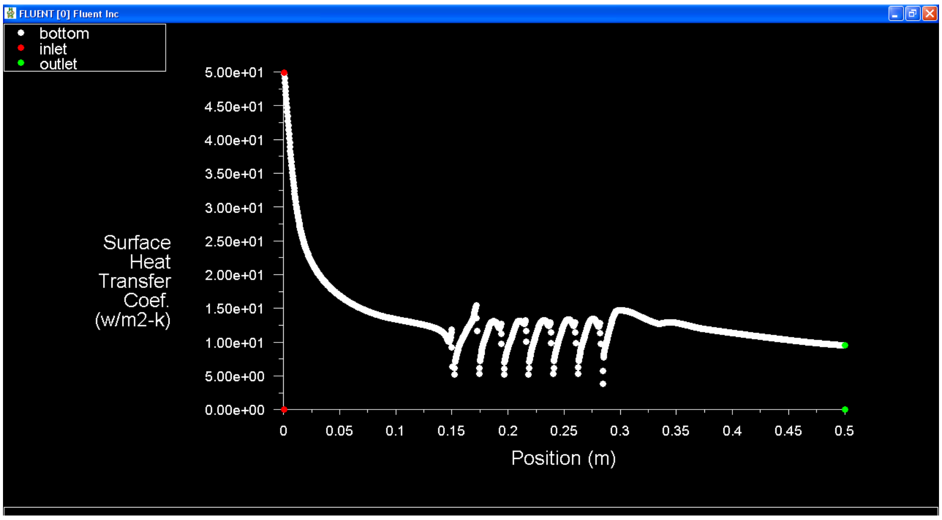


Figure 3.6 Variation in heat transfer coefficient along the Solar plate, When Re=10000, I=800 W/m2

IV. Result

COMPARISON OF AVERAGE HEAT TRANSFER AND FRICTIONB CHARACTERISTICS

The normalized friction factors in a square duct roughened with various-shaped ribs at the same pitch ratio (P/e =12). In the given Reynolds number range, the trapezoidal-shaped ribs have the highest friction loss; whereas, the trapezoidal-shaped ribs have the lowest pressure drop. Furthermore, the triangular-shaped ribs have slightly higher friction factor than that of square-shaped ribs. Based on the law of the wall similarity, Chandra et al. developed semi empirical formulas to predict the heat transfer coefficient and friction factor in a square duct roughened by the square-shaped ribs on one wall.

