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Numerical Heat Transfer and Turbulent Flow in a Circular Tube Fitted with Opened Rings Having Square Cross Section

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ABSTRACT

In this study; heat transfer and thermal performance characteristics are numerically investigated in a steel tube of 50 cm long, outside diameter of 60 mm and inside diameter of 30 mm with constant outside surface temperature of 1000, 1200 and 1400 K^o. The renormalization group k-ε model is used to simulate turbulence in ANSYS - FLUENT 14.5. The ribs assembly (5x5 mm cross section) were fitted in the tube and separated by 8cm pitch. Results of temperature and velocity distribution along the tube center line for the case of tube with internal ribs were compared with that of plain tube, these results show that the use of internal ribs enhance the heat transfer rate and found to possess the highest performance factors for turbulent flow.

KEYWORDS: CFD, heat transfer enhancement, cooling enhancement, internal ribs, turbulators and turbulent flow.

1. INTRODUCTION

Heat transfer enhancement technology is the process of improving the performance of a heat transfer system by increasing the convection and radiation heat transfer coefficients. Over the past forty years, this technology has been extensively used in heat exchangers and other heat transfer equipment in thermal power plants, chemical processing plants, air conditioning equipment, refrigerators and vehicle radiators [Marner-1983, Bergles-1985]. The use of the turbulence promoters or roughness elements, such as ribs, grooves or wires on the surface, is a common passive technique to enhance the rate of heat transfer [Bilen, 2009].Turbulator devices inserted in tubes have been commonly used so as to improve the heat transfer in heat exchangers. Turbulators create asecondary flow and so the boundary layers of fluid occurred near the surface of tube are distributed. To enhance heat transfer in heat exchangers, the several shaped turbulators have been investigated such V-nozzle, conical-nozzle, combined conical-ring and coiled wire, circular cross sectional ring, baffles and so on [Eiamsa-ard-2006,Yakut-2004,Promvonge-2007,Ozceyhan-2008,Onur-2007].

Bergles and Webb [Bergles-1985, Webb-1994] have reported comprehensive reviews on techniques for heat transfer enhancement. For a single-phase heat transfer, the enhancement has been brought using roughened surfaces and other augmentation techniques, such as swirl/vortex flow devices and modifications to duct cross sections and surfaces.

Cheng and Kuznetsov [Cheng, 2005] carried out an investigation of laminar flow in a helical pipe filled with a fluid saturated porous medium.

Rahimi et al. [Rahimi, 2009] carried out experimental and CFD studies on heat transfer and friction factor characteristics of a tube equipped with modified twisted-tape inserts. The investigations are with the classic and three modified twisted-tape inserts.

Smithberg and Landis [Smithberg, 1964] have estimated the tape-fin effect assuming a uniform heat transfer coefficient on the tape wall, equal to that on the tube wall.

Megerlin et al. [Megerlin, 1974] carried out the experiments with spiral brush inserts for turbulent flows and found out that heat transfer coefficient can be improved as much as 8.5 times that in a smooth tube, but pressure drop was very high.

In this paper, the effect of fitting opened rings with square cross section in a pipe with internal air flow and constant wall surface temperature will be investigated.

2. CFD METHODOLOGY

In this investigation a 3-D numerical simulation of the conjugate heat transfer was conducted using the CFD code FLUENT 14.5. The CFD modeling involves numerical solutions of the conservation equations for mass, momentum and energy. These three equations are used to model the convective

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heat transfer process with the following assumptions, (a) steady 3-D fluid flow and heat transfer, (b) incompressible fluid and flow, and (c) physical properties of cooling fluid are temperature dependent. These equations for incompressible flows can be written as follows:

2.1 mass conservation:

$$\frac{\partial(u_i)}{\partial x_i} = 0..........................(1)$$

2.2 momentum conservation:

$$\frac{\partial(u_i)(u_j)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}[\mu(\frac{\partial(u_i)}{\partial x_j} + \frac{\partial(u_j)}{\partial x_i}) - \rho(u_i^{/}u_j^{/})] + \rho g_i ....(2)$$

2.3 Energy Conservation:

$$\frac{\partial}{\partial x_i}((u_i)(\rho E + p)) = \frac{\partial}{\partial x_i}(K_{eff}\frac{\partial T}{\partial x_i} + u_j(\tau_{ij})_{eff}).......................(3)$$

2.4 Boundary conditions:

The boundary zone location is specified in the GAMBIT itself; the inlet, outlet and the wall condition location is specified.

