INTERNATIONAL JOURNAL OF INNOVATIVE TRENDS IN ENGINEERING (IJITE) ISSN: 2395-2946
ISSUE: 98, VOLUME 73, NUMBER 02, FEBRUARY 2021

A Review CFD Simulation on Computational Fluid Dynamic Analysis of Tube Heatexchanger Having Discontinuous Helical Baffles

Shashank Dixit[1], Sachin Baraskar[2], Anil Verma[3], Prof. G.R. Selokar[4]. Dr. Nilesh Diwakar[5]

[1]*Research Scholar, Department of Mechanical Engineering, School of Engineering, SSSUTMS, Sehore*

[2]*Assistant Professor, Department of Mechanical Engineering, School of Engineering, SSSUTMS, Sehore*

[3]*Head of Department of Mechanical Engineering, School of Engineering, SSSUTMS, Sehore*

[4]*Registrar, SSSUTMS, Sehore*

[5]*Dean (SOE), SSSUTMS, Sehore*

Abstract - Heat exchanger is an apparatus to carry heat from one channel to another. Due to the significance of heat exchanger in different field there is a pressure to enhance heat transfer rate on researcher. Requirement of excessive heat transfer from small area generate the concept of close pack heat exchanger. For different applications compact heat exchanger were employ to transfer heat at a much faster rate than the conventional heat exchanger. To expand the fulfillment of heat exchanger researchers had optimized the different process parameters on which the operation of heat transfer depends. To enhance the turbulence interior the heat exchanger dissimilar category of baffles were used, with the help of baffles turbulence were created inner side the heat exchanger. To improve the heat transfer here in this work perforated irregular helical baffles are used to growing the heat transfer. Here in this effort square, circular and triangular perforated intermittent helical baffles were operating to increase the heat transfer rate. It also determine the effect of changing Reynolds number on heat transfer, to evaluate the effect of altered Reynolds number here it considered four altered Reynolds number that is 6000, 8000, 10000 and 12000. It also calculates the significance of Darcy friction factor for discrete perforated interrupted helical baffles at different Reynolds number. After doing the CFD analysis and mathematical calculation it is establish that the baffles having square perforation shows supreme heat transfer as compared to the other categories of perforation. For calculating the effect of dissimilar perforation shape on heat transfer thermal performance of heat exchanger were also calculated in this work.

Keyword: heat exchanger, helical baffles, perforation, thermal enhancement, flow rate.

I. INTRODUCTION

Heat exchanger

Heat exchanger is a mechanism that is typically used to happen the resolve of an equipment to switch heat among two procedure streams.The fluids may be detached by using a solid wall to prevent mixing or they may be in direct contact. They are commonly used in space heating, refrigeration, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. Example of heat exchanger is shown in an internal combustion engine where fluids flows through radiator coils and air flows over the coils, which cool the coolant and heats the coming air. Another instance is the heat sink which is a inert heat exchanger that convey the heat generated by an electronic or a mechanical equipment to a fluid norm, air or a liquid fluid.

1.2 Types of heat exchanger

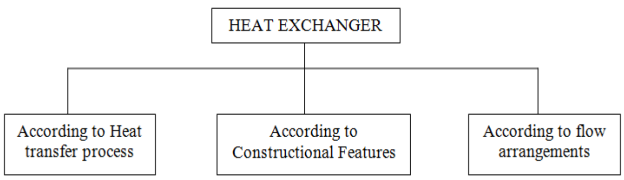

Fig.1.1 Schematic diagram showing the types of heat exchanger

1.2.1 According to Heat transfer process

1.2.1.1 Direct contact type heat exchanger

Here in this exchanger two immiscible fluids are mixed with each other to exchange heat between two fluids.

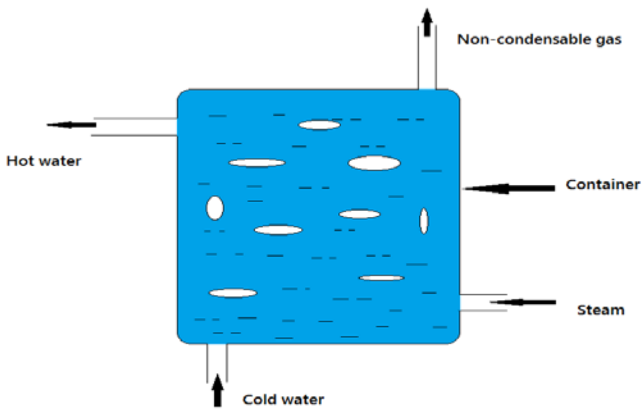

Fig. 1.2 Schematic diagrams showing direct contact heat exchanger

The two streams must also be at the same pressure in a direct contactor, which could result in additional fees. The benefits in utilizing a direct contactor include the dearth of surfaces to corrode or foul, or otherwise degrade the warmth transfer performance.Cooling tower, jet condenser, de-super heaters, open feed water heater are the example of this sort of heat exchanger

