

# EFFECT OF PERFORATED AND NON-PERFORATED TURBULATOR IN TUBE IN TUBE TYPE HEAT EXCHANGER

<sup>1</sup>Ankit Suryawanshi, <sup>2</sup>Prof. N.V. Saxena

Millennium institute of technology, Bhopal

**Abstract:** A heat exchanger is usually a device employed to transfer heat amongst a solid object and simply a fluid or between two or even more fluids. The fluids could possibly be segregated 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. In order to increase the heat transfer rate different types of baffles were used inside the heat exchanger. here in this work semi-circular shape turbulators were used inside the heat exchanger. Perforation was also given on semi-circular turbulator, different number of perforations was given on turbulators and measure the value of Nusselt number and friction factor for each case. In order to analyse the effect of different Reynolds number on different geometries of heat exchanger was also analysed.

**Keywords:** heat exchanger, turbulator, Nusselt number, heat exchanger geometries

## 1. Introduction

A Heat Exchanger may be stated as a device which transfers energy from a hot fluid to a cold fluid, either maximum or minimum rate within least investment as well as operating cost. In this process never two fluids mixed with each other. Heat exchanger is the main unit in action that gives the efficiency as well as security to numerous of the processes. In such type of job, we have to estimate the enactment of the heat exchangers of different types that is tubular, plate and shell & tube. 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 ways 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, effect of semi-circular turbulator with and without perforation was analyzed in tube in tube type heat exchanger. In order to increase the performance of the heat exchanger different critical geometries turbulators was used by researchers in previous work. Though the critical design of turbulator increases the heat transfer from heat exchanger, but in the other hand increase the pressure loss inside the heat exchanger with ultimately degrade the overall performance of the heat exchanger. So, to overcome this problem simple turbulator design are required which increases the heat transfer from heat exchanger and also have nominal increase in pressure drop. In the same order here semi-circular turbulator was considered as a turbulator and to further increase the intensity of turbulence perforation was given. In order to analyzed the effect of perforate and non-perforated turbulators four different cases was considered during this work. (a) Semi-circular turbulator without any perforation, (b) Semi-circular turbulator with single perforation, (c) Semi-circular turbulator with double perforation and (d) Semi-circular turbulator with three perforations. In order to analyzed the effect of change in velocity on different geometries of turbulator four different Reynolds number was considered during the work that is 6000, 8000, 10000 and 12000. For each case of analysis Nusselt number and friction factor was calculate and comparison was done. For performing the numerical analysis, first we have developed the solid model of heat exchanger having different perforation shapes of circular turbulator. On the basis of geometrical condition as mention in chapter 3 we have developed the numerical model. After validating the numerical analysis of perforated helical tabulator heat exchanger, semi-circular turbulator type heat exchanger solid model was made considering same geometric parameters as considered during previous work.

## 2. Development of numerical model of heat exchanger

For the validation of the numerical analysis here first it considered heat exchanger having circular perforation circulator turbulator as considered in base paper. The solid model of heat exchanger is developing on the basis of geometry considered by Sheikholeslami et.al [6] 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)	6	
Turbulator Width (mm)	7	

During the development of solid model of heat exchanger here it considered 5.83 pitch ratio in between the two turbulators. The solid model of the heat exchanger is shown in the below fig.

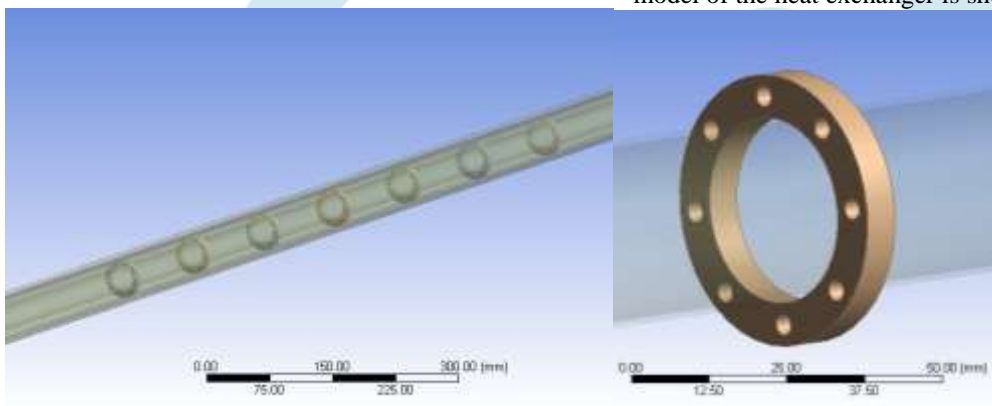


Fig.1 solid model of the heat exchanger with perforated circular turbulators

For the initial analysis here it considered circular perforated circular discontinuous turbulators. 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 [6].