2.5 Fluid entry boundary condition:

The inlet air flow velocity is 10 m/s with constant temperature of 300 K^{o}.

2.6 Wall Boundary Conditions:

The pipe wall is provided with wall boundary condition, a constant heat flux is provided for plain and ribbed tube. The outside surface wall temperature is varied from 1000 to 1200 and 1400 K^{o}.

2.7 Detailed geometry of the Test Section

The test section shown in fig. (1) is steel tube with outside diameter of 60 mm and inside diameter of 30 mm at which the air is flow in , and having steel square cross section opened rings (5x5 mm) located at each 8 mm along the tube. The test section was drawn using AUTO CAD 2013.

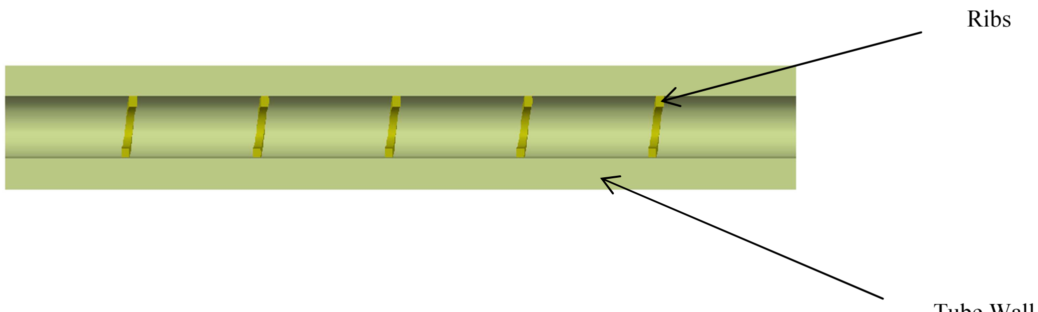


Fig. 1. Geometry of the Test Section

3. RESULTS AND DISCUSSION

Figures (2), (3) and (4) show the contours of temperature distribution along the whole test section geometry at constant surface wall temperatures of 1000, 1200 and 1400 K^{O}, respectively.

Figure (5).shows the temperature distribution along the pipe center line for two cases , one without ribs and the other with ribs at surrounding surface temperature of 1000K^{o}. It shows that the pipe with ribs has highest outlet air temperature. This means that the pipe with ribs, has highest surface area resulted in enhancing the heat transfer.

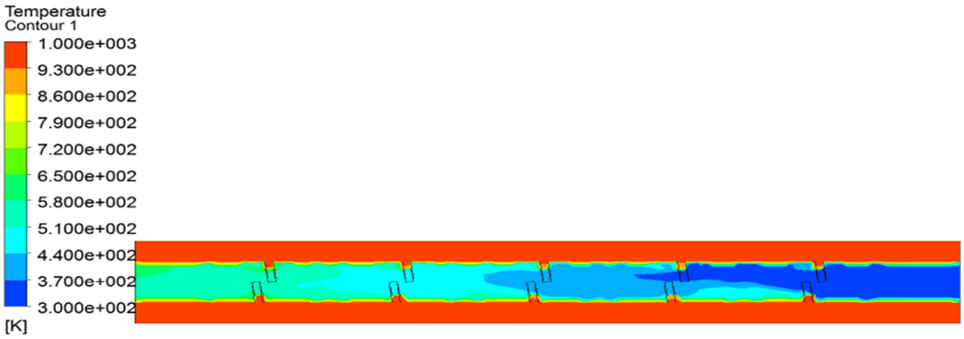
Figure (6).shows the temperature distribution along the pipe center line for two cases , one without ribs and the other with ribs at surrounding surface temperature of 1200K^{o}. It shows that the pipe with ribs has highest outlet air temperature. This means that the pipe with ribs, has highest surface area resulted in enhancing the heat transfer.

Figure (7).shows the temperature distribution along the pipe center line for two cases, one without ribs and the other with ribs at surrounding surface temperature of 1400K^{o}. It shows that the pipe with ribs has highest outlet air temperature. This means that the pipe with ribs, has highest surface area resulted in enhancing the heat transfer.

