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CFD based heat transfer analysis in circular tube with different orientation of insert for laminar flow

Kaushal Kishor Sharma
kaushalkishorsharma84@gmail.com
University Institute of Technology, RGPV, Bhopal, Madhya Pradesh

Dr. A.C. Tiwari
aseemctiwari@yahoo.com
University Institute of Technology, RGPV, Bhopal, Madhya Pradesh

ABSTRACT

The process industry is continuously working to incorporate enhancement in heat transfer. Enhancement techniques can be classified as active methods, which require external power or Passive methods, which require no direct application of external power. The enhanced surfaces are routinely used to improve the thermal and hydraulic performance of heat exchangers. This thesis presents a CFD analysis of heat transfer problem. The enhancement of heat transfer with mass in a tube has been investigated without and with insert. The combinations of without inserts, two inserts, four inserts, six inserts, eight inserts, and ten inserts have been used. An 800 mm long pipe with 26 mm inner diameter and 30 mm outer diameter is considered for our simulation. It was noticed that outlet temperature decreases with increase in Reynolds number when insert orientation was changed.

Keywords— *Inserts, Turbulent flow, Heat transfer coefficient, Reynolds number, Exit temperature*

1. INTRODUCTION

The high-performance heat transfer system is of great importance in many industrial applications. The performance of conventional heat exchangers can be substantially improved by a number of heat transfer enhancement techniques. A variety of complex, highly viscous liquids are involved that undergoes heat exchange process while flowing through heat exchangers. Because of their vicious nature, they tend to have low flow rates and generally represent the dominant thermal resistance due to their vicious nature, adversely affecting the size and cost of the heat exchanger. The process industry is continuously working to incorporate enhancement in heat transfer. Enhancement techniques can be classified as active methods which require external power and passive methods, which require no direct application of external power. The enhanced surfaces are routinely used to improve the thermal and hydraulic performance of heat exchangers. These heat exchangers are used in process industries, air conditioning, refrigeration, power generation etc. Secondary flows are created by these techniques, causing the separation of the boundary layer results in better bulk fluid mixing which reduces the temperature gradients in the fluid flow. It is expected that a heat transfer augmentation device should produce a significant increase in heat transfer.

2. LITERATURE REVIEW

Wei Yuan (2018) studied the effects of ball turbulators (BTs) on the heat transfer and fluid friction characteristics in a circular tube are investigated through numerical simulation. The Reynolds number (Re) is in the range of 5000–35,000 under a condition of uniform heat-flux. BTs with different diameter ratios (e.g., 0.5, 0.75, and 1) and spacer lengths (40, 51.77, and 62.5 mm) are inserted in the circular tubes. The results show that the heat transfer rates in the tube equipped with BTs are around 1.26– 2.01 times that of those in the plain tube. The BTs with a ball diameter ratio of one provide higher friction factors than 0.75 and 0.5 by about 34.6–46.2% and 51.1–63.4%, respectively.

Virendra Patidar (2018) analysed the change in the heat transfer rate due to the change in enhancement technique by a baffled twisted tape insert in a heat exchanger by the different literature reviews.

Sachin S. Surywanshi (2017) focused on heat transfer enhancement of heat exchanger using the helical strip in a circular pipe with working fluid as water. Circular pipe helical strip geometry is not reported yet in the open literature. This geometry helps to generate swirl motion of fluid flow and disturbs the boundary layer to increase the effective surface area, residence time, reduce pressure drop and increase heat transfer coefficient.

Durgesh V. Ahire (2017) carried out experiments with copper and aluminum conical rings by varying two pitches of 3 cm and 5 cm respectively. The inserts when placed in the path of the flow of the fluid, create a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop. The work includes the determination of friction factor and heat transfer coefficient for various conical rings with varying pitches and different materials. The results of varying pitches in conical rings with two materials will be compared with the values for the smooth tube. The conical insert of copper 3mm thick and 30mm pitch has a greater Nusselt number in the range of 88 to 141 with approx. 6700Re to 13000Re hence found to optimum.

V. Tirupati Rao (2017) presented a study a circular tube fitted with conical-ring turbulators and a twisted-tape swirl generator placed in a plain tube at different pitch ratio's=1.0,2.0,3.0,4.0,5.0 to enhance the heat transfer in a plain tube. The air is used as working fluid in the range of Reynolds number 7696 to 15410 based on the consideration of different mass flow rates of air(m_a) = 20 kg/hr, 25kg/hr, 30kg/hr, 35kg/hr, 40kg/hr. Two twisted-tapes of different twist ratio's Y=2.5 and 4.5 are introduced in each run. The maximum heat transfer rate of 370% is found for using the conical-ring and the twisted tape of Y=2.5. The correlations for Nusselt number and Friction factor evaluation criteria to assess the real benefits in using the turbulator and swirl generator of the enhanced tube are determined.

