"CFD investigation of Heat transfer characteristics of heat exchanger tube with different shape inserts"

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Abstract
In the present study,the transfer of heat is an order of thermal engineering and an important phenomena of heat exchanger system. The Phenomena of heat transferchangedmany times into various procedure such as thermal phase changes. The phase changes are classified into thermal convection, thermal conduction and radiation. In this paper thermal conduction and convection phase changes to improve thermal performance and its capacity of flow of heat from circulation flow zone of cooling and heating area of design model.. The length of the cutting cone is denoted by l = 18 mm. The thickness of the cutting cone t = 2 mm, pitch variation of the cutting cone P = 40 - 120 mm. The height of the object is measured in millimeters as cutting cone vortex = 52, and the variation in the Reynolds number Re = 4000 - 16,000. All the results have been investigated by CFD software program which is used maximally for fluid related problemsThe maximum thermal efficiency is observed η_{max} = 2.012881 at P = 80 mm, P/D_h = 1.33, N = 2, Re = 16,000, and l = 18 mm.

Keywords
Heat Exchanger Tube, Twisted Tape Insert, PCC Tube, Reynolds Numbers.

1.0 Introduction

The phenomena of transfer of heat from one physical body to another body are known as heat exchange system and tube body system is known as heat exchanger tube. The heat exchanger system is employed in many application as compact heat exchanger power plants, processing of foods plants, refrigeration circular system, as in process industries, Hydraulic power plants etc. The main motive of heat exchanger system is to maintain the phenomena of heat transfer with all points of views.Thejaraju R. Et al. [1] Angle plate inserts (API) oriented in transverse direction was used to investigate the thermal efficiency of a curved channel. Within the range of 1.34-1.63, the value of the performance factor is reduced. Jafar et al. [2] The impacts of a whirling producer on the thermal efficiency of a heat - transfer pipe were investigated. A spirally twisting tube with something like a five-lobe pass was employed as the swirl generator. Shekholeslam M. Et al. [3] Perforated tabulators were used to analyze the heat transfer enhancements with a double pipe converter. The highest value of the thermo physical properties factor was 1.59, which was found for Re = 6000, PR =1.06, and =.07.S.Vgneshetal.[4] wrinkled tube heat exchangers were used to investigate the tubular heat converter at varied flow rates. Because as hydraulic fluid, liquid was employed. In addition, the inner thermal conductivity was 56% higher than the plain tube. The performance of the dimpled tube were found to be 55 percent higher than that of the flat tube.SanjayKumarSinghetal.[5]Employing dimpled inserts, researchers evaluated the influence of dimple size on heat transport in a double tube as shown in figure .2.5. At a D/H ratio of 3, twisted films with varying dimple diameters vs. 3, 5, and 7 mm was employed. At a dimple width of 5mm, the Nusselt number reached its maximum value.Aharwaret.al.[6]In some kind of a turbulent flow producer with tube heat exchanger, various twisted tape insertion expanded surfaces, or swirling stream generators were investigated. For various P/d ratios of 4, 5, and 7 the fluctuations in Nusselt number, proportion factor, pumping power, & LMTD were investigated. At P/d=4 and Re=10000, the maximum Nusselt number was discovered to be 48.127.Biswas S et.al. [7] Wire coil inserts were used to evaluate tube side thermal performance. As inclusions, steel wires with a diameter of 2.8 mm as well as a coil height of 24 mm were employed. The Nusselt number of heat flux rose as the Reynolds number has increased, according to the results of the experiments.Eknath D. Kurhe et al. [8] The impacts of angled swirling ring in tubing with varied slopes were examined. The maximum Sherwood number was attained at a swirling ring angle approximately 35°, however thermal efficiency was reduced due to the considerable friction factor. At b/D=0.1, P/D=0.5, with angle=30°, the superior heat efficiency was evaluated.