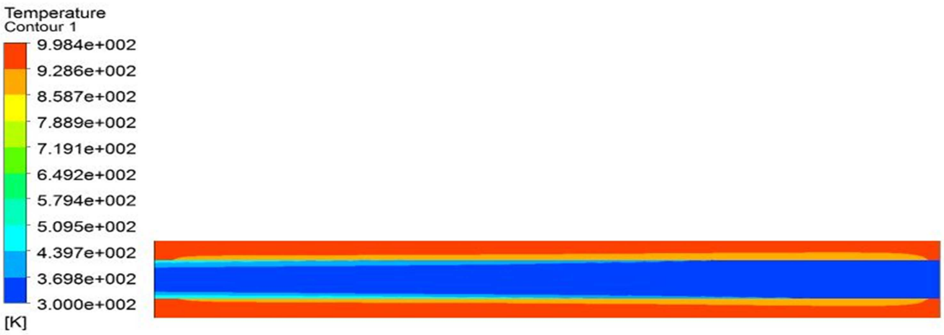
Figure (8) shows the velocity distribution along the pipe center line for two cases, one without ribs and the other with ribs at surrounding surface temperature of 1000 K^{o}. It shows that the pipe with internal ribs having more velocity distribution than the case of plain pipe. This because of the swirls generated from the use of opened rings.

Figure (9) shows the velocity distribution along the pipe center line for two cases, one without ribs and the other with ribs at surrounding surface temperature of 1200 K^{o}. It shows that the pipe with internal ribs having more velocity distribution than the case of plain pipe. This because of the swirls generated from the use of opened rings.

Figure (10) shows the velocity distribution along the pipe center line for two cases, one without ribs and the other with ribs at surrounding surface temperature of 1400 K^{o}. It shows that the pipe with internal ribs having more velocity distribution than the case of plain pipe. This because of the swirls generated from the use of opened rings.

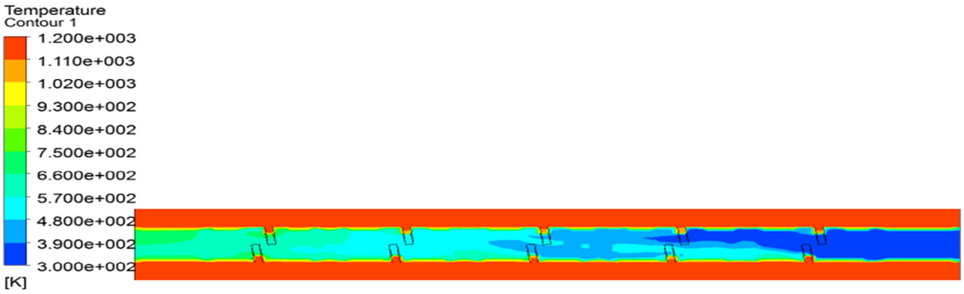


(A)

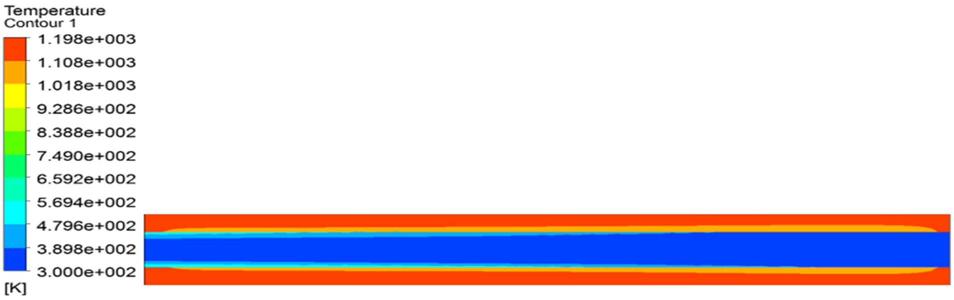


(B)

Fig.2. Contour of Temperature Distribution at Constant Surface Temperature (1000 k^{o})
(A) With Ribs
(B) Without Ribs

