

NUMERICAL ANALYSIS AND ENHANCEMENT OF HEAT TRANSFER THROUGH COMPUTATIONAL MODEL

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Abstract: In order to increase the heat transfer rate different types of baffles were used inside the heat exchanger. Researchers use the different types of turbulators to increase heat transfer rate inside the heat exchanger. In order to further increase the heat transfer rate, this work carryout the effect of different inclination angle of continuous helical turbulator was analyzed. Five different inclination angles that are 20, 23, 25, 27 and 30 degrees of continuous helical turbulator was considered during the numerical analysis. And through analysis it is found that with 25-degree inclination angle it is showing the maximum heat transfer.

Keywords: heat exchanger, inclination angle, turbulator, heat transfer, twisted tape

1. Introduction

In recent years, the study of different techniques of heat transfer enhancement in heat exchanger devices has gained valuable attention and abundant research had been finished in both heat transfer and thermodynamic consideration. Knowledge pertaining to heat exchanger strategies and altered heat transfer practices is the persistence of this chapter. The heat exchangers could be upgraded to execute heat-transfer duty by transferring of heat and upsurge techniques as active and passive techniques. The active technique involves exterior forces, e.g. electric field and surface vibrations etc. The passive technique requires fluid flow behavior and distinct apparent geometries. Curved tubes are used for transferring of heat improvement procedures, relatively a lot of heat transfer applications. A heat exchanger is an adiabatic machine based on open system built for resourceful heat transfer from a solid object and a fluid, or between two or more fluids. The fluids could possibly be separated by a solid wall to eliminate mixing or they may possibly be in direct contact. The rate by which heat transfers is reliant on the conductivity concerning the separating wall and then convective heat transfer coefficient between the wall and simply fluids.

Water to air heat exchanger can be selected on the basis of different application. It can be utilized for residential heating and dehumidification. Swirl flow device are one of the similar way for heat transfer enhancement which becomes popular due to low price. To find out the effect of different Reynolds number (Re) on heat transfer hear it considered four different Re of cold fluid that is 6000, 8000, 10000, 12000. Here in this work we have calculated the effect of inclination of helical turbulator on heat transfer and optimized the inclination angle of helical turbulator. For calculating the effect of different inclination angle of continuous helical turbulator here we have considered five inclination angles that is 20, 23, 25, 27 and 30. For performing the numerical analysis, first we have developed the solid model of heat exchanger having continuous helical turbulator. On the basis of geometrical condition we have developed the numerical model.

2. Material Used and Development of numerical model of heat exchanger

Here in this work water is used as a hot fluid, which is flowing in the inner tube, whereas air is used as a cold fluid which is flowing in the outer tube. Here in this work inner tube is prepared of copper whereas outer tube is of Plexiglas.

2.1 Development of solid model of heat exchanger

For the validation of the numerical analysis here first it considered heat exchanger having circular perforation helical turbulator as considered in base paper. The solid model of heat exchanger is developed on the basis of geometry considered by Sheikholeslami et.al [8] considered during the experimental analysis the geometric specification of solid model of heat exchanger is given in the below table

Table.1 Value of geometric specification

Geometric specification	Values	
Inner pipe diameter (mm)	Inner diameter D_i	28
	Outer diameter D_o	30
Outer pipe diameter (mm)	Inner diameter d_i	50
	Outer diameter d_o	60
Turbulator Thickness (mm)	2	
Turbulator Width (mm)	7	

The solid model of the heat exchanger is shown in the below fig.