2.0 Methodology of Design Model

The geometric modeling of smooth tube and with inserts of perforated cutting Cone was generated in Ansys Fluent 14.0. (Fg. 1) and the geometric model contains a single tube with cone which are cut in different length and diameter which are converted into the cutting cone. The complete working length (L) of tube is 1440 mm, the tube has inner and outer diameter of 60 and 64 mm respectively.We have taken the cutting cone in such a manner that it has number variations in the perforated holes n the cutting cones N = 0, 2 and 3.The Vortex generating cutting cones further supplemented with holes to further increase the efficiency of the HET tube. In total length of HET is 1440 mm, and from the entrance the pitch of the inserts are taken as 40, 60, 80, 100, and 120 mm. The range of the Reynolds number is 4000 to 16000 whch was used for maximum thermal efficiency.

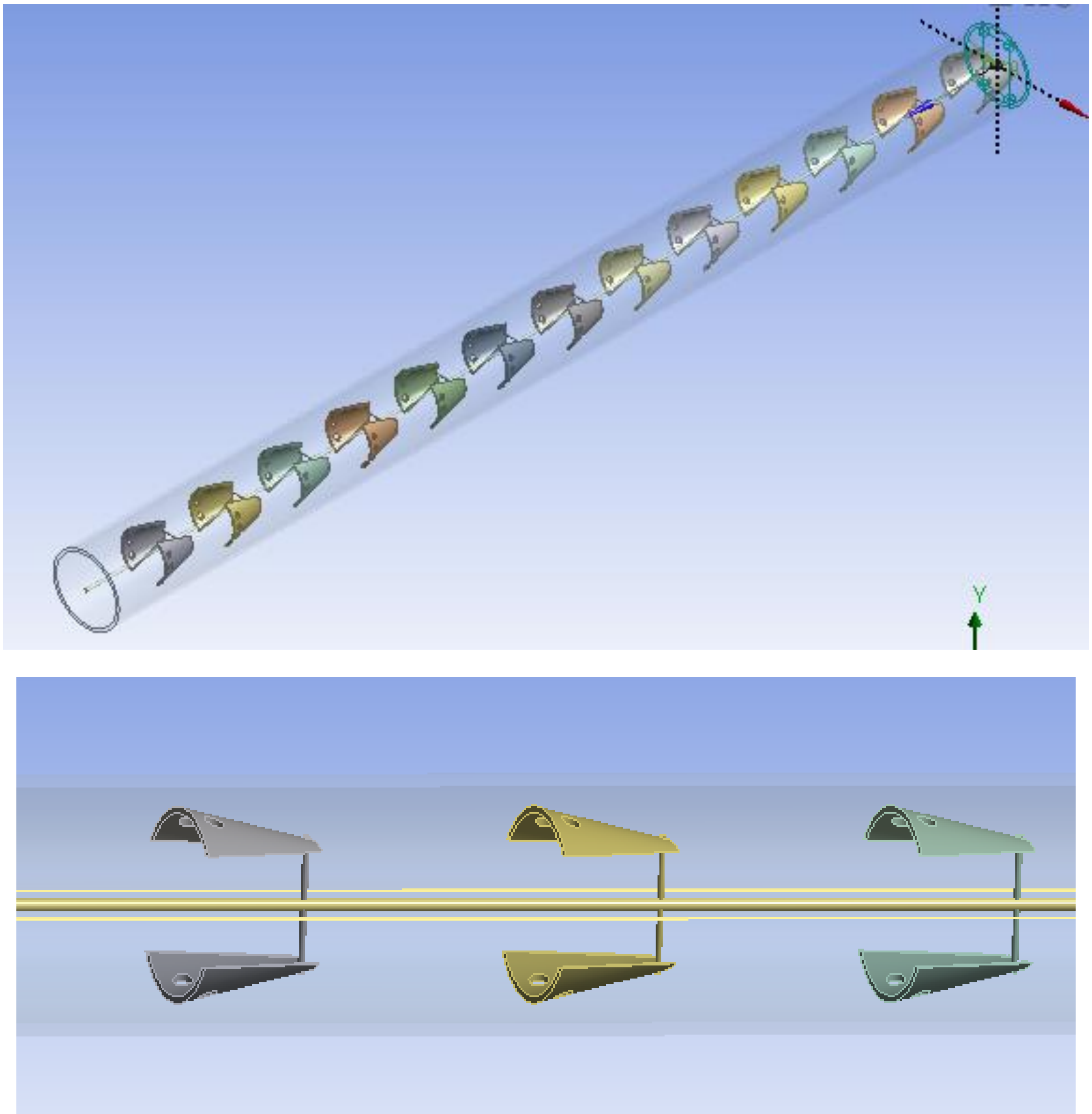

Figure1geometry of the smooth tube with perforated cutting cone inserts (PCC).

2.1 Mathematical data for HET

All CFD base design model are simulated and calculated by the some mathematical equations, which are Mass preservation, Newton's second law, and energy efficiency are all in play. known as governing equations.

$$\frac{\partial \vec{u}}{\partial x} + \frac{\partial \vec{v}}{\partial y} + \frac{\partial \vec{w}}{\partial z} = 0 \qquad (1)$$

Equations of Momentum

The equations are purposed by Newton's second law and according to law, the sum of all forces acting on fluid elements due to this fluid elements get accelerated or rate of change of momentum. The complete acceleration activity of fluid s calculated by momentum equations 2, 3, and 4 for all direction of fluid.