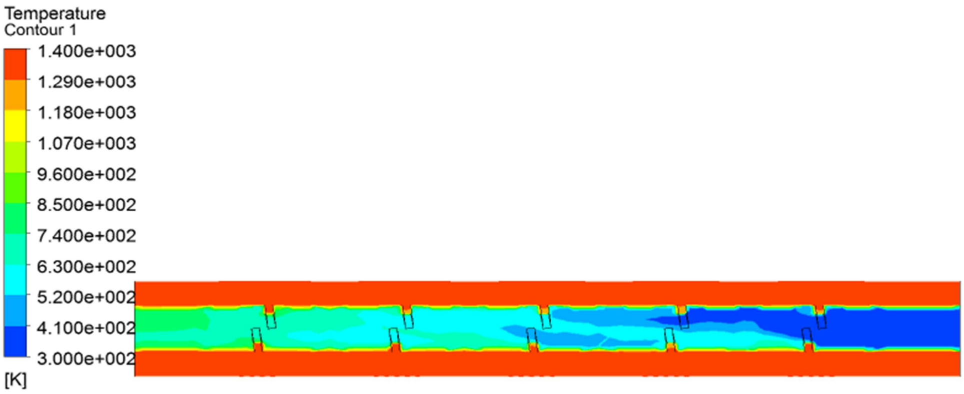


(A)



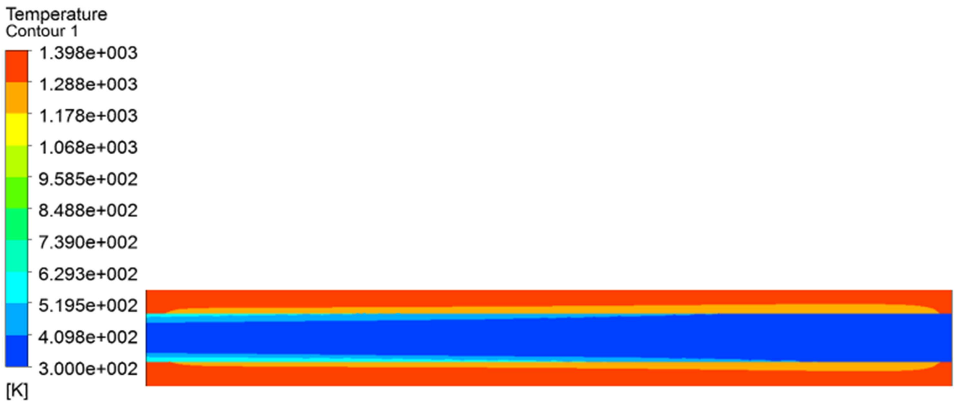
(B)

Fig.3. Contour of Temperature Distribution at Constant Surface Temperature (1200 k^o)
(A) With Ribs
(B) Without Ribs



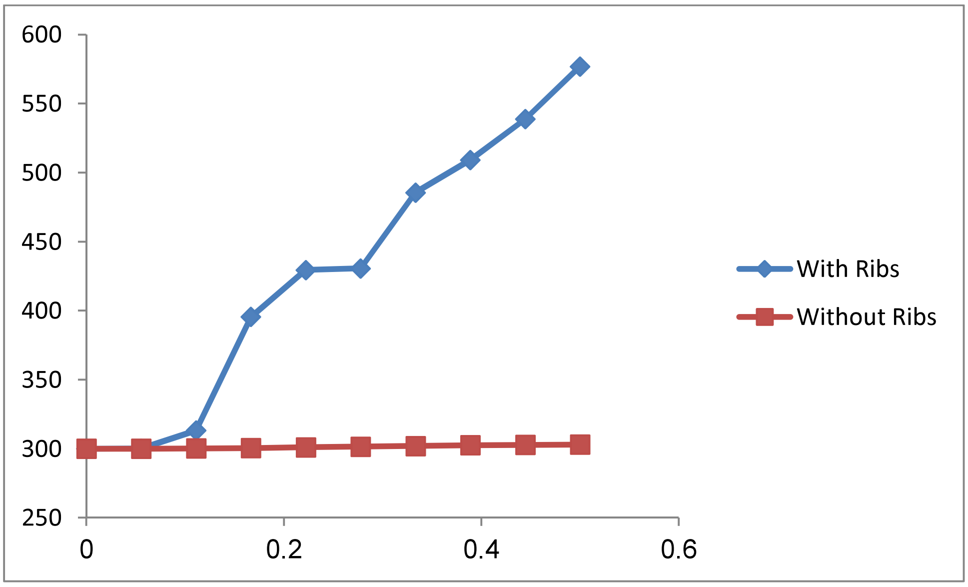
(A)