ISSN : 2455-9679
SJIF Impact Factor : 6.008

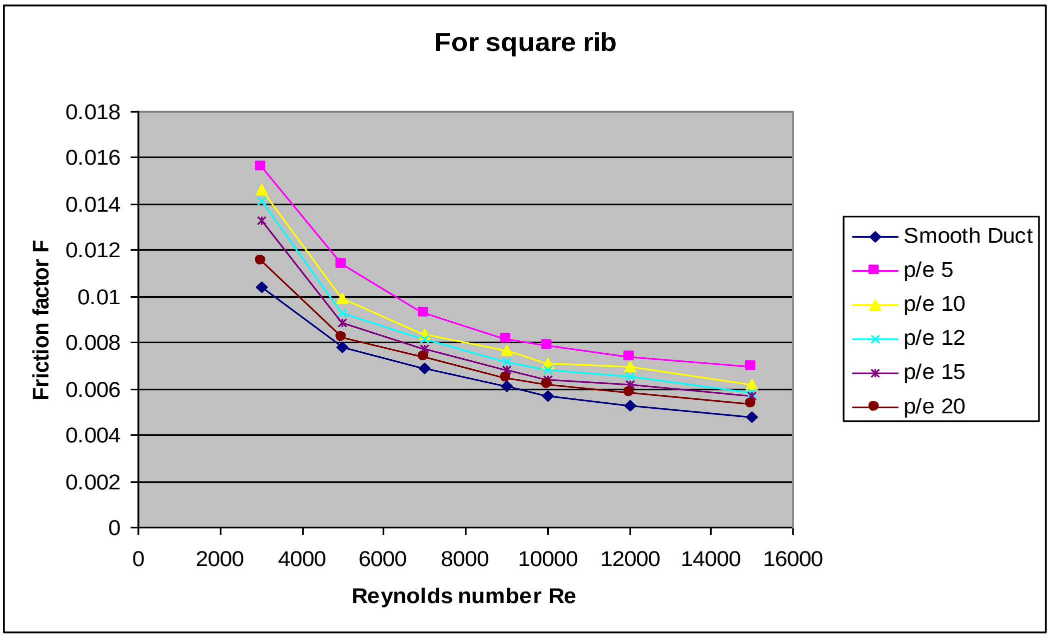


Figure 4.1 Variation of Friction factor with Reynolds number for Square Ribs

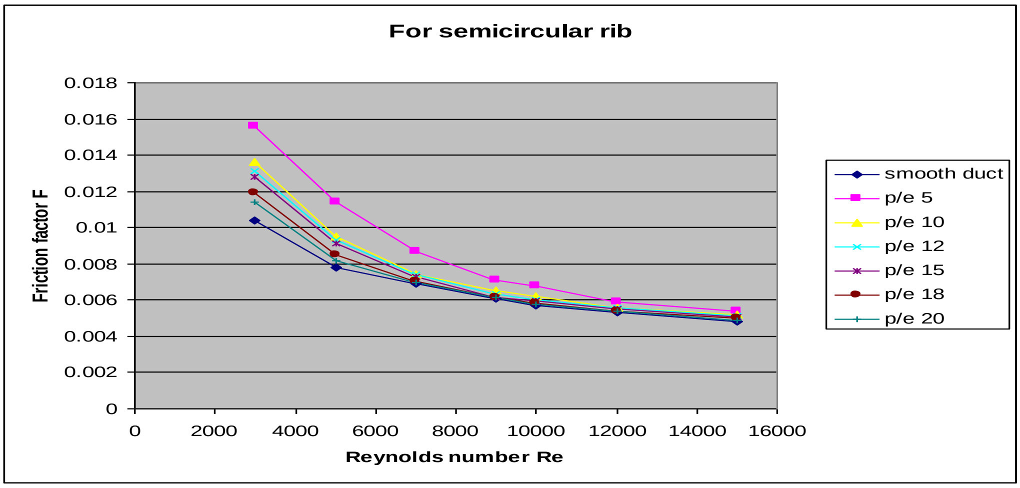


Figure 4.2 Variation of Friction factor with Reynolds number for Semicircular ribs