$$\left(\vec{u}\frac{\partial\vec{u}}{\partial x}+\vec{v}\frac{\partial\vec{u}}{\partial y}+\vec{w}\frac{\partial\vec{u}}{\partial z}\right)=-\frac{1}{\rho}\frac{\partial p}{\partial x}+v\left(\frac{\partial^2\vec{u}}{\partial x^2}+\frac{\partial^2\vec{u}}{\partial y^2}+\frac{\partial^2\vec{u}}{\partial z^2}\right) \quad (2)$$

Y- Momentum equaton:

$$\left(\vec{u}\frac{\partial\vec{v}}{\partial x}+\vec{v}\frac{\partial\vec{v}}{\partial y}+\vec{w}\frac{\partial\vec{v}}{\partial z}\right)=-\frac{1}{\rho}\frac{\partial p}{\partial y}+v\left(\frac{\partial^2\vec{v}}{\partial x^2}+\frac{\partial^2\vec{v}}{\partial y^2}+\frac{\partial^2\vec{v}}{\partial z^2}\right) \quad (3)$$

Z – Momentum equatons:

$$\left(\vec{u}\frac{\partial\vec{v}}{\partial x}+\vec{v}\frac{\partial\vec{v}}{\partial y}+\vec{w}\frac{\partial\vec{v}}{\partial z}\right)=-\frac{1}{\rho}\frac{\partial p}{\partial z}+v\left(\frac{\partial^2\vec{v}}{\partial x^2}+\frac{\partial^2\vec{v}}{\partial y^2}+\frac{\partial^2\vec{v}}{\partial z^2}\right) \quad (4)$$

Energy equation

Energy equation is the part of conservation of energy that is applied to fluid elements in this paper. In equation 3.5, internal energy of fluid is expressed by left side and from right side expressed thermal energy of fluid of turbulent flow.

Viscosity or friction effects are taken negligible

$$\vec{u}\frac{\partial t}{\partial x}+\vec{v}\frac{\partial t}{\partial y}+\vec{w}\frac{\partial t}{\partial y}=\alpha\left(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial y^2}\right) \quad (5)$$

Reynolds number (Re) = $\frac{\rho v d}{\mu}$ (6)

Reynolds number will be important to calculate the velocity of the fluid which is to be given to the fluid at the initial end of the pipe.

Prandlt number (Pr) =$\frac{\mu Cp}{k}$ (7)

Prandlt number will be necessary to calculate Nusselt number.