3. RESEARCH METHODOLOGY AND MODELING OF PIPE

This work presents a FEM based heat transfer problem. The heat transfer enhancement technology has been developed and applied to heat exchanger applications such as refrigeration, process industry etc. There have been many techniques proposed over the years for enhancing the heat transfer with mass in tubes by using different types of insert. Hence the present work is concerned with carrying out three-dimensional simulations on a circular copper tube with inserts, through which water flows.

In our work, we designed a horizontal circular pipe without insert, two inserts, four inserts, six inserts, eight inserts and ten inserts with different orientation and different shapes. The tube has a total length of 800 mm, inner diameter and the outer diameter of 26 mm and 30 mm [Sabbir Hossain et al. (2015)].

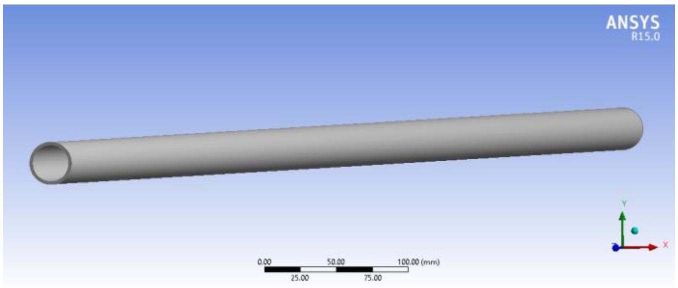


Fig. 1: Domain with no insert

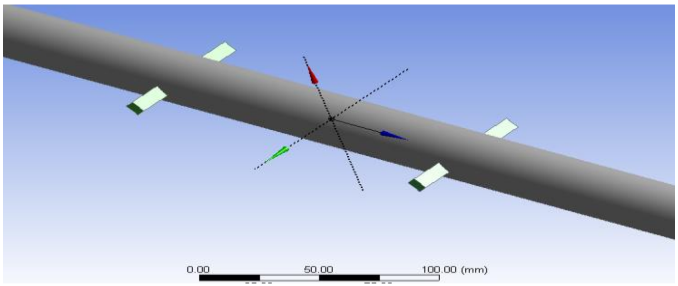


Fig. 2: Domain with 2 inserts

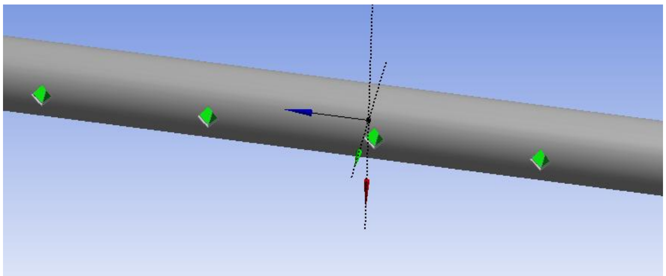


Fig. 3: Domain with 4 inserts

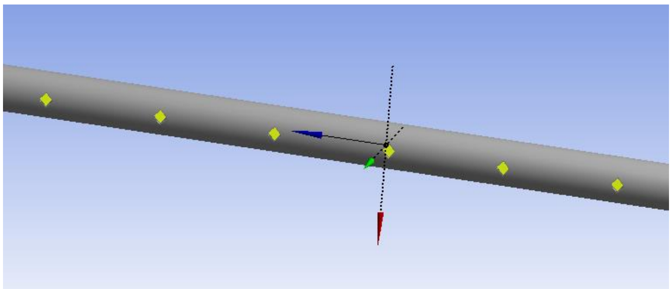


Fig. 4: Domain with 6 inserts

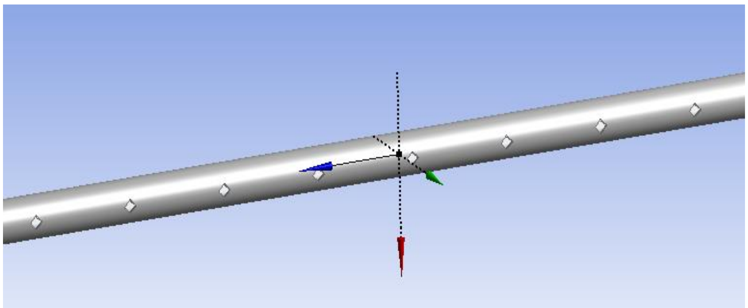


Fig. 5: Domain with 8 inserts

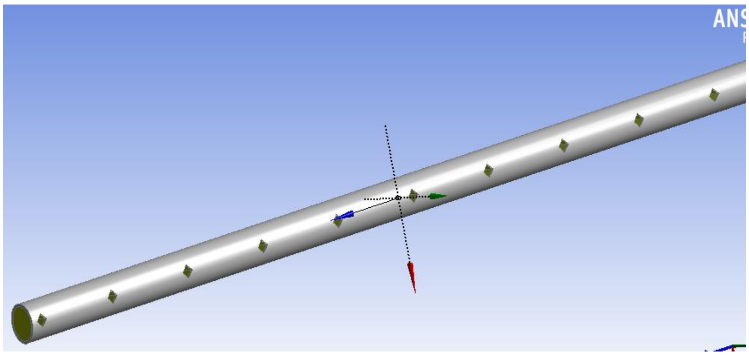


Fig. 6: Domain with 10 inserts

Table 1: Operating and Geometrical parameters used for CFD analysis

Operating and Geometrical parameters	Value / Range
Length of pipe	800 mm
Outer diameter	30 mm
Inner diameter	26 mm
No. of insert	2, 4, 6, 8, 10
Shape of insert	Diamond