1.2.1.2 Transfer type heat exchanger

In transfer kind or recuperate sort of heat exchanger two fluids flow concomitantly through two tube seprated by walls. A recuperator is a distinctive motive counter flow power regaining heat exchanger situated within the supply and deplete air streams of an air coping system, or within the exhaust gases of a industrial process in order to recover the waste heat.

1.2.1.3 Regenerator type heat exchanger

In Regenerator type heat exchanger the cold fluid glide and warm fluid flow instead on same surface. In the course of the recent fluid switch the surface wall of warmth exchanger get heated and when the cold fluid flows through it, wall heat get transferred to the cold fluid and heat exchanges in direction that the temperature of cold fluid get increase. The common instance of these kind of heat exchangers is pre-heater for blast furnace, steam power plant and so on.

1.2.2 On the Basis of Constructional Features

1.2.2.1 Tubular Heat Exchanger

Tubular heat exchangers are the category of heat exchange device in which two different fluids having changed temperatures are separate by the two concentric tubes. It is mostly used in many engineering application like power plant.

1.2.2.2 Shell and Tube type Heat Exchanger

Shell and tube cluster of warmth exchanger consists of shell and large variety of parallel tubes. The warmth transfer takes places when one fluid flows through the tube and another fluid flows outside the tube that is privileged the shell of the exchanger. These varieties of device having giant surface area. Through baffles heat transfer rate of warmth exchanger get improved or it increases the turbulence inside the warmth exchanger.

1.2.2.3 Finned tube Heat Exchanger

In order to improve the heat transfer rate, fins are provided on the outer surface of the heat exchangers. Those are used in gas to liquid heat exchanger and fins are placed on the gas side. These are used in gas turbine, aero plane, warmness pumps, automobiles etc.

1.2.2.4 Compact heat exchanger

A compact heat exchanger to be characterized as heat exchanger which has area density (β) greater than $700m^2/m^3$ for gas or higher than $300m^2/m^3$ when working in liquid or two phase streams. For example car radiators which has an area density in order to 1100 m^2/m^3. Compact heat exchanger are cross flow type where two fluid flows perpendicular to each other.

1.2.3 According to flow arrangement

There are three primary classifications of warmth exchangers on the premise of flow. In parallel-flow heat exchangers, the two form of fluids enter the money changer at the identical finish, and travel in parallel to one another to the opposite finish. In counter-flow heat money changers the fluids enter the exchanger from completely different ends. The counter current style is that the utmost effective, it will transfer the foremost heat from medium per unit mass due the common activity on any unit size is higher. See countercurrent exchange. In an exceedingly cross-flow device, the fluids travel equally at right angles to one another through the money changer. For potency, heat exchangers are created to maximize the extent of the wall between the two fluids, whereas reducing resistance to fluid flow within the money changer. The exchanger's act may also be littered with the addition of fins, that increase extent and should waterway fluid flow or induce commotion. The driving temperature across the warmth transfer surface varies with position, however associate appropriate mean temperature are often well-defined. In most straightforward systems this is often the "log mean temperature difference" (LMTD).

1.2.3.1 Parallel Flow

A double tubes device may be running in parallel flow mode as shown within the diagram. equally a shell and tube device area unit running in near parallel flow whereas having two fluids enter at one aspect and exit at the opposite aspect. With same direction flow the temperature distinction between the two fluids is massive at the coming into finish, however it develops tiny at the exit finish because the two fluid temperatures near one another.