Temperature (K°)



(B)

Fig.4. Contour of Temperature Distribution at Constant Surface Temperature (1400 k°)
(A) With Ribs
(B) Without Ribs



Distance (m)

Fig.5.Variation of Temperature Along the Center line of Tube at Constant Surface Temperature (1000 K°)

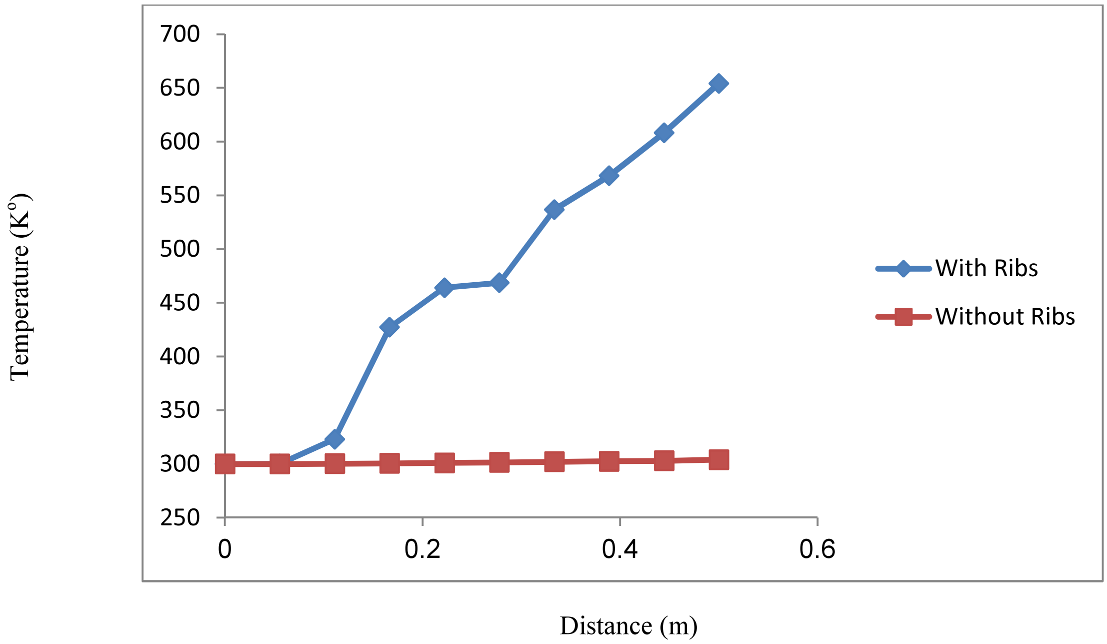


Fig.6.Variation of Temperature Along the Center line of Tube at Constant Surface Temperature **(1200 K°)**