Nusselt number (Nu) = $0.023\ Re^{0.8}Pr^{n}$ (8)

The above equation is called Dittus-Boelter equation

Nusselt number is a direct measure of the amount of heat transfer taking place across the pipe. Greater the value of Nusselt number greater will be the heat transfer

ASSUMPTION

Following assumptions have been considered during the numerical simulation

(1) Steady flows
(2) Pressure variation in y dr. is zero.
(3) Shear force in y dr. is zero.
(4) Body forces due to gravity have 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.

3.0 MESH GENERATION

Mesh is a discrete representation of the design model with perforated cutting cone. All requirements can be hardly fulfilled at the same time of meshing and it is necessary to compromise.The meshing generation of tube using perforated cutting cone vortex following condition: span angle centre – fine, smooth transition, and virtual topological. The element size – 0.008 m as shown in figure 2

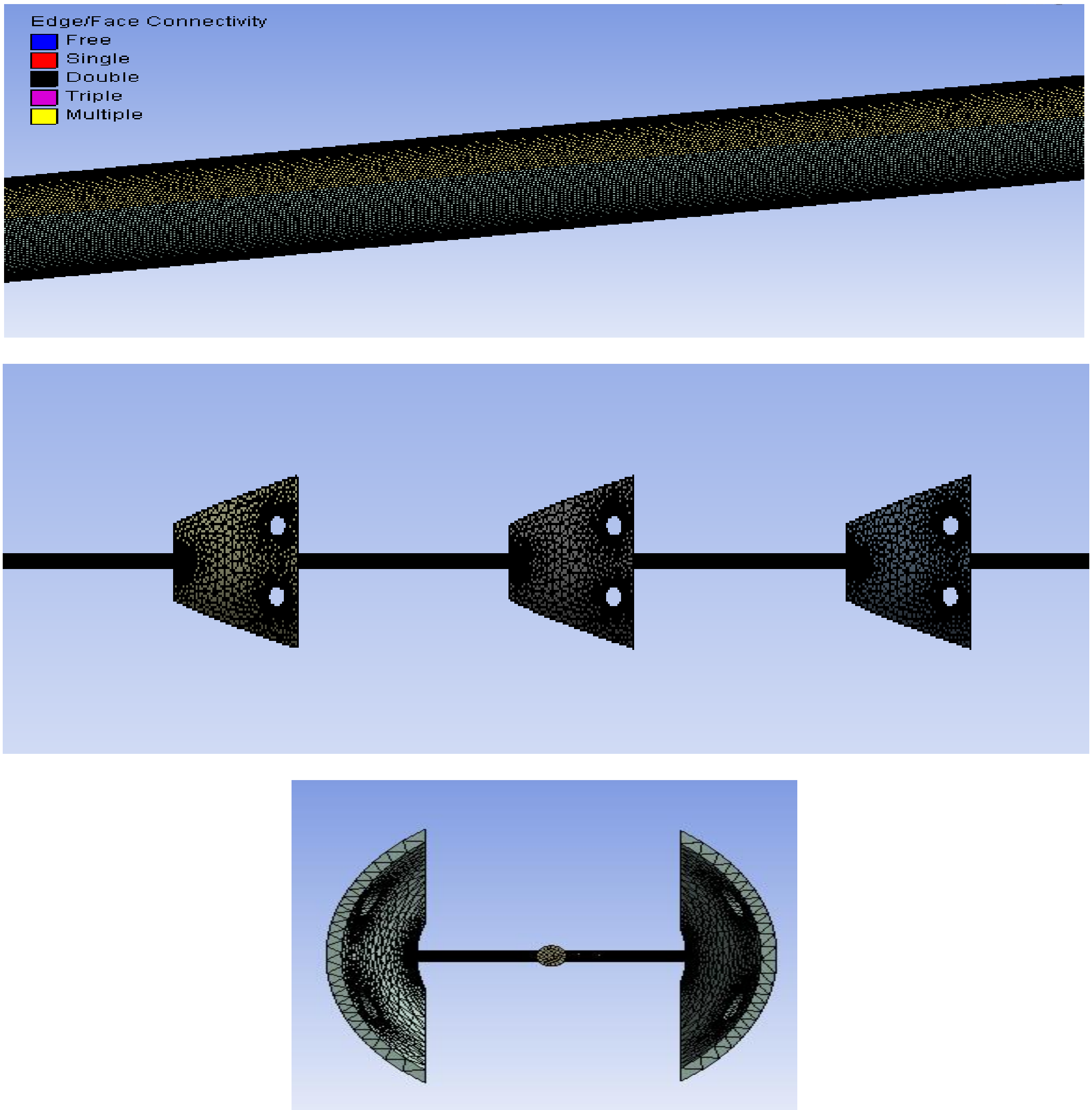

Figure 2:meshedmodelofHET with PCC.

4.0 Results and Discussion

The article present the phenomena of heat transfer rate from tube to environment. The heat transfer rate is shown as Nusselt number in form of numerical method. The numerical investigation of the heat exchanger tube using perforated cutting cone as heat exchanger covered the different types of fluid flow condition.In this paper, the results of denoted as Nusselt number (Nu), friction factor (Fr), Smooth tube Nusselt number (Nu_s), Average Nusselt number (Nu/Nu_s), Thermal Hydraulic performance (THP / η_{max}). The hydraulic diameter (60 mm) of tube is used to pass of fluid as air which the velocity as Reynolds formula (Re = 4000 - 16,000). The greater nusselt number indicates greater convective heat transfer; which can also be seenin the increase in the temperature. In figure 3, The Dittus-Boelterreference equation used. The figure 4 found maximum Nusselt number at N = 0 because - surface area s large as compared to perforated area of cutting cone. Velocity of fluid increased without any disturbance and increased velocity increases kinetic energy as well as heat flow.The variations in the pitch space (P) between cutting cone and number of holes (N_c) as shown in figures 5.The figure 5 shows the average Nusselt number between smooth and PCC tube.Figure 6 shows velocity contour of the tube with cutting cone. Velocity profile is generated to understand the flow of fluid with velocity and variations in the tube.