Constant heat flux, q	32087 w/m^2
The range of Reynolds number	2000-10000

Reynolds number was varied from 2000-10000. Constant heat flux of value approximately 32087 W/m2 was supplied only on the pipe. Simulations were performed assuming the flow to be steady. The operating and geometrical parameters used for computational analysis are listed in Table 1.

4. CFD RESULTS AND DISCUSSION

4.1 Results with no insert

4.1.1 Effect of Reynolds number on convective heat transfer coefficient: Figure 7 shows the variation of the convective heat transfer coefficient with Reynolds number. As the Reynolds number increases, the heat transfer coefficient also increases. The variation in the heat transfer coefficient is low at small Reynolds numbers while it is large at higher Reynolds numbers. This behavior seems due to increased turbulence at higher Reynolds numbers and also due to breakage of the thermal boundary layer at higher Reynolds numbers.

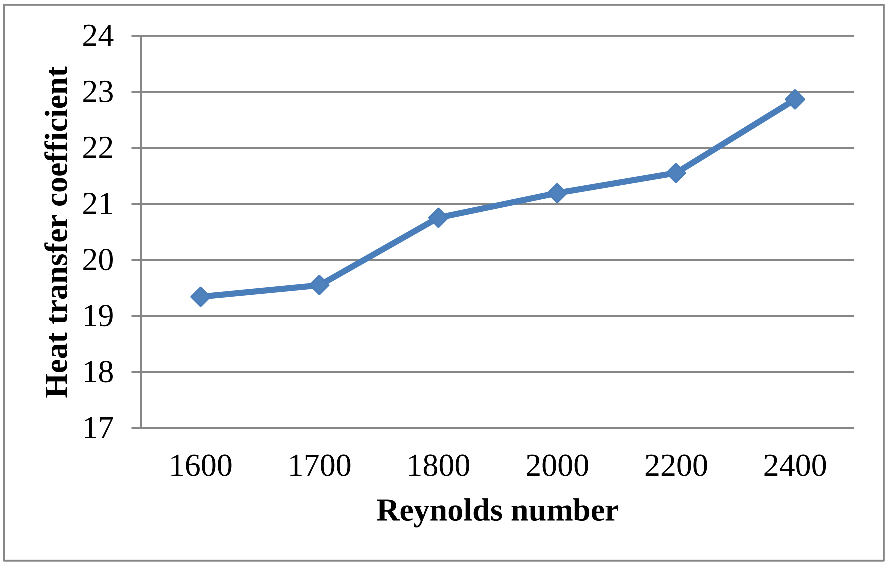


Fig. 7: Variation of heat transfer coefficient for different values of Reynolds number

4.1.2 Effect of Reynolds number on outlet temperature: Most of the flow which occurs in practical applications are in general turbulent in nature. In the turbulent region, the velocity of the particles very near to surface becomes almost zero. In this region, the particle has very low kinetic energy. This region is called laminar sub-layer. These laminar sub-layer acts as a barrier of heat transfer from heated surface to the fluid medium.