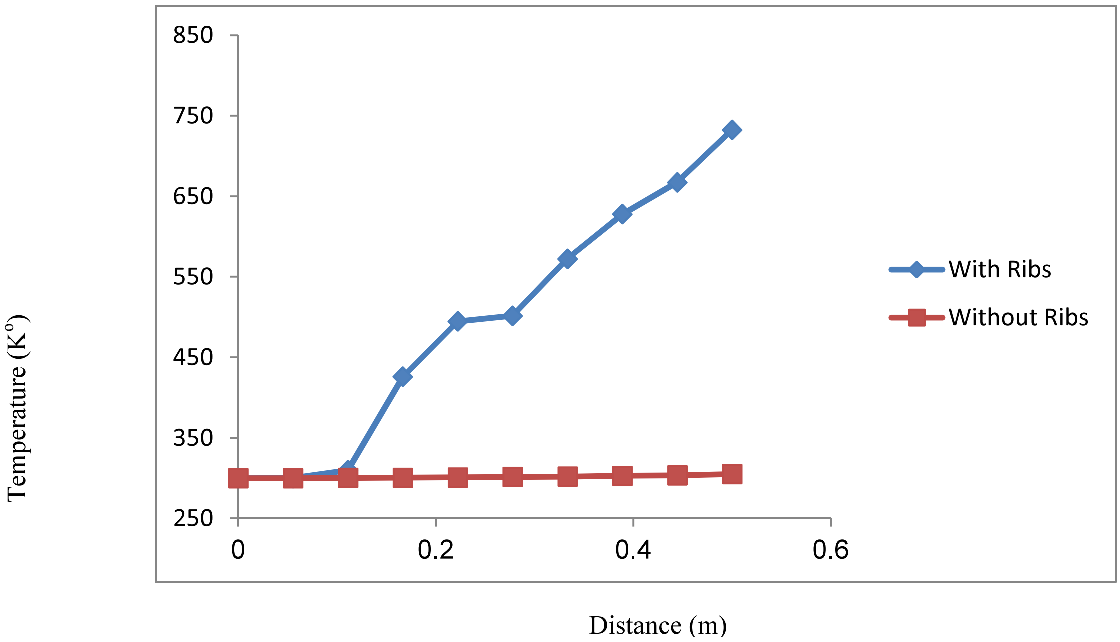


Fig. 7.Variation of Temperature Along the Center line of Tube at Constant Surface Temperature (1400 K°)

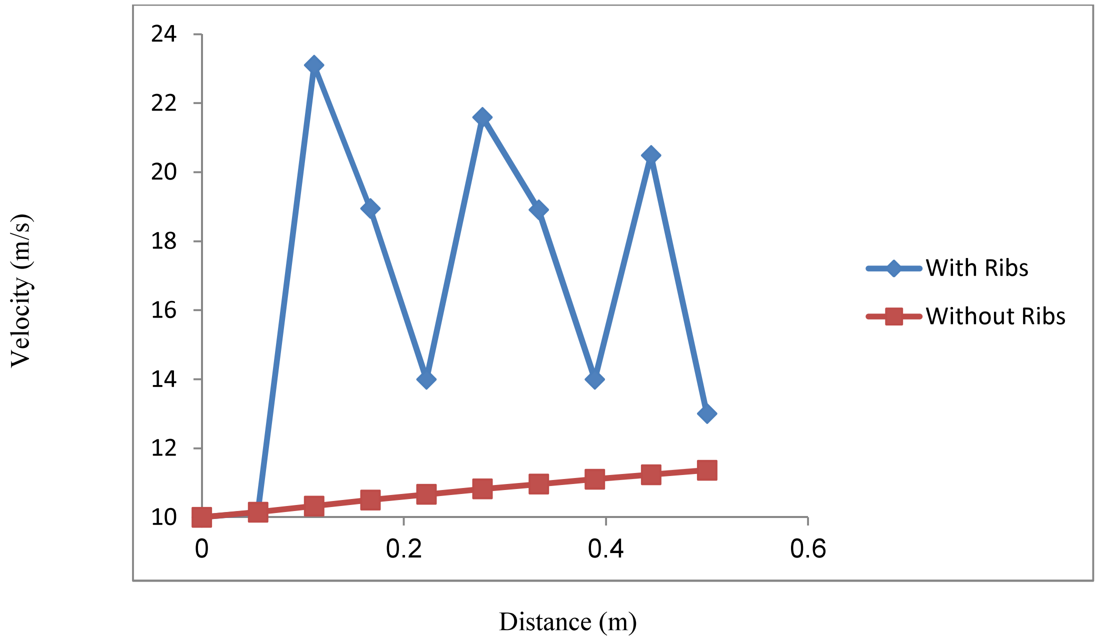


Fig. 8. Variation of Velocity Along the Center line of Tube at Constant Surface Temperature (1000 K°)