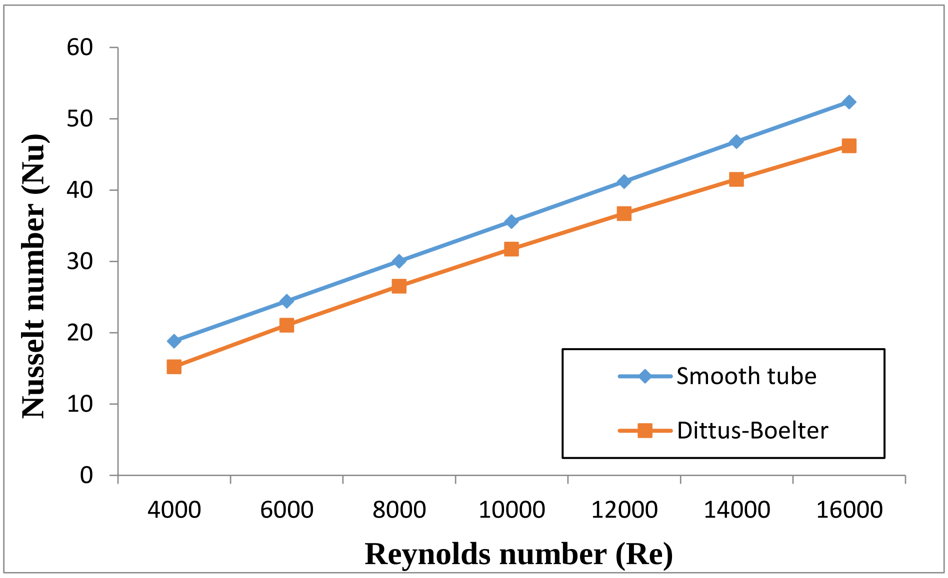

Fig. 3. Comparison of Dittus-Boelter equation w.r. to the results of smooth tube

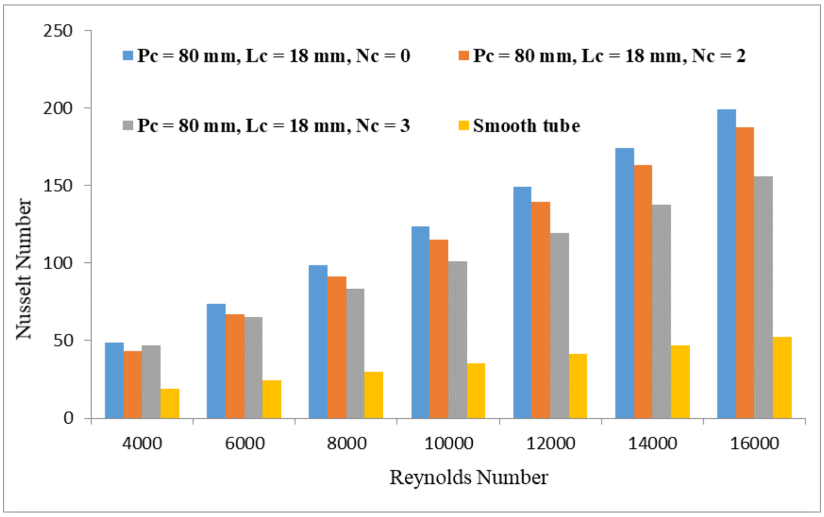

Figure 4. Results of Nusslts number at P = 80 mm.

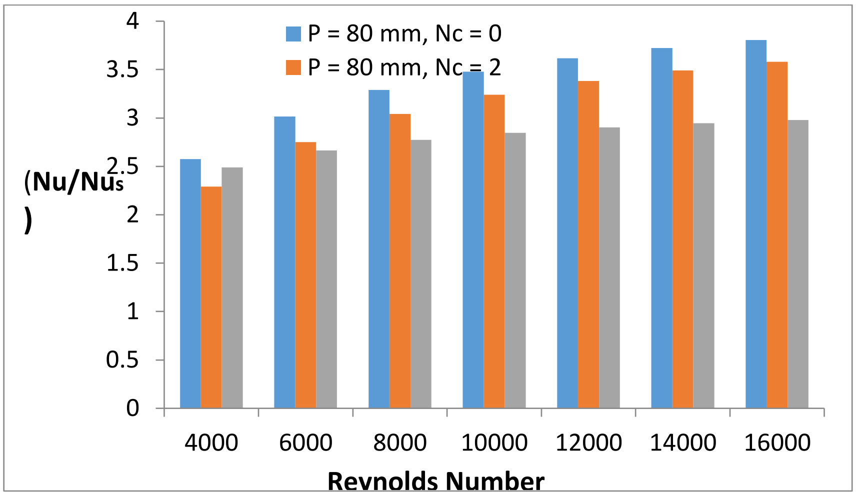

Figure 5. Variation of Average Nusselt number (Nu/Nu_s) at P = 80 mm.