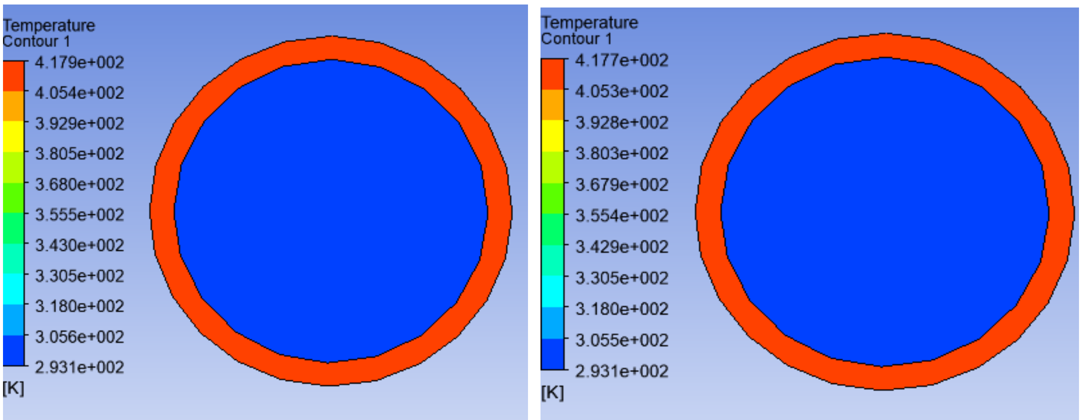


Fig. 8: Temperature distribution of water domain

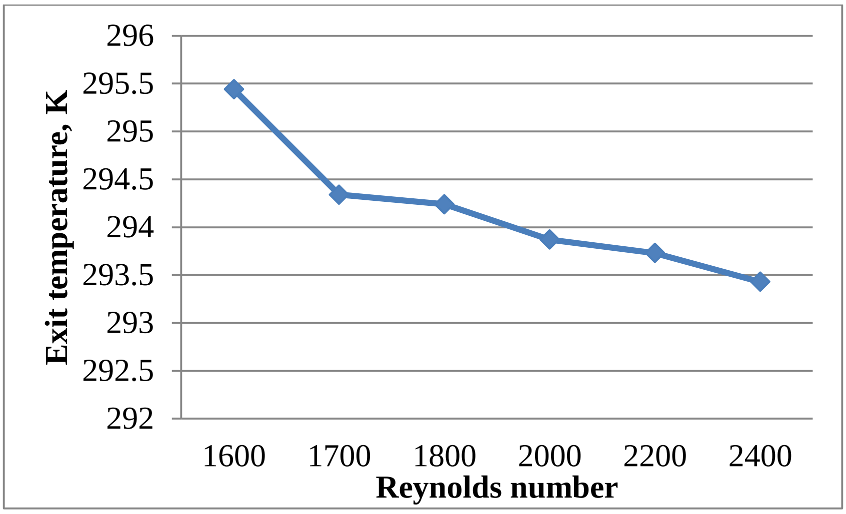


Fig. 9: Variation of exit temperature for different values of Reynolds number with no insert

Figure 9 shows the variation of the temperature of the air at the exit with the Reynolds number. As the Reynolds number increases, the heat carrying capacity of air increases. Because of this heat utilization also increases, but the rate of increase of heat capacity is more significant than the rate of increase of heat utilization. Therefore the temperature of the air at exit decreases as a result increase in Reynolds number.

4.2 Results on effect of insert

4.2.1 Effect of Reynolds number on convective heat transfer coefficient: Figure 10 shows the variation of the convective heat transfer coefficient with Reynolds number. As the Reynolds number increases, the heat transfer coefficient also increases for a different number of the insert. The variation in the heat transfer coefficient is low at small Reynolds numbers while it is large at higher Reynolds numbers. This behaviour seems due to increased turbulence at higher Reynolds numbers and also due to breakage of the thermal boundary layer at higher Reynolds numbers.