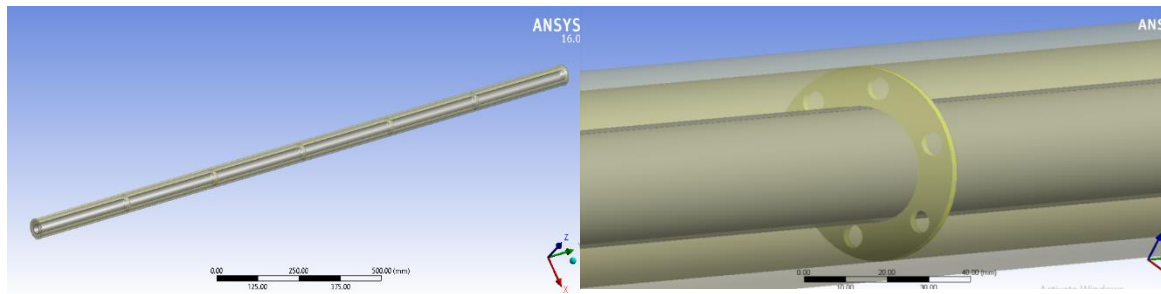


Fig.1 solid model of the heat exchanger with perforated helical baffles

For the initial analysis here it considered circular perforated helical discontinuous baffles. To validate the numerical model of heat exchanger, same geometric and boundary condition were considered for the initial analysis as considered in experimental analysis performed by Sheikholeslami et.al [8].

2.2 Meshing

To perform the numerical analysis here it has to discretize the solid model into a number of elements and nodes. To perform proper mesh different meshing tool was used for the refinement of mesh. In order to perform the mesh independent test, here in this work it has done meshing with different number of elements and calculate the value of temperature of hot fluid at the exit of heat exchanger. For the mesh of the heat exchanger 404586 numbers of elements are used. To minimize the computational time here it considered minimum number of elements to perform the numerical analysis. Mesh with minimum optimum number of element is shown in the below fig.

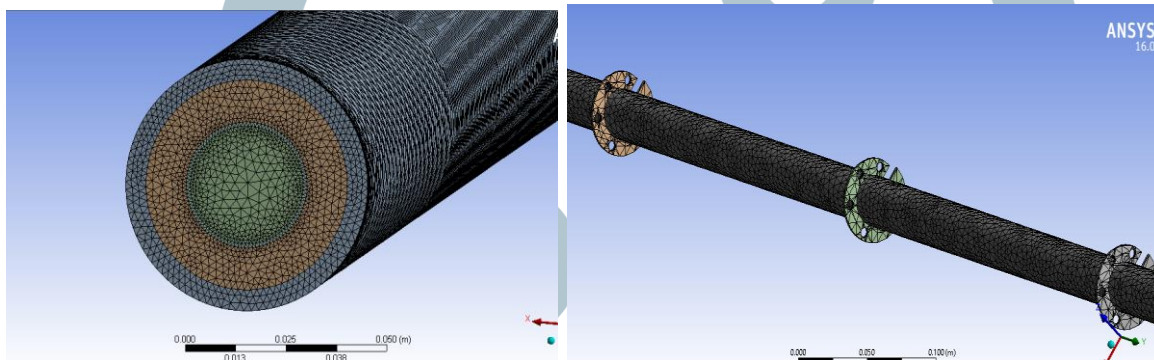


Fig.2 shows the mesh of heat exchanger considered during analysis

2.3 Solution method and Boundary condition

To examine the heat exchanger, here in this work it uses the K-epsilon (turbulent kinetic energy rate of dissipation) model with standard wall function. The procedure of solution method is shown in the block diagram. Due to standard wall function, the velocity of air or water particles which come in contact with the wall is zero that is no slip (zero velocity of fluid relative to the boundary) condition is applicable at the wall of inner and outer pipe. The temperature of warm fluid at inlet is 346.11 K and flowing at a velocity of 0.063 m/s. whereas cold fluid is flowing at a velocity of 0.9669 m/s and temperature of cold fluid at inlet 301.16 K as considered during the experimental analysis performed by Sheikholeslami et.al [8].

3. Validation of CFD model

For validating the CFD model of heat exchanger having discontinuous helical turbulator, here it examines the heat exchanger having helical discontinuous turbulator with circular perforation as considered during the experimental analysis performed by Sheikholeslami et.al [8]. The inlet and outlet conditions of hot fluid and cold fluid were same as considered during the experimental analysis and calculating the value of Nusselt number, Darcy friction factor. The contour of temperature and velocity for different Re numbers are shown in the below section.

3.1 For Re 6000

The temperature contours for 6000 Re number is shown below.