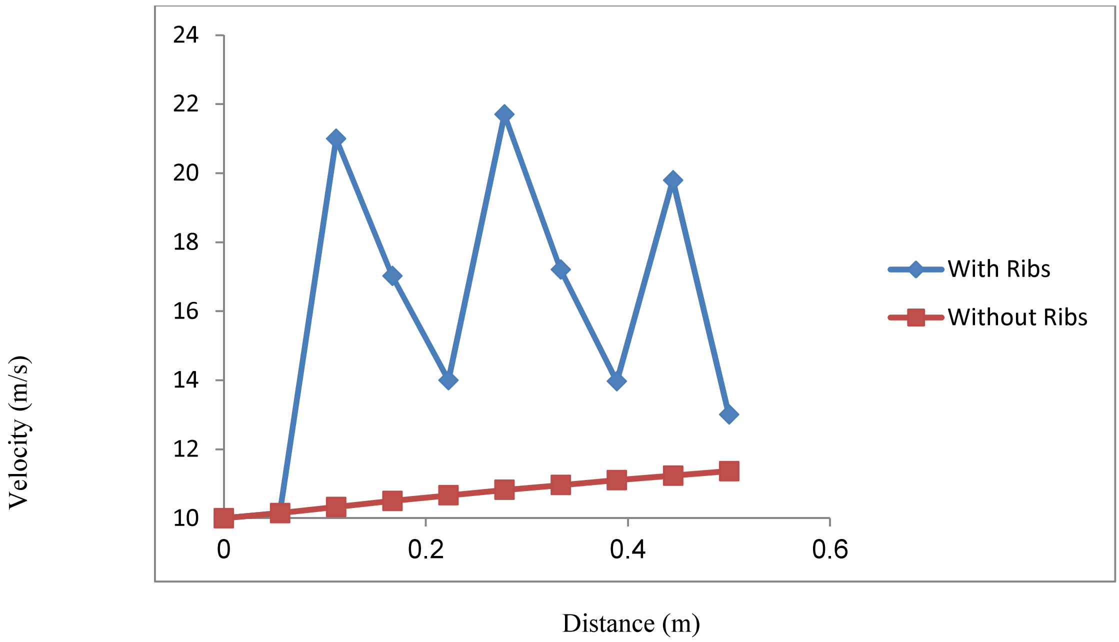


Fig. 9. Variation of Velocity Along the Center line of Tube at Constant Surface Temperature (1200 K°)

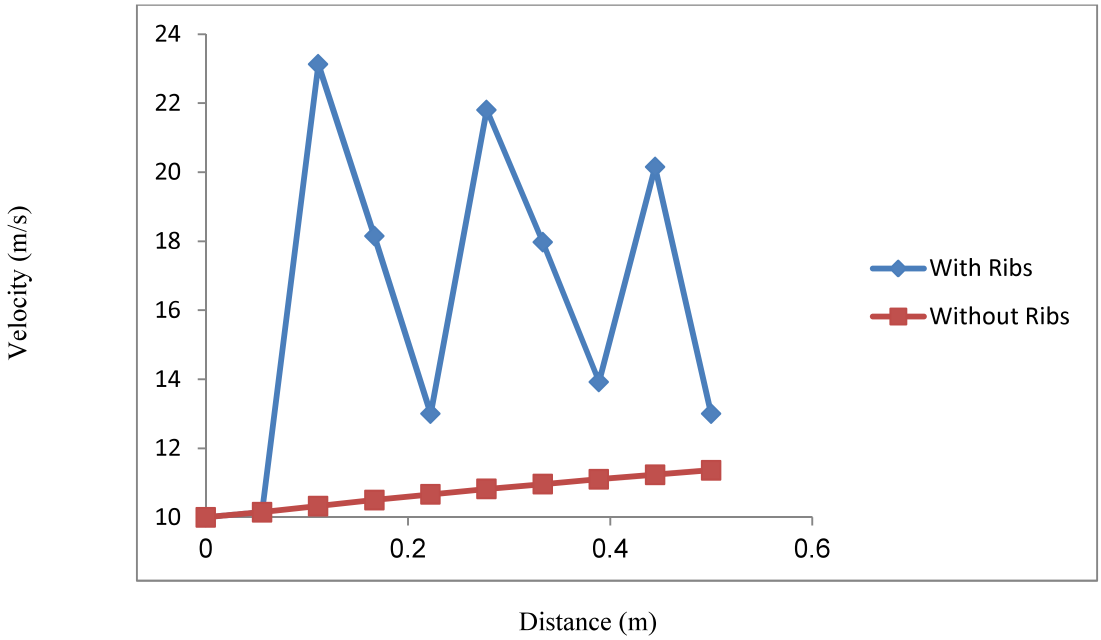


Fig. 10. Variation of Velocity Along the Center line of Tube at Constant Surface Temperature (1400 K^o)

4. Conclusions

Numerical simulation has been presented on heat transfer characteristics for the flow of cooling air in heated tube under steady state turbulent flow. The CFD predictions for the case of tube with ribs were compared against the tube without ribs.