### 3. 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. Mesh of the circular turbulators heat exchanger is shown in the below fig. 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.

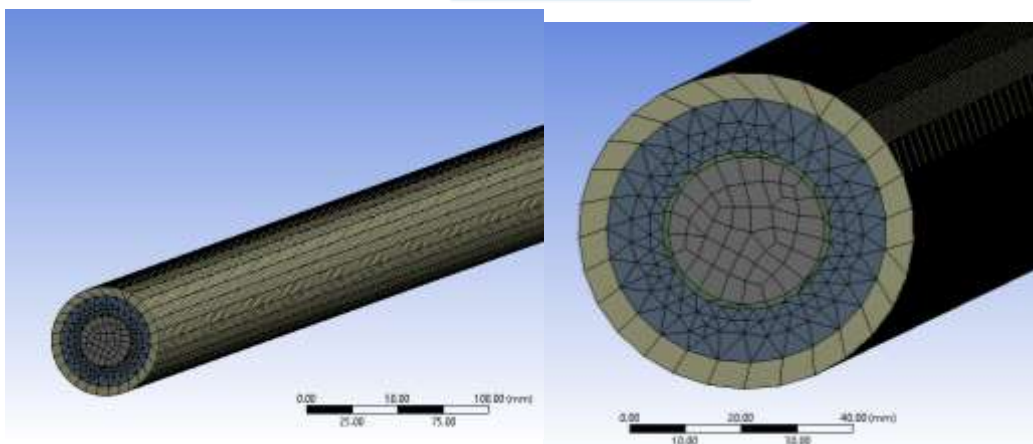


Fig.2 shows the mesh of the circular turbulator heat exchanger

#### 4. Material and Solution Method

Here in this work warm fluid water is flowing in the inner tube whereas cold fluid that is air is flowing in the outer pipe. The inner pipe of heat exchanger is made of copper material whereas outer tube is made of Plexiglas which acts as a thermal insulating material. 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 where shown in the block diagram.

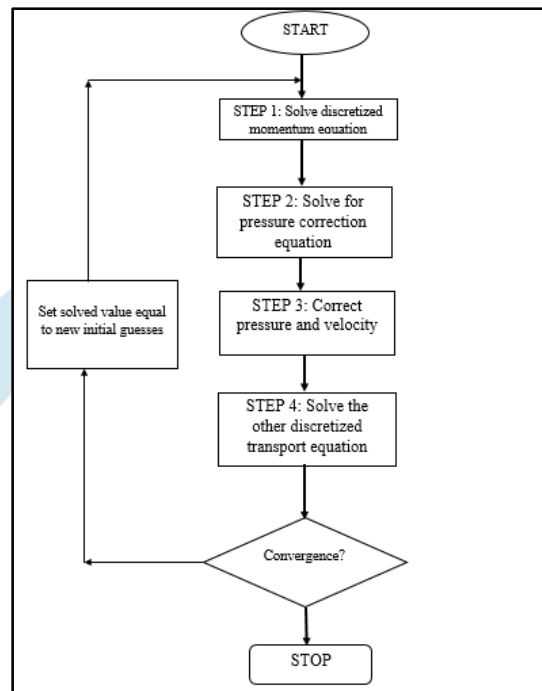


Fig.3 Block diagram of solution method used during the analysis

#### 5. Boundary condition

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 [6]. For validating the CFD model of heat exchanger having discontinuous perforated circular turbulator, here it examines the heat exchanger having circular discontinuous turbulator with circular perforation as consider during the experimental analysis performed by Sheikholeslami et.al [6]. 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.