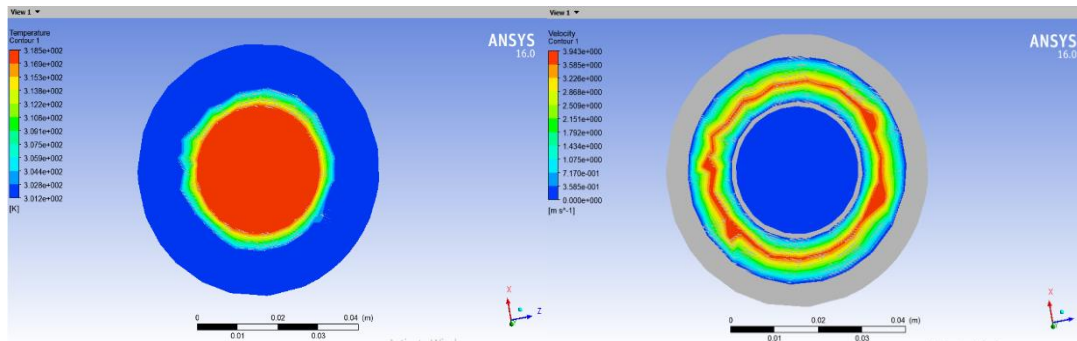


Fig.3 temperature and velocity contour of hot fluid outlet for Re 6000

As counter flow heat exchanger is used in this analysis, maximum heat transfer is taken place. Through numerical investigation we have calculated the value of nusselt number for different Re number and through calculation we have calculated the value of Darcy friction factor and Thermal performance. The evaluate of nusselt (Nu) for circular perforation discontinuous helical baffles is shown in the below table

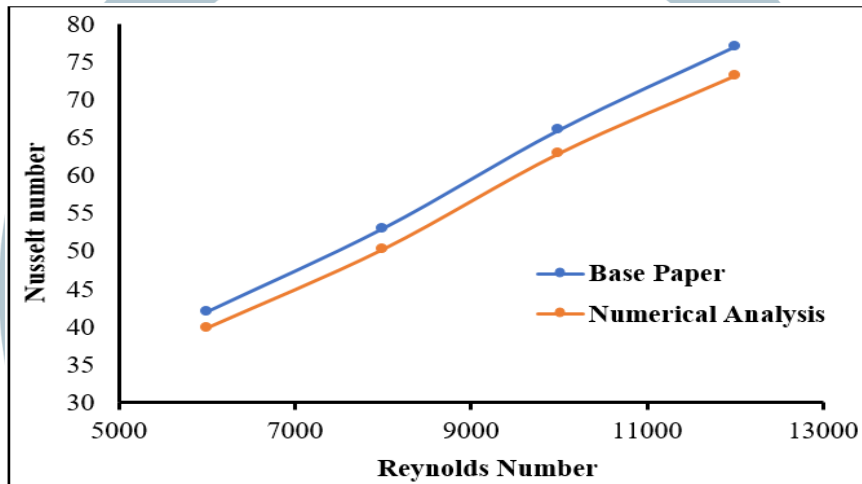


Fig.4 Comparison of value of Nu for different Re numbers

Form the above comparison graph it is found that the value of Nu for different Re number calculated through Numerical analysis is near to the value of Nu obtained from the base paper. So the numerical model of discontinuous helical turbulators heat exchanger is correct. For examine the value of Darcy friction factor (f) following mathematical calculation where used. The mathematical equation used for calculating friction factor

$$f = \frac{2 \Delta P D_H}{L \rho u^2} \dots\dots\dots (1)$$

Where ΔP is the pressure difference at the inlet and outlet, D_H is the hydraulic mean diameter, L is the length of heat exchanger, ρ density of air and u is the velocity of air at inlet. With the support of eq. 1 we can calculate the value of friction factor for different Re numbers.