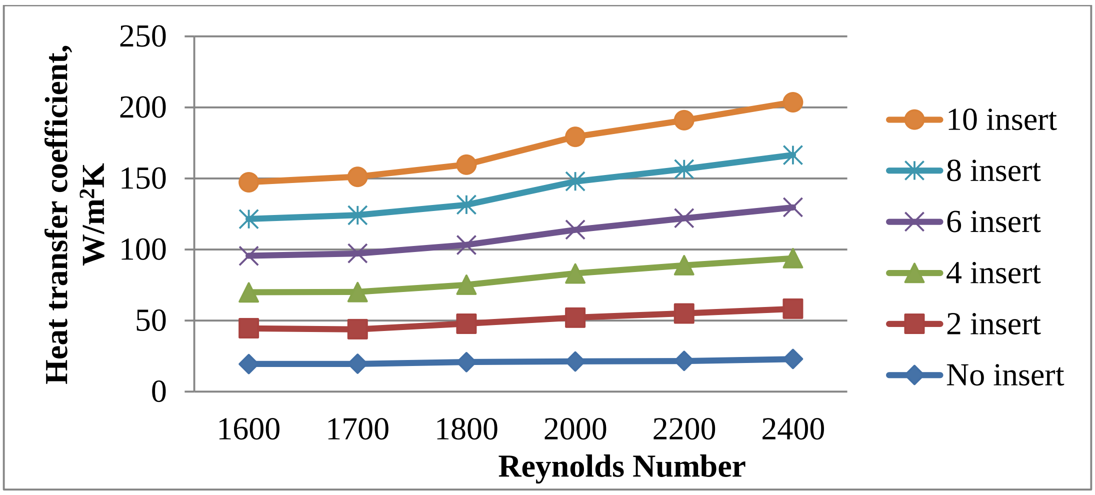


Fig. 10: Variation of heat transfer coefficient for different values of Reynolds number with inserts

4.2.2 Effect of Reynolds number on outlet temperature: Most of the flow which occurs in practical applications are in general turbulent in nature. In the turbulent region, the velocity of the particles very near to surface becomes almost zero. In this region, the particle has very low kinetic energy. This region is called laminar sub-layer. These laminar sub-layer acts as a barrier of heat transfer from heated surface to the fluid medium.

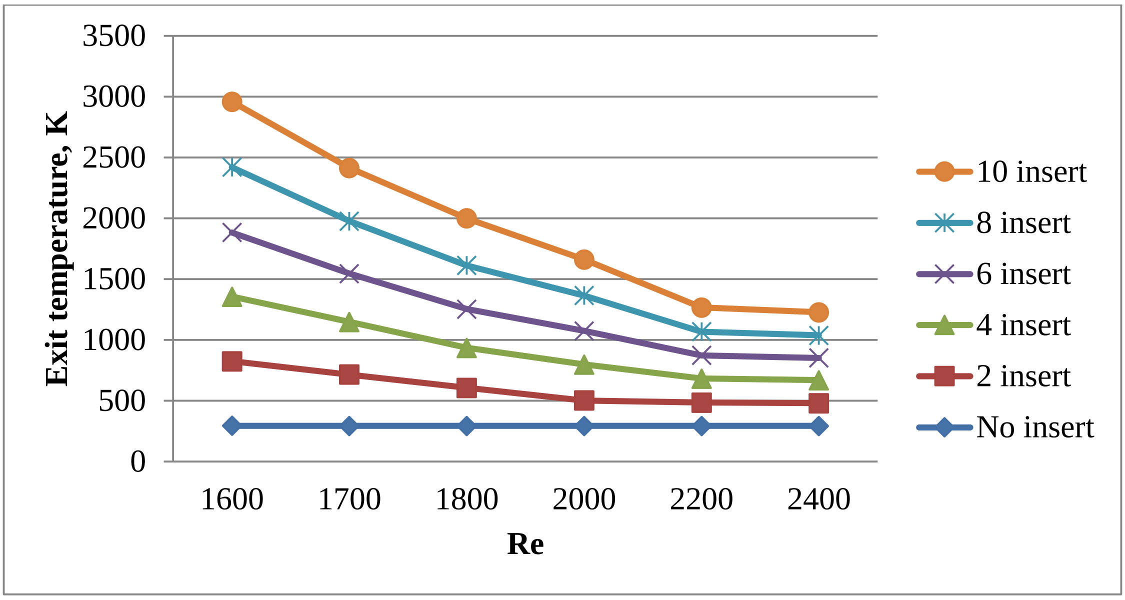
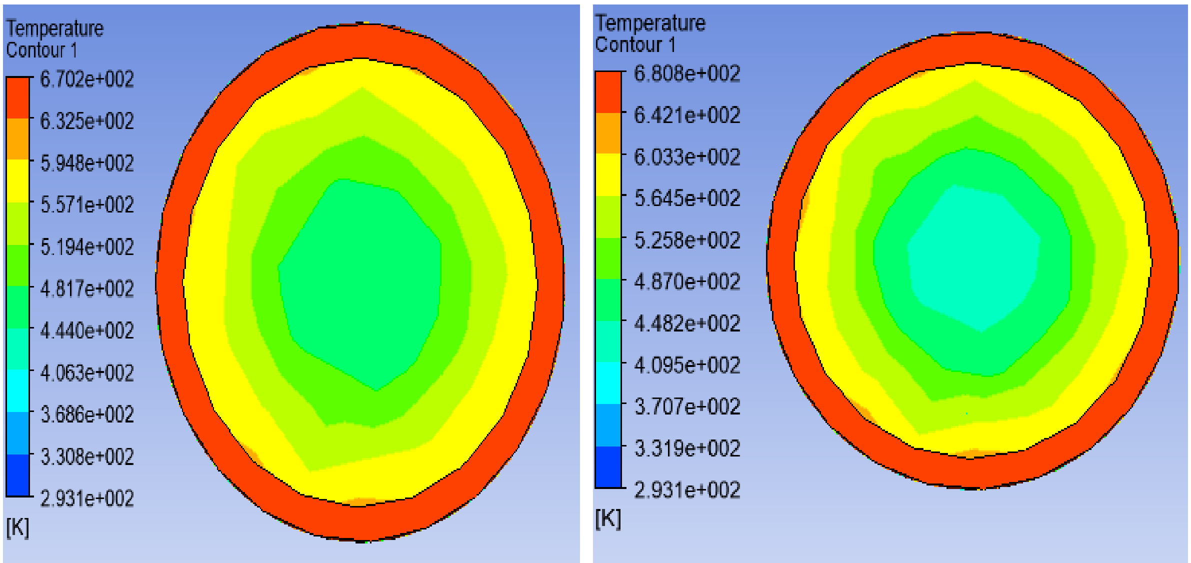