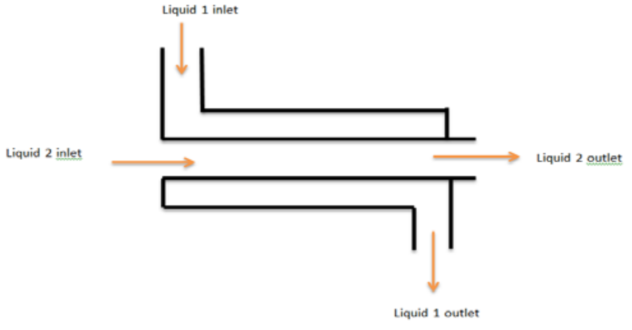

Fig. 1.3 Schematic diagram of a double pipe parallel flow heat exchanger

The general live of heat transfer driving pressure, the log mean temperature distinction is larger for counter flow, then the warmth money dealer surface region demand could also be larger than for a counter associate with the flow device with the identical recess and outlet temperatures for the recent and the cold fluid.

1.2.3.2 Counter Flow

A counter flow device is that the only pattern of flow of the three. It ends up in all-time low needed device area as a result of the log mean temperature drop is that the perfect for a counter flow device. A counter flow device has the recent fluid getting into at one finish and cold fluid at the choice stop. Kind of flow most typically type liquid-liquid device, as a result of it's for higher effective compare to alternative.

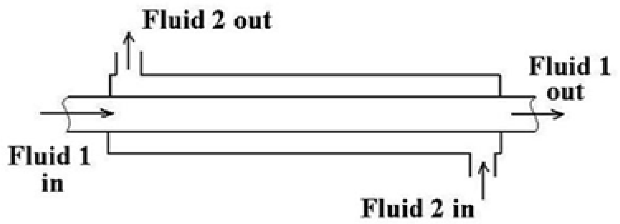

Fig. 1.4 Schematic diagram of a double pipe counter flow heat exchanger [23]

1.2.3.3 Cross flow

An automobile radiator associate cooling system evaporator coil are samples of cross flow heat exchangers. In every instances heat transfer is taking location among a liquid flowing interior a tube or tubes and air flowing on the so much facet the tubes. With a vehicle radiator, the new water among the tubes is being cooled by air flowing via the radiator between the tubes. With associate cooling system evaporator coil, air flowing past the evaporator coils are cooled by implies that of the cold refrigerant flowing within the tubes of the coil. Cross float heat exchangers are typically used for heat switch between petroleum and a liquid as in those examples.

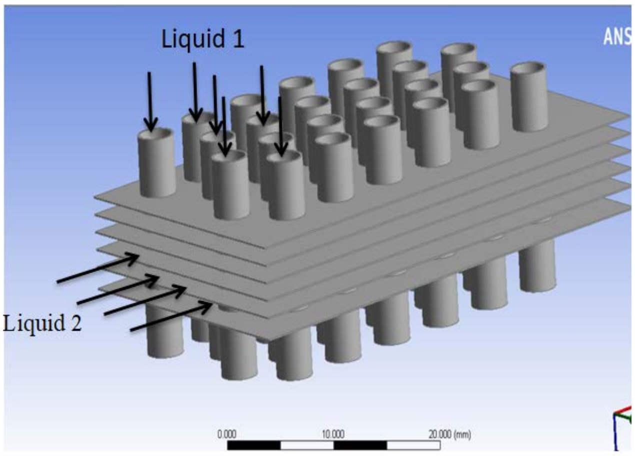

Fig. 1.5 Schematic diagram of cross flow heat exchanger

1.3 Types of heat exchanger

Double pipe heat exchangers are the sole exchangers utilized in industries. On one hand, those heat exchangers are low-cost for each style and preservation, creating them an honest want for tiny industries. On the opposite hand, their low performance including the excessive space occupied in massive scales, has semiconductor diode trendy industries to use additional economical heat exchangers like shell and tube or plate. However, owing to the actual fact double pipe heat exchangers are easy, used to device layout basics to students because the elementary tips for all heat exchangers are the equal.

1.3.1 Shell and Tube Heat Exchanger

Shell and tube heat exchangers embrace assortment of tubes. One set of those tubes contains the fluid that has to be compelled to be either heated or cooled. The other fluid runs over the tubes which might be being heated or cooled so as that it's ready to either offer the heat or take in the warmth needed. A set of tubes is understood because the tube package deal and should be made of varied kinds of tubes: easy, lengthwise finned, etc. Shell and tube heat exchangers square measure typically used for excessive-stress programs (with pressures further than thirty bar and temperatures further than 260 °C). That's as a result of the shell and tube heat exchangers square measure sturdy due to their form. Varied thermal layout capabilities have to be compelled to be taken into thought while coming up with the tubes within the shell and tube heat exchangers, there could also be several variations on the shell and tube style. Generally, the ends of every tube square measure joined to plenums via holes in tube sheets. The tubes are often instantly or bent within the form of a U, referred to as U-tubes.