##### 5.1 For Re 6000

The temperature contours for 6000 Re number is shown below

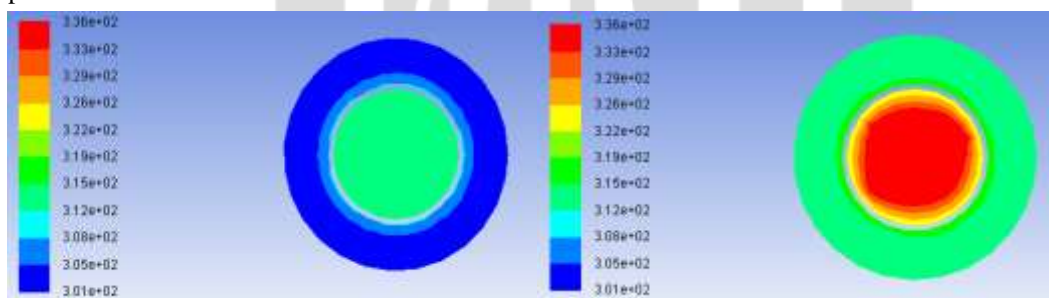


Fig.4 Temperature contour of hot fluid outlet and inlet for Re 6000

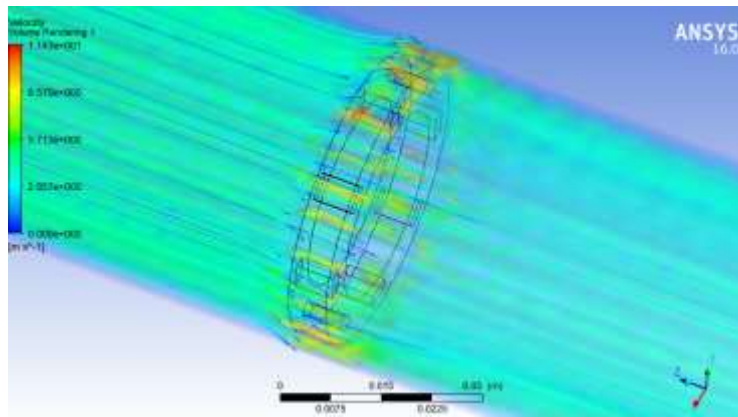


Fig.5 Shows the flow of air from the perforated turbulators

From the above fig. it is found that temperature of air increases from inlet to outlet and it is maximum at the exit of heat exchanger. 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.

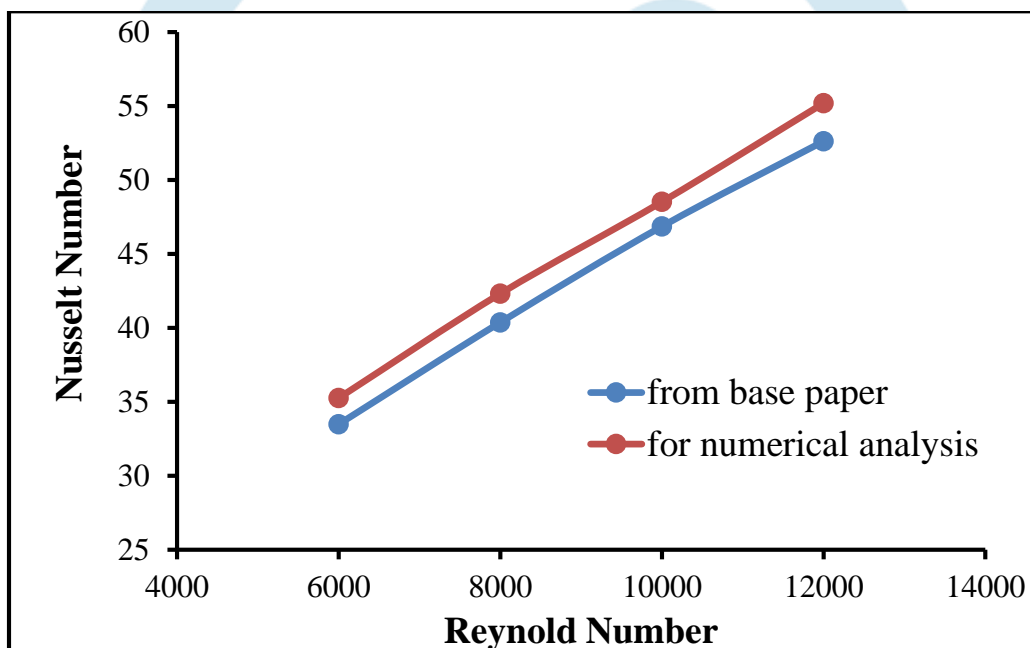


Fig.6 Comparison of value of Nu for different Re numbers

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 number obtained from the base paper. So the numerical model of discontinuous circular 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