Fig. 11: Variation of exit temperature for different values of Reynolds number with inserts

Figure 11 shows the variation of the temperature of the air at the exit with Reynolds number. As the Reynolds number increases, the heat carrying capacity of air increases. Because of this heat utilization also increases, but the rate of increase of heat capacity is more significant than the rate of increase of heat utilization. Therefore the temperature of the air at exit decreases as a result increase in Reynolds number.

It is observed that outlet temperature increases to 313.15 K when two inserts are being fitted into the tube. We get the lowest outlet temperature for ten inserts. Therefore after 8 inserts outlet temperature decreases.



(a) Re= 1600 **(b) Re= 1700**

Fig. 12: Temperature variation of water domain with 6 inserts

4.3 Effect of orientation of insert

In this case, we fit inserts in the pipe at 90º and 0º alternatively. The distance between these inserts is also varied. Then we run our simulation for these domains.

4.3.1 Effect of Reynolds number on convective heat transfer coefficient: Figure 13 shows the variation of the convective heat transfer coefficient with Reynolds number. As the Reynolds number increases, the heat transfer coefficient also increases for a different number of the insert. The variation in the heat transfer coefficient is low at small Reynolds numbers while it is large at higher Reynolds numbers. This behaviour seems due to increased turbulence at higher Reynolds numbers and also due to breakage of the thermal boundary layer at higher Reynolds numbers.

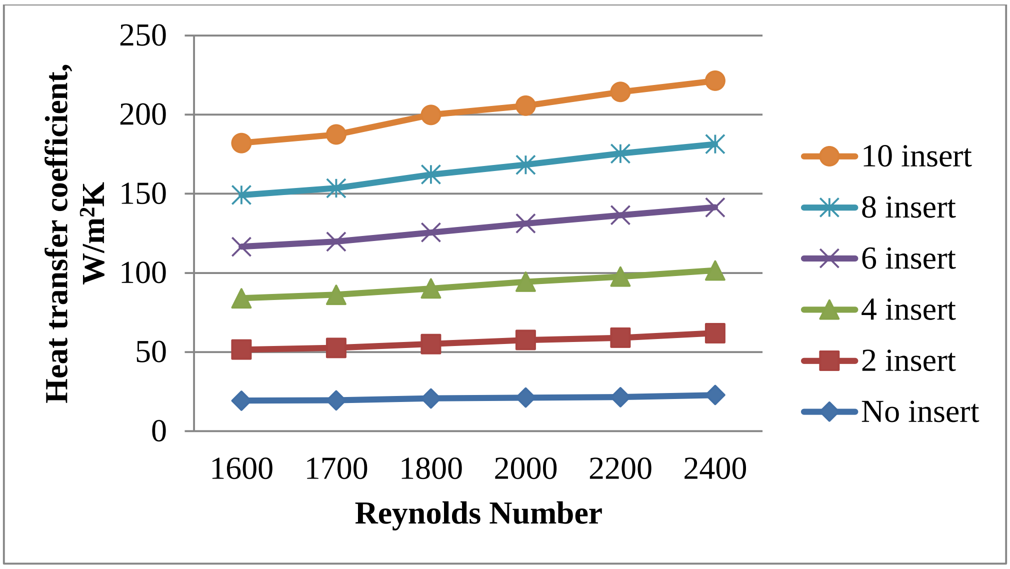


Fig. 13: Variation of heat transfer coefficient for different values of Reynolds number with inserts