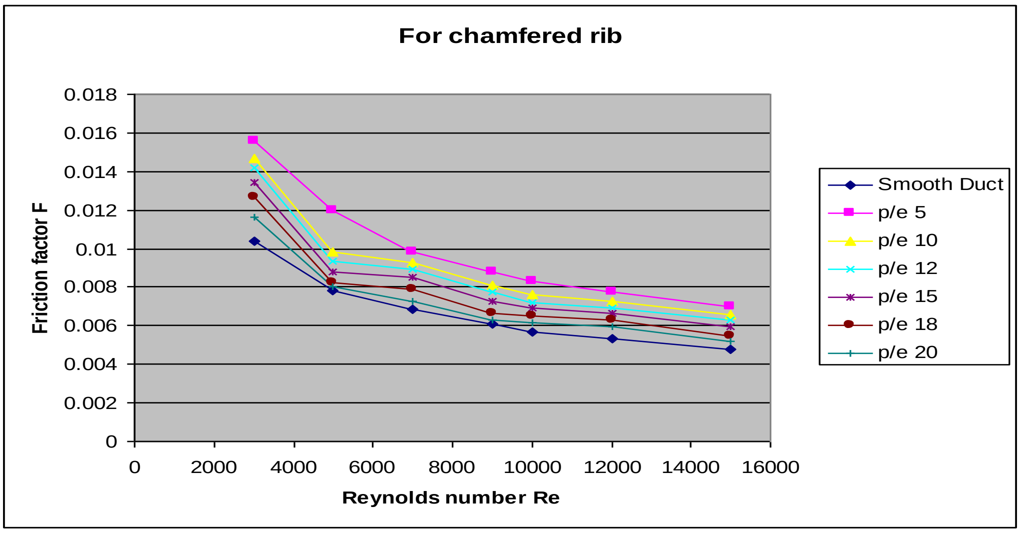


Figure 4.3 Variation of Friction factor with Reynolds number for Chamfered rib

ISSN : 2455-9679
SJIF Impact Factor : 6.008

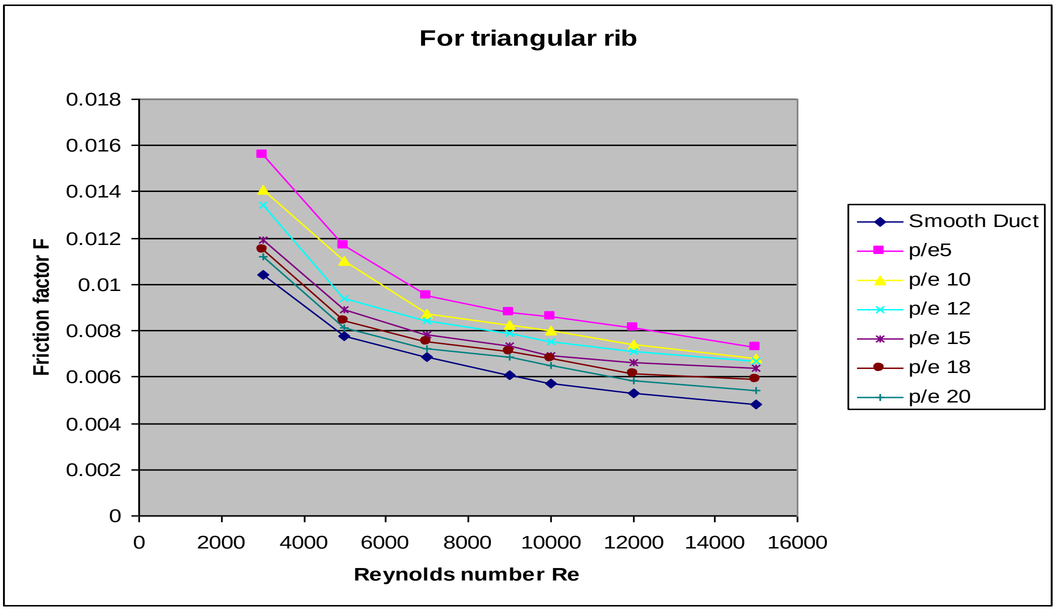


Figure 4.4 Variation of Friction factor with Reynolds number for triangular rib

V. CONCLUSION

The Following broad conclusions can be drawn from the Results and Discussion:The present analysis demonstrates that the SST K-w model gives good results for the prediction of heat transfer and friction characteristics in high aspect ratio rib roughened rectangular duct. In the view of present analysis the following conclusions are drawn:

1. It is observed that the 2D analysis model itself yields results, which are closer to the experimental ones as compared to 3D models. The 3D model requires much higher memory and computational time compared to 2D ones. It may be because of negligible effect of secondary flow in transverse ribbed duct surface. Hence, it is sufficient to employ a simpler 2D model which being more economical with the memory and computational time requirement.
2. In the inter-rib region, the model predicts well near the central high heat transfer area but it under predicts around ribs.
3. The turbulence intensity is found maximum at peak of the local heat transfer coefficient in the inter-rib regions.
4. Chamfered shape ribs giving highest heat transfer enhancement. So It giving 3 to 4 times Nusselt Number enhancement as compared to smooth duct.
5. CFD results also predicted that Nusselt number also increasing as ribs spacing increasing.
6. Thermal performance is decreases as Reynolds number is increasing. Thermal performance of square ribs is decreasing as Reynolds number increasing from 5000 to 8000, but as Reynolds number goes 8000 to 9000 then slightly increase in thermal performance.
7. Because of artificial roughness Nusselt number is increasing but simultaneously it will also increasing friction factor. So performance of solar air heater duct can be provided on the basis of thermo hydraulic performance which incorporates both the thermal as well as hydraulic considerations.
8. The local heat transfer is strongly dependent on the rib shape in the region just downstream the rib while this dependence is small in the boundary layer redevelopment zone. The trapezoidal-shaped rib is the most likely one to suppress the local hot spot.

REFERENCES

[1] Verma, S.K.; Prasad, B.N. Investigation for the optimal thermohydraulic performance of artificially roughened solar air heaters. Renew. Energy 2000, 20, 19–36. [Google Scholar] [CrossRef]