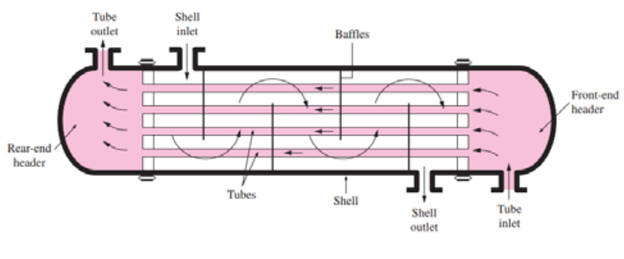

Fig. 1.6 Schematic diagram of a shell and tube heat exchanger [23]

1.3.2 Plate Heat Exchanger

Some other moderately device is that the plate device. Those exchangers square measure composed of the numerous skinny, slightly separated plates that have surface regions and tiny fluid flow passages for heat switch. Advances in seal and brazing technology have created the plate-type device plenty of and plenty of realistic. In HVAC used, giant heat exchangers of this kind square measure cited as plate-and-body, whereas utilized in open loops, these heat exchangers square measure typically of the seal kind to allow periodic activity, cleansing, and review. There square measure many forms of permanently secure plate hotness exchangers, at the side of dip-brazed, vacuum-brazed, and welded plate varieties, and that they square measure typically specific for closed-loop programs like refrigeration. Plate heat exchangers to boot fluctuate inside the kinds of plates that square measure used, and among the configurations of these plates. Some plates might even be sealed with "chevron", dimpled, or different styles, whereby others may additionally have machined fins and/or grooves. Once as compared to shell and tube exchangers, the stacked-plate arrangement typically has decrease quantity and value. Another distinction between the two is that plate exchangers generally serve low to medium pressure fluids, as compared to medium and excessive pressures of shell and tube. A third and crucial distinction is that plate exchangers rent larger countercurrent waft rather than move trendy waft that permits lower approach temperature variations, heat modifications, and accelerated efficiencies.

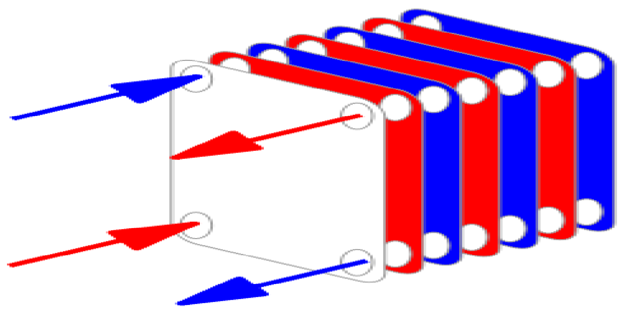

Fig. 1.7 Schematic diagram of a plate heat exchanger [10]

II. LITERATURE REVIEW

2.1 Introduction

In later on the far side year, the changes in computing energy have extended the interest of engineers and researchers to simulate their troubles with procedure and numerical techniques. Plenty of procedure apparatuses and techniques are created within the foremost recent a protracted time to interrupt down liquid float, combustion, and specific techniques of heat alternate. Usage of warmth exchangers in widespread type of uses attracts within the professionals and researchers to paintings on this discipline.

.**Anurjew et.al [1]**Investigated completely different small structure cross flow heat exchangers and considered their heat exhibitions. The facility transfer per unit volume is directly proportional to the perform of warmth supply and warmth sink for higher heat transfer lesser are going to be the space. They found that heat transfer are often upgraded by decreasing the pressure driven distance across of the small channels and in their work conjointly emphasize the electrically.