4.3.2 Effect of Reynolds number on outlet temperature: Most of the flow which occurs in practical applications are in general turbulent in nature. In the turbulent region, the velocity of the particles very near to surface becomes almost zero. In this region, the particle has very low kinetic energy. This region is called laminar sub-layer. These laminar sub-layer acts as a barrier of heat transfer from heated surface to fluid medium

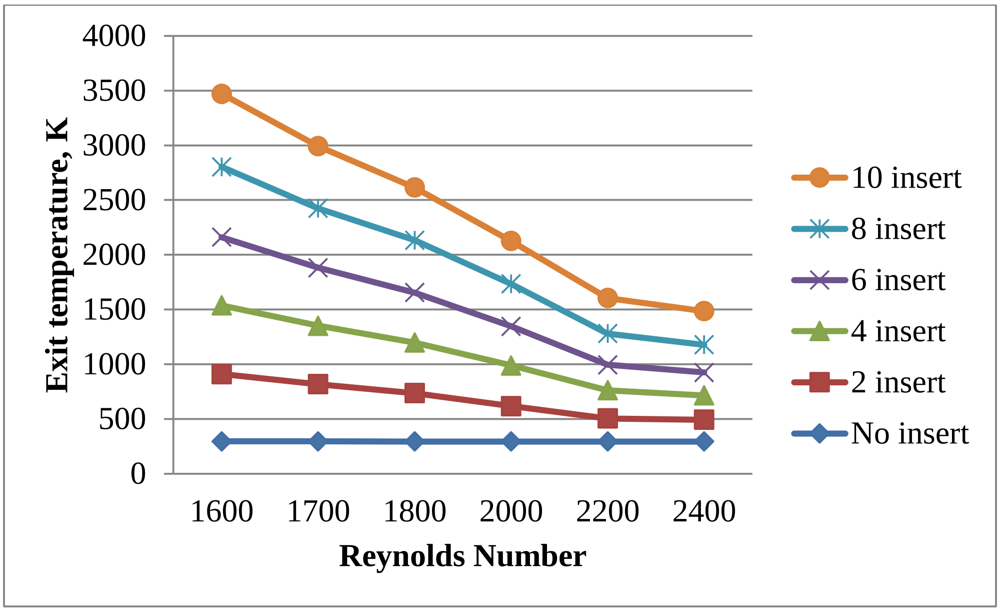


Fig. 14: Variation of exit temperature for different values of Reynolds number with inserts

We have noticed that outlet temperature decreases with increase in Reynolds number. However with the increase in a number of the insert in tube outlet temperature also increases. Maximum outlet temperature was found maximum with 10 inserts. It is also observed that variation was also found with an increase of distance among inserts simultaneously with increasing number of the insert. Using inserts we find exit temperature increases from 107 % to 126% as compare to the tube with no insert.

5. CONCLUSIONS

A CFD simulation study on heat transfer characteristics of the fluid in a circular tube without and with inserts under constant boundary heat flux for turbulent flow has been presented. The conclusions from the simulation are as follows:

1. It was noticed that outlet temperature decreases with increase in Reynolds number when insert orientation was changed. However, with the increase in a number of the insert in the tube, outlet temperature also increases. Maximum outlet temperature was found maximum with 10 inserts. It was also observed that variation was also found with an increase of distance among inserts simultaneously with increasing number of the insert. Using inserts one can find exit temperature which increases from 107 % to 126% as compared to the tube with no insert.
2. As the Reynolds number increases, the heat transfer coefficient also increases. The variation in the heat transfer coefficient is low at small Reynolds numbers while it is large at higher Reynolds numbers. This behaviour seems due to increased turbulence at higher Reynolds numbers and also due to breakage of the thermal boundary layer at higher Reynolds numbers.
3. As the Reynolds number increases, the heat carrying capacity of air increases. Because of this heat utilization also increases, but the rate of increase of heat capacity is more significant than the rate of increase of heat utilization. Therefore the temperature of the air at exit decreases as a result increase in Reynolds number.

4. The heat transfer increases with increase in Reynolds number due to an increase in axial convection. Increase in Reynolds number increases the heat transfer due to a disturbance in the boundary layer causing increased convection heat transfer from wall to the fluid.
5. It is observed that outlet temperature increases to 313.15 K when two inserts are being fitted into the tube. The lowest outlet temperature was obtained for ten inserts. Therefore after 8 inserts outlet temperature decreases.
6. It is observed that outlet temperature increases to 313.25 K when two inserts are being fitted into the tube. The highest outlet temperature was obtained for four inserts. Therefore it was noticed that there is an irregular variation of outlet temperature and one cannot come to certain decision to find out the reasons for such irregularities.
7. After changing inserts position, the greater outlet temperature is obtained.
8. Optimum distance among the inserts also plays a major role which will cause improvement in the heat transfer rate.
9. The optimum distance among the inserts should be considered for executing the design which makes it economical and easy to manufacture.