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

Where  $\Delta P$  is the pressure difference at the inlet and outlet,  $D_H$  is the hydraulic mean diameter, L is the length of heat exchanger,  $\rho$  density of air and u is the velocity of air at inlet. With the support of eq. 2 we can calculate the value of friction factor for different Re numbers.

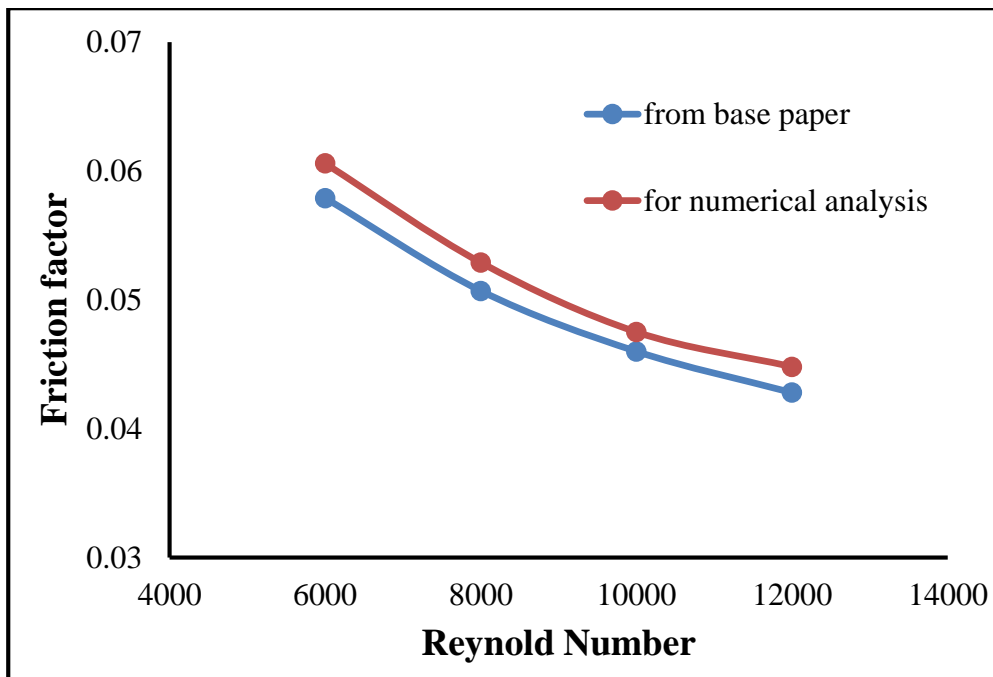


Fig.7 Comparison of value of friction factor for different Reynolds number

From the above fig. it is found that the value of friction factor decreases as the Re number increases. 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.

**6. Heat exchanger having semi-circular non perforation turbulators**

Tube in tube heat exchanger having semi-circular turbulator without perforation was considered during this case. The solid mode of heat exchanger is shown in the below figure.