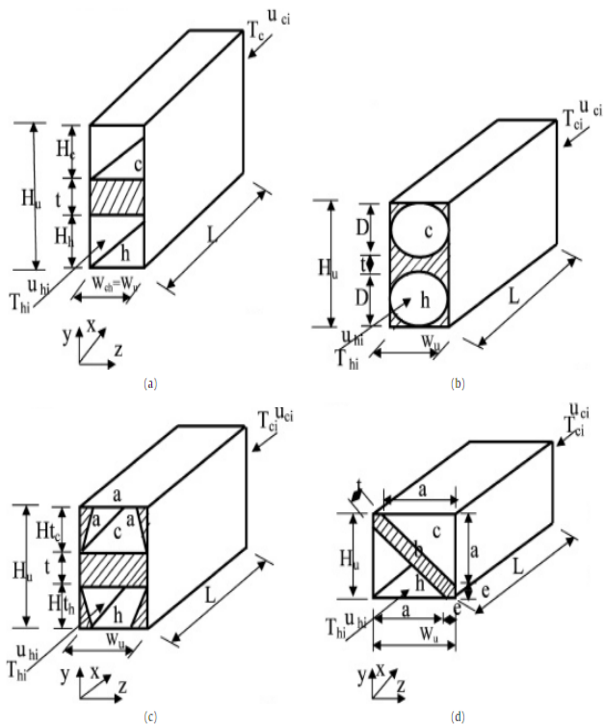

Fig. 2.1 Schematic of a heat exchanger unit [13]

Tanget. al [2]In the gift paper they did investigation through by experimentation on fin-and-tube heat exchangers with the Sir Joshua Reynolds range varies from 4000 to ten thousand,and the improvement of warmth money handler with vortex generator(VGs) is additionally self-addressed and at high Sir Joshua Reynolds numbers, best heat transfer performance achieved by slit fin device. The high angle of attack, low height and {better} length of vortex generators can cause better overall performance of warmth exchangers with VGs. The optimized vortex-generator fin will give higher heat transfer performance than slit fin.

Yang et al. [3]It is vital to get the warmth transfer characteristics of hard-hitting syngas within the cooler. Heat transfer in convection cooling section of controlled coal gasified with the membrane whorled coils and membrane snaky tubes below air mass is through an experiment investigated. Air mass single gas (He or N2) and their mixture (He + N2) gas function the check media within the check pressure vary from zero.5 MPa to 3.0 MPa. The results show that the convection heat transfer constant of air mass gas is influenced by the operating pressure, gas composition and symmetry of flow round the coil, of that the operating pressure is that the most important issue. The typical convection heat transfer coefficients for varied gases in heat exchangers area unit consistently analyzed, and therefore the correlations between alphabetic character and Re for two styles of membrane heat exchangers area unit obtained.

Yakaret. al [4]Examined by experimentation the air aspect heat exchange constant and also the heat steady electrical phenomenon in finned tubes. Water is employed because the heating medium, in turbulent conditions and streaming at varied temperatures within the tube. Petukhov's relationship has been chosen to determine the water heat move constant within the tube. A fitting of the knowledge provides a relationship to the three containers of assorted outside breadth (30 millimeter, 22 mm, and 15.6 mm) that concurs exceptionally well with the experimental esteems. Assessed the contact heat resistance amongst balances and tubes to increment visible of the Reynolds range and also the heat contact resistance square measure evaluated and adjusted.

Jayakumar et al. [5]The heat exchanger is analyzed considering conjugate heat transfer and temperature dependent properties of warmth transport media.The CFD predictions match fairly well with the experimental results inside experimental error limits. Supported the results a correlation was developed to calculate the inner heat transfer constant of the turbinate coil. Supported the boldness gained within the CFD predictions, the results generated beneath totally different conditions could use additional to get a generalized correlation. additionally for prediction of warmth transfer during a state of affairs of fluid-to- fluid heat transfer, because it happens within the case during a device, discretional boundary conditions like constant wall temperature, constant heat flux.

Venugopal et al [6]Conducted associate experimental study k regarding on the amalgamated convective heat move in an exceedingly vertical channel loaded with tinny porous structures. The semi permeable medium model created within the gift examination shows thermo-hydrodynamic execution like those found in metal froths. A correlation has been made for foreseeing the Nusselt variety from the pure mathematics beneath thought. The key curiosity within the gift work is that the development of another relationship for the Nusselt variety that doesn't need any knowledge from hydraulics investigations. Over the scope of parameters thought of, the most important increment within the traditional Nusselt variety of 4.52 times that for clear stream is seen with a semipermeable material of consistency of 0.85.