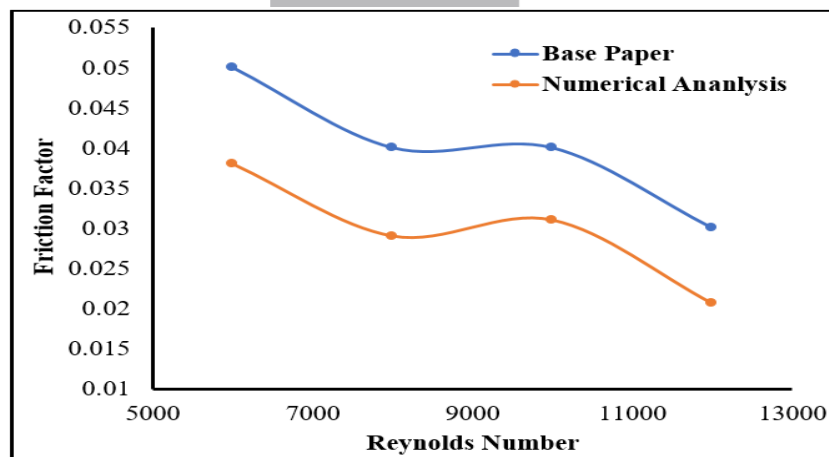


Fig.5 Comparison of value of friction factor for different Reynolds number

The value of friction factor calculated from numerical analysis is near to the value of friction factor give in the base paper, so the numerical model develop for discontinuous helical turbulator is correct.

4. Result and Discussion

4.1 Effect of different inclination angle of turbulator

After validation of the numerical model of discontinuous helical baffle heat exchanger, here in this work we have calculated the effect of continuous helical turbulator and also calculated the effect of inclination of turbulator on heat transfer enhancement. The solid model of continuous helical turbulators is shown in the below fig.

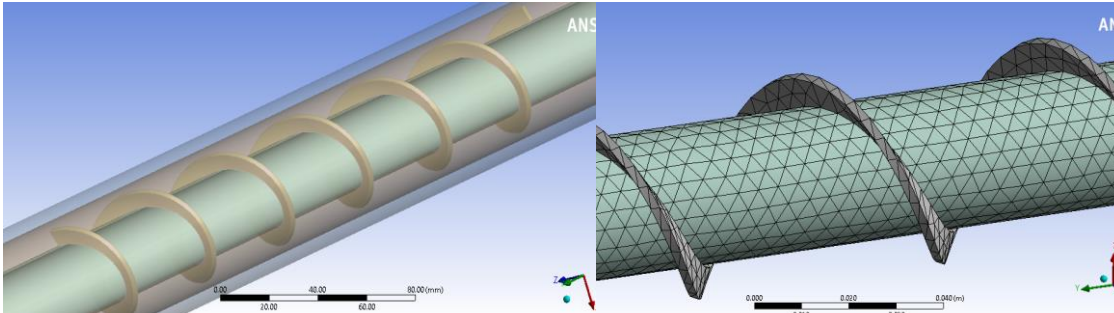


Fig.6 Solid model and mesh of heat exchanger having continuous helical turbulator

4.1.1 For 20° inclination

Here in this section helical turbulator is inclined at an angle of 20° and calculated the value of Nu and friction factor for different Reynolds number. Here in this analysis we have also find out the temperature distribution inside the heat exchanger and also shows the velocity distribution inside the heat exchanger. The temperature and velocity contours for different Reynolds number is shown in below figures.

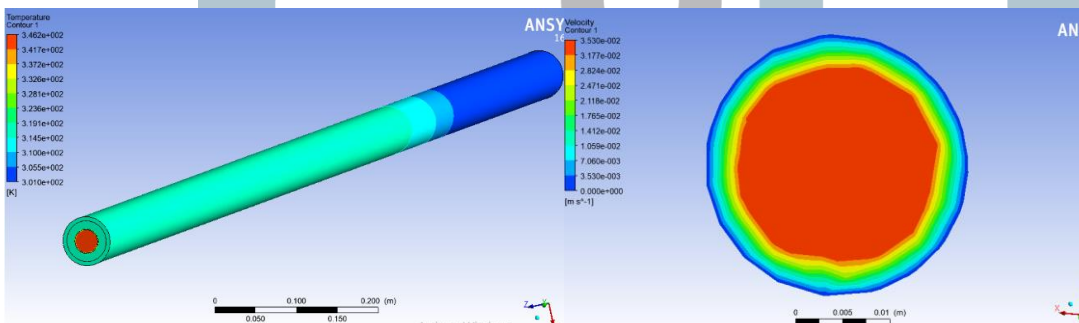


Fig.7 shows the temperature and velocity contours of continuous helical turbulator heat exchanger at 20° inclination Likewise, the above analysis effect of different inclination angle was analyzed through numerical analysis and calculates the value of Nusselt number and friction factor for different inclination angle turbulator having different Re numbers. The comparison of different cases was done in the current work.