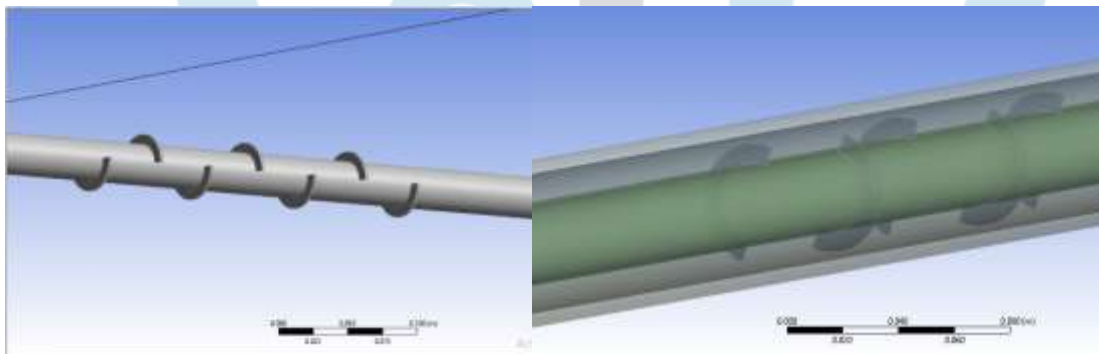


Fig.8 solid model of heat exchanger having semi-circular turbulator without perforation

**6.1 For Re = 6000**

In this case the 6000 Re number was considered at the inlet of heat exchanger for cold fluid, whereas other boundary conditions will remain same. The temperature and velocity contours of for this case is shown in below fig.

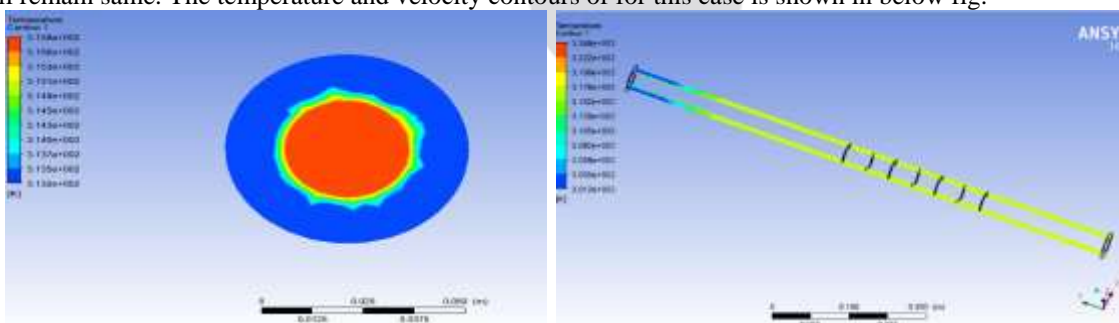


Fig.9 Velocity contours of hot fluid at the exit of heat exchanger

## 7. Comparison of different Geometric design of turbulators

After calculating the value of nusselt number and friction factor for different geometric condition of tube in tube heat exchanger comparison was done. From numerical analysis it is found that with perforation the Nusselt number get increase which is mainly due to increase in turbulence inside the heat exchanger.