5.2 Future scope of work

Further detailed studies can be carried out in this area either through experiments or with the aid of software. The nusselt number and friction factor values can be obtained with the same pitch at different shapes and different pitch in order to study the effect of insert shape and pitch respectively on the Nusselt number and friction factor. Some other inserts may be used and similar investigations can be done and the values compared to those of wire coil inserts. Drilled twisted tape inserts with holes of different geometric shapes like triangular, rhombus & almond can also be used, and a combined study of experimental and CFD investigation of heat transfer and friction factor for these tape inserts can be done.

6. REFERENCES

[1] Wei Yuan (2018), Heat Transfer and Friction Characteristics of Turbulent Flow through a Circular Tube with Ball Turbulators, Applied Sciences, 8(6), 1-13.
[2] Virendra Patidar (2018), Enhancement of Heat Transfer Through Pipe with the Help of Various Types of Turbulators – A Review, 5(1), 698-704.
[3] Sachin S. Surywanshi (2017), Numerical Heat Transfer Analysis of Flowing Fluid through a Circular Tube with Helical Twisted Strip Inserts, Journal of Advances in Science and Technology, 13(1), 88-94.
[4] Durgesh V. Ahire (2017), Experimental Investigation of Heat Transfer Enhancement in Circular Pipe using Conical Ring Inserts, International Journal of Mechanical And Production Engineering, 5(6), 83-88.
[5] V. Tirupati Rao (2017), Augmentation Heat Transfer in a Circular Tube Using Conical Ring And Twisted Tape Insert, International Journal of Scientific Research Engineering & Technology, 6(1), 15-22.
[6] M. Ashham (2017), Simulation of Heat Transfer in a Heat Exchanger Tube with Inclined Vortex Rings Inserts, International Journal of Applied Engineering, 12(20), 9605-9613.
[7] Mukesh P. Mangtani (2016), Performance Analysis of Copper Twisted-Tape Inserts for Heat Transfer in a Circular Tube, Int. Journal of Engineering Research and Application, 6 (11), 25-28.
[8] Yogesh B. Rakate (2016), Experimental and Numerical Analysis of Heat Transfer Augmentation through a Pipe using Twisted Tapes, International Journal for Innovative Research in Science & Technology, 2(10), 65-71.
[9] Avinash Savekar (2015), Analysis of Heat Transfer in Pipe with Twisted-Tape Inserts, International Conference on Fluid Flow, Heat and Mass Transfer, Ottawa, Ontario, Canada, April 30 – May 1, 143-1.
[10] Dipak Sen, Rajdeep Ghosh (2015), A Computational Study of Very High Turbulent Flow and Heat Transfer Characteristics in Circular Duct with Hemispherical Inline Baffles, International Journal of Mechanical and Mechatronics Engineering, 9(6), 1046-1051.
[11] K. Gowrisankar (2015), Augmentation Heat Transfer in a Circular Tube Using Divergent Nozzle as Insert, International Journal for Research in Applied Science & Engineering, 3(9), 143-149.
[12] Vinay Kumar Patel (2015), Heat Transfer Enhancement using Passive Enhancement Technique, International Journal of Engineering Sciences & Research Technology, 4(9), 394-399.
[13] Shivaji V. Mundhe (2014), Experimental Analysis of Heat Transfer for Turbulent Flow through Circular Pipe, International Journal of Innovative Research in Advanced Engineering, 1(3), 70-75.
[14] Rupesh G. Telrandhe, T.S. Karhale, B.B. Deshmukh (2013), Thermal Analysis of Circular Inclined Pipe Subjected To Natural Convection Using CFD, Int. Journal of Engineering Research and Applications, 3(5), 1911-1913.
[15] Sami D Salman (2013), CFD analysis of heat transfer and friction factor characteristics in a circular tube fitted with horizontal baffles twisted tape inserts, International Conference on Mechanical Engineering Research, 3(5), 1-7.
[16] Pawan A. Sawarkar (2013), Experimental Analysis of Augmentation in Heat Transfer Coefficient Using Twisted Tape with Semi-Circular Cut Insert, International Journal of Science and Research, 4(4), 1174-1179.