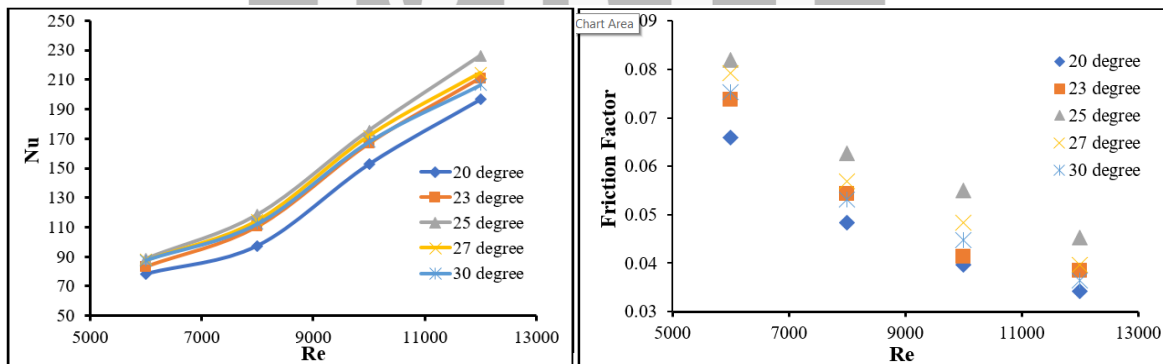


Fig.8 Comparison of value of Nu and Friction factor for different inclination angle of helical turbulator

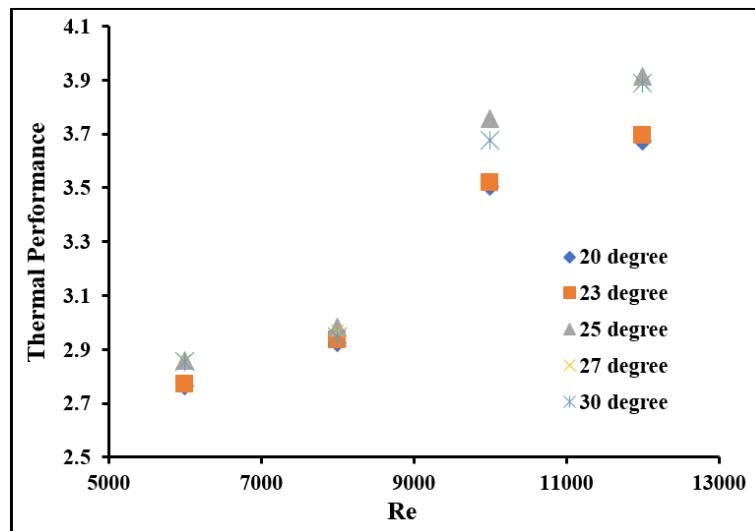


Fig.9 Comparison of value of thermal performance for different Reynolds number

From the above analysis it is found that the value of Nu number is maximum in case of 25-degree inclination angle of helical turbulator. Through analysis it is found that as the inclination angle of helical turbulator start increasing from 20-degree, the value of Nusselt number increases and maximum at 25-degree. After 25 degree inclination angle of helical turbulator the value of Nusselt number start decreasing, whereas the thermal performance of heat exchanger is also maximum in case of heat exchanger having 25-degree inclination. But through numerical analysis, it is also found that the value of friction factor is also higher in case of 25-degree inclination as compared to other inclination angle of helical turbulators.

5. Conclusion

The value of Nu number and friction factor depends on the type of turbulator used inside the heat exchanger. Value of Nu number and friction factor is maximum in case of turbulator having 25-degree inclination. So, the heat transfer is maximum in this case as compared to other inclination angle. The thermal performance of heat exchanger having 25-degree inclination angle helical turbulator is maximum as compared to the other inclination angle of heat exchanger. Through analysis it is also found that the heat exchanger having different inclination angle of helical turbulators shows the same nature in respect to thermal performance and heat transfer. Overall it shows that 25-degree inclination angle of helical turbulator is the optimum inclination angle of continuous helical turbulator.

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