The following conclusions can be drawn from the present study:

1. CFD predictions were shown to reproduce the enhancement in heat transfer for the use of internal ribs, with respect to the plain tube.
2. Based on CFD analysis, higher thermal hydraulic performance were obtained for the tube with ribs than the tube without ribs.
3. tube with ribs gave more velocity disturbance than the tube without ribs.
4. The temperature of the plain pipe was found to be approximately unaffected for cases of 1000, 1200 and 1400 K^o. While when ribs are used, the effect was to increase the temperature by 275 , 375 , and 450K^o for the cases above, respectively.

REFERENCES

A. E. Bergles, “Techniques to augment heat transfer,” in Handbook of Heat Transfer Applications, J. P. Hartnett, W.M. Rohsenow, and E. N. Ganic, Eds., chapter 1, McGraw-Hill, New York, NY, USA, 2nd edition, 1985.

Bergles A.E. and Webb R.L., Guide to the literature on convection heat transfer augmentation, Advanced in Enhanced Heat Transfer, 43, 81–89 (1985).

Bergles A.E., Techniques to augment heat transfer, In: Rohsenow W.M., Hartnett J.P. and Ganie E., (Eds) Handbook of Heat Transfer Application, McGraw-Hill, New York, (1985).

Bilen, K., Çetin, M., Gül, H. and T. Balta, The investigation of groove geometry effect on heat transfer for internally grooved tubes, Appl. Therm. Eng. 29(4),753-761, 2009.

Eiamsa-ard, S. and Promvonge, P., Experimental investigation of heat transfer and friction characteristics in a circular tube fitted with V-nozzle turbulators, IntCommun Heat Mass Transfer 33, 591–600, 2006.

E. Smithberg and F. Landis, "Friction and forced convection heat transfer characteristics in tubes with twisted tape swirl generators," Journal of Heat Transfer, vol. 86, no. 1, pp. 39–49,1964.

L. Cheng and A. V. Kuznetsov, "Investigation of laminar flow in a helical pipe filled with a fluid saturated porous medium," European Journal of Mechanics, B/Fluids, vol. 24, no. 3, pp.338–352, 2005.

L. Cheng and A. V. Kuznetsov, "Heat transfer in a laminar flow in a helical pipe filled with a fluid saturated porous medium," International Journal of Thermal Sciences, vol. 44, no. 8, pp.787–798, 2005.

M. Rahimi, S. R. Shabanian, and A. A. Alsairafi, "Experimental and CFD studies on heat transfer and friction factor characteristics of a tube equipped with modified twisted tape inserts," Chemical Engineering and Processing, vol. 48, no. 3, pp. 762–770, 2009.

Megerlin et al., 1974. F.E. Megerlin, R.W. Murphy and A.E. Bergles, Augmentation of heat transfer in tubes by use of mesh and brush inserts‖. J. Heat Transfer, 145–151(1974).

Marner W.J., Bergles A.E. and Chenoweth J.M., On the presentation of performance data for enhanced tubes used in shell and tube heat exchangers, Transaction ASME Journal Heat Transfer, 105, 358–365 (1983).

Ozceyhan, V., Gunes, S., Buyukalaca, O. and. Altuntop, N., Heat transfer enhancement in a tube using circular cross sectional rings separated from wall, Appl Energy 85, 988–1001, 2008.

Onur, N., Turgut, O., Demirel, D., Numerical investigation of the effects of baffles, placed between two parallel plates, on flow and heat transfer under condition of laminar forced convection, J. of Thermal Science and Technology 27(2), 7-13, 2007.

Promvonge, P. and Eiamsa-ard, S., Heat transfer behaviors in a tube with combined conical-ring and twisted-tape insert, IntCommun Heat Mass Transfer 34, 849–859, 2007.

R. L. Webb, Principle of Enhanced Heat Transfer, John Wiley, New York, NY, USA, 1994.

Yakut, K. and Sahin, B., Flow-induced vibration analysis of conical rings used of heat transfer enhancement in heat exchanger, Appl Energy 78, 273–288, 2004.