ISSN : 2455-9679
SJIF Impact Factor : 6.008

[2] Alam, T.; Saini, R.P.; Saini, J.S. Effect of circularity of perforation holes in V-shaped blockages on heat transfer and friction characteristics of rectangular solar air heater duct. Energy Convers. Manag. 2014, 86, 952–963. [Google Scholar] [CrossRef]
[3] Yadav, A.S.; Bhagoria, J.L. A CFD (computational fluid dynamics) based heat transfer and fluid flow analysis of a solar air heater provided with circular transverse wire rib roughness on the absorber plate. Energy 2013, 55, 1127–1142. [Google Scholar] [CrossRef]
[4] Yadav, A.S.; Bhagoria, J.L. A CFD based thermo-hydraulic performance analysis of an artificially roughened solar air heater having equilateral triangular sectioned rib roughness on the absorber plate. Int. J. Heat Mass Transf. 2014, 70, 1016–1039. [Google Scholar] [CrossRef]
[5] Yadav, A.S.; Bhagoria, J.L. A numerical investigation of square sectioned transverse rib roughened solar air heater. Int. J. Therm. Sci. 2014, 79, 111–131. [Google Scholar] [CrossRef]
[6] Singh, S.; Singh, B.; Hans, V.S.; Gill, R.S. CFD (computational fluid dynamics) investigation on Nusselt number and friction factor of solar air heater duct roughened with non-uniform cross-section transverse rib. Energy 2015, 84, 509–517. [Google Scholar] [CrossRef]
[7] Akpinar, E.K.; Koçyiğit, F. Experimental investigation of thermal performance of solar air heater having different obstacles on absorber plates. Int. Commun. Heat Mass Transf. 2010, 37, 416–421. [Google Scholar] [CrossRef]
[8] Singh, A.P. Heat transfer and friction factor correlations for multiple arc shape roughness elements on the absorber plate used in solar air heaters. Exp. Therm. Fluid Sci. 2014, 54, 117–126. [Google Scholar] [CrossRef]
[9] Singh, S.; Chander, S.; Saini, J.S. Heat transfer and friction factor correlations of solar air heater ducts artificially roughened with discrete V-down ribs. Energy 2011, 36, 5053–5064. [Google Scholar] [CrossRef]
[10] Kumar, A.; Kim, M.-H. CFD Analysis on the Thermal Hydraulic Performance of an SAH Duct with Multi V-Shape Roughened Ribs. Energies 2016, 9, 415.
[11] Karim, M.A.; Hawlader, M.N.A. Development of solar air collectors for drying applications. Energy Convers. Manag. 2004, 45, 329–344. [Google Scholar] [Ho, C.D.; Hsiao, C.F.; Chang, H.; Tien, Y.E.; Hong, Z.S. Efficiency of recycling double-pass V-corrugated solar air collectors. Energies 2017, 10, 875. [Google Scholar] [CrossRef][Green Version]
[12] Zheng, W.; Zhang, H.; You, S.; Fu, Y. Experimental investigation of the transpired solar air collectors and metal corrugated packing solar air collectors. Energies 2017, 10, 302. [Google Scholar] [CrossRef][Green Version]
[13] Kabeel, A.E.; Hamed, M.H.; Omara, Z.M.; Kandeal, A.W. Solar air heaters: Design configurations, improvement methods and applications–A detailed review. Renew. Sustain. Energy Rev. 2016, 70, 1189–1206. [Google Scholar] [CrossRef]
[14] Gawande, V.B.; Dhoble, A.S.; Zodpe, D.B.; Chamoli, S. A review of CFD methodology used in literature for predicting thermo-hydraulic performance of a roughened solar air heater. Renew. Sustain. Energy Rev. 2016, 54, 550–605. [Google
[15] Kumar, B.V.; Manikandan, G.; Kanna, P.R.; Taler, D.; Taler, J.; Nowak-Ocłoń, M.; Mzyk, K.; Toh, H.T. A performance evaluation of a solar air heater using different shaped ribs mounted on the absorber plate—A review. Energies 2018, 11, 3104. [Google Scholar] [CrossRef][Green Version]
[16] Alam, T.; Saini, R.P.; Saini, J.S. Heat and flow characteristics of air heater ducts provided with turbulators—A review. Renew. Sustain. Energy Rev. 2014, 31, 289–304. [Google Scholar] [CrossRef]
[17] Ho, C.D.; Chang, H.; Hsiao, C.F.; Huang, C.C. Device performance improvement of recycling double-pass cross-corrugated solar air collectors. Energies 2018, 11, 338. [Google Scholar] [CrossRef][Green Version]
[18] Singh, S. Thermal performance analysis of semicircular and triangular cross-sectioned duct solar air heaters under external recycle. J. Energy Storage 2018, 20, 316–336. [Google Scholar] [CrossRef]
[19] Pushkar Dwivedi, Shankar Singh" Review Paper on the Use of Artificial Roughness inside a Solar Air Duct to Increase the Heat Transfer Rate Inside It" International Journal of Scientific Engineering and Technology Volume 2 Issue 4, pp : 314-317, 1 April 2013 (ISSN : 2277-1581)