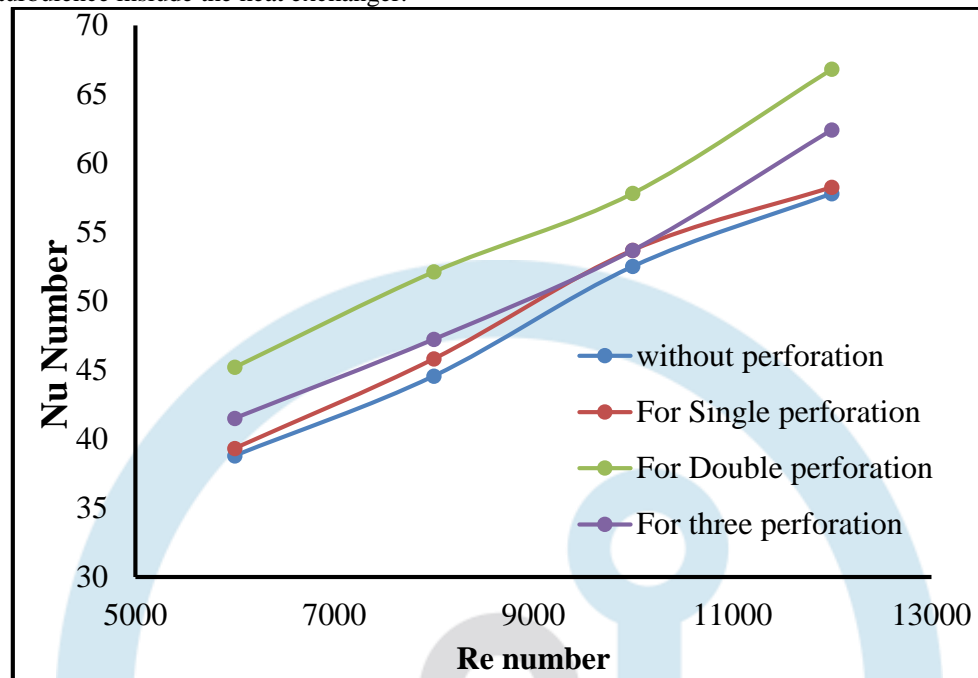


Fig.10 Comparison of Nusselt number for different Reynolds number

Due to perforation the turbulence intensity of hot fluid get increase which helps in increasing the heat transfer rate from heat exchanger. In perforation geometries, heat exchanger having double perforation shows maximum heat transfer as compared to other perforation geometry. With double perforation the Nusselt number increases significantly as compared to without perforation turbulator. After comparing the value of nusselt number the value of friction factor for different geometrics of tube in tube heat exchanger was done.

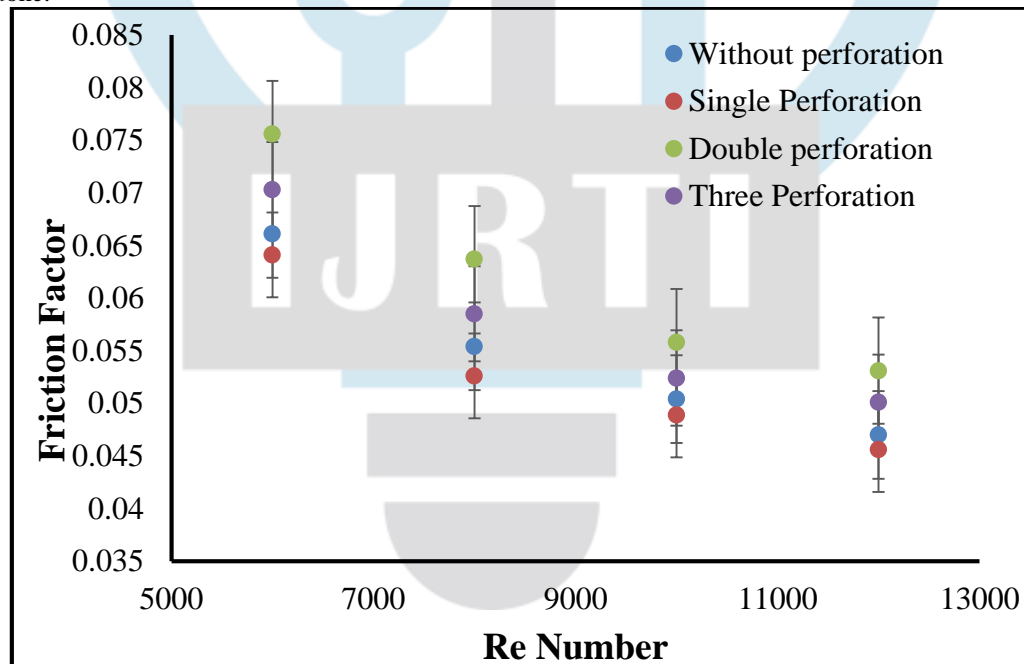


Fig.11 comparison of value of friction factor for different Re numbers

Through figure it is also concluded that with double perforation the performance of heat exchanger increase significantly, whereas with other perforation it increases marginally with other perforation. Overall it is found that with double perforation the performance of heat exchanger more as compared to other heat exchanger geometry.

## 8. Conclusion

CFD analysis of heat exchanger was done and validated with the experimental work performed in the base paper. Through CFD it is found that flow behavior of air plays an important role in heat transfer in tube in tube type heat exchanger. With semi-circular turbulator the performance of the heat exchanger gets enhanced marginally. In order to further increase the performance of the heat exchanger, perforation was made on the semi-circular turbulator. With single perforation the heat transfer increase marginally as compared to without perforation geometry. Whereas with double perforation the heat transfer increase significantly as compared to

without and single perforation heat exchanger geometry. Though the friction factor is more in case of heat exchanger having double perforation, but the overall thermal performance is also more for this case.

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