Lingdong et.al[7]Conducted Numerical studies to research the airside thermal-hydraulic characteristics of blank tube bank and plain finned tube heat exchangers meant to be used in aero-engine cooling. The exchangers use little diameter tubes (3.0 mm) with compact tube layout and operate at high temperatures with massive temperature changes over the money handler depth. Calculations are performed for frontal air velocities between five and twenty m/s, airside heat transfer and pressure loss characteristics of blank tube bank and plain finned tube heat exchangers are numerically foretold considerately of the air property variations caused by the air temperature variations.

Pawar et.al [8] Investigated the experimental analysis on constant temperature steady state and non-isothermal unsteady state conditions in spiraling coils. that they had thought of each the Newtonian moreover as non-Newtonian fluids for operating fluid. For Newtonian fluid they thought of water and glycerol–water mixture (10 and 2 hundredth glycerol). For non-Newtonian fluid they thought of zero.5–1% (w/w) dilute liquid compound solutions of Na Carboxy methyl cellulose and Na Alginate. The correlation was distinguished between the Nusselt range and non-dimensional range, ‘M’, Prandtl range and coil curvature quantitative relation. They found the warmth transfer rate beneath equal steady state and non-isothermal unsteady state conditions in laminar and flow conditions.

M. Sheikholeslami et.al [9] The turbulent hydrothermal study of forced convection during a device of double pipe is existed much. Currently perforated turbulators area unit utilized in annulus space. Predicament generate the cold air within the outer tube hotter. Completely different quantities of magnitude relation of pitch, magnitude relation of open space and Sir Joshua Reynolds range area unit deliberated. Relationships for Nusselt range, performance of thermal and darcy issue of friction area unit tested. Impacts of perforated circular ring on stream kind and thermal treatment during a device of water to air area unit ascertained. The impact of PR, open space magnitude relation and Re on hydrothermal activity area unit calculated. Relationships of letter, f and thermal performance are provided. The Outcomes indicate that loss in pressure and letter no. reduces with supplement of thermal performance. So, open space magnitude relation is associate up parameters of thermal performance. optimum worth of thermal conditions area unit obtained

III. METHODOLOGY AND MATERIAL USED

3.1 Introduction

Here in this chapter is considered step that are taken to fulfill the objective of the work and also contains the material used for the different purposes.

3.2 Steps to be followed

1. Study of heat exchanger and there types.
2. Literature survey and problem identification.
3. Development of solid model of heat exchanger on the basis of geometry given in the base paper.
4. Development of CFD model of the heat exchanger for numerical analysis.

5. Validation of the numerical analysis with the experimental analysis performed in the base paper.
6. Finding the effect of different shape of perforation on the heat transfer inside the heat exchanger.
7. Finding the effect of transformation in velocity on the heat transfer.
8. Calculating the value of nusselt number and friction factor for altered geometry at different velocity.
9. Comparison of different types of baffles for heat transfer.
10. Report preparation.

3.3 Material Used

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. The properties of different material used .

3.3.1 For Hot Fluid

Water is used as a hot fluid which is flowing in the inner tube. Here properties of water are a function of temperature. The polynomial equation according to which properties of water varies is mention here

$$\text{Property} = A_1 + A_2 \times T + A_3 \times T^2 + A_4 \times T^3 + A_5 \times T^4 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where A_1, A_2, A_3, A_4, A_5 are the coefficient, the value of coefficient for different property of water is shown in the below table.

Table 3.1 Value of coefficient for different properties of water

Constant	Density (ρ) (kg/m^3)	Specific Heat (Cp) (J/kg-K)	Dynamic Viscosity (μ) (kg/m-s)	Thermal Conductivity (K) (W/m-k)
A_1	-1.66E02	1.22E04	4.55E-01	2.11E-01
A_2	1.22E01	-9.29E01	-5.26E-03	-4.06E-03
A_3	-4.65E-02	4.07E-01	2.29E-05	4.05E-05
A_4	7.71E-05	-8.03E-04	-4.45E-08	-9.56E-08
A_5	-5.03E-08	6.05E-07	3.24E-11	6.77E-11

3.3.2 For cold fluid

Air is used as a cold fluid which is flowing in the outer tube of heat exchanger, here the property of air is also varying with respect to temperature. Properties of air vary with respect to the equation (1) as mention in the above section. The value of coefficient for different properties are mention in the below table

Table 3.2 Value of coefficient for different properties of air

Constant	Density (ρ) (kg/m^3)	Specific Heat (Cp) (J/kg-K)	Dynamic Viscosity (μ) (kg/m-s)	Thermal Conductivity (K) (