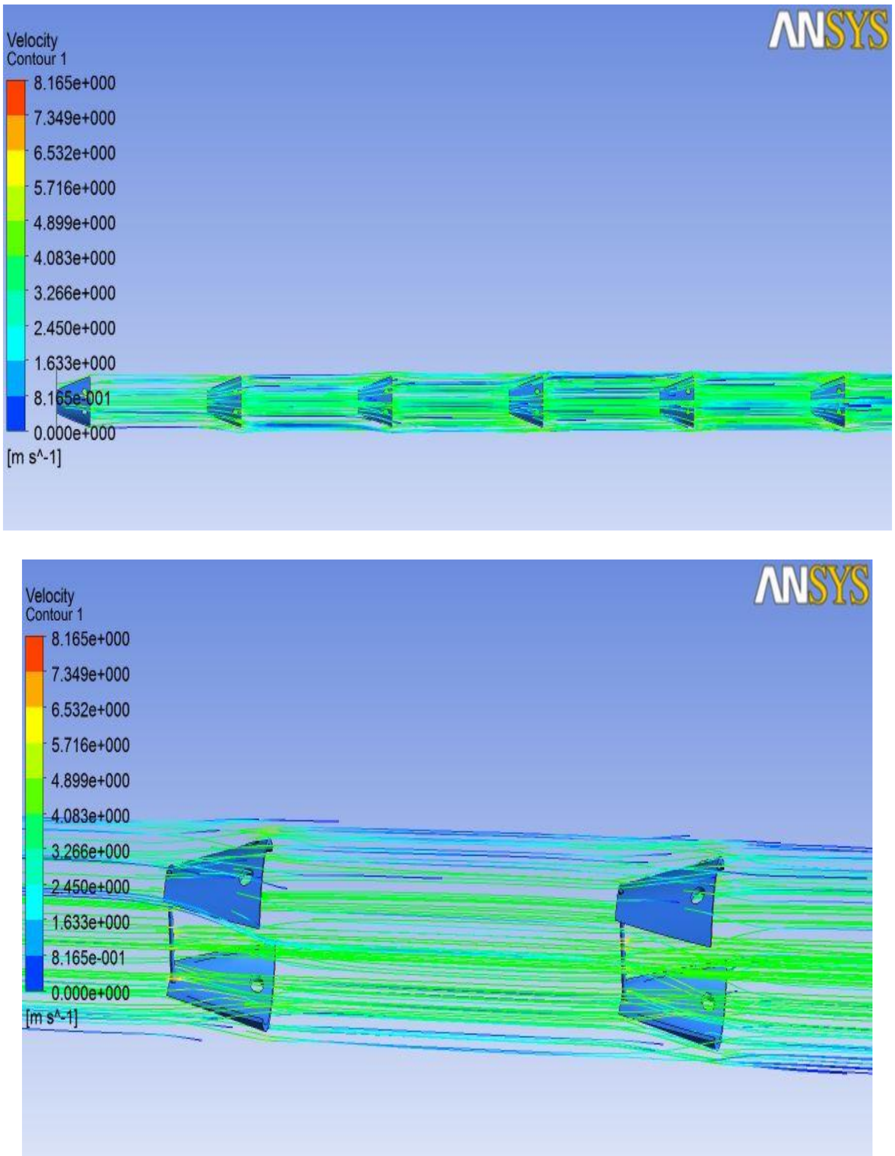

Fig. 6. Perforated cuttng cone tube at N_c = 2

6. Conclusion

In this chapter, all the results have been investigated by CFD software program which is used maximally for fluid related problems. The problems are solving by use of different parameters of design heat exchanger tube. The following parameters was helpful as ptch space (P_c) between cutting cone, Number of perforation (N_c), length of the cutting cone (L_c), hydraulic diameter (D_h), and Reynolds number (Re = 4000 - 16,000). Finally conclusion stats that heat transfer increased with Reynolds number, pressure drop observed maximum for non perforated cutting cone and friction factor maintained by number of holes..For perforated cutting cone inserts tube, the maximum Nusselt number is 187.45 and 199.28 for non-PCC tube at P/D_h = 1.33, Re = 16,000, and P_c = 80 mm.Heat transfer rate is maximum of 3.67 times for smooth tube at number of perforation of cutting cone and 3.8 times for non-PCC tube.Minimum friction factor is obtained Fr = 0.01921996 at N_c = 3, P = 40 mm, P/D_h = 0.66, and Re = 16,000. The maximum thermal efficiency is observed η_{max} = 2.012881 at P = 80 mm, P/D_h = 1.33, N_c = 2, Re = 16,000, and L_c = 18 mm.

6.1 Future Scope

1. Diameter of cutting cone can be changed for better improved of heat transfer rate

2. Variations of Pitch space between inserts roughness can improved heat transfer rate.

3. Thermal performance of HET can by changing n the parameters of cutting cone inserts

4. Friction factors can be decrease by using of variations n PCC tube

5. Number of perforation and diameter of perforation can be change for maximum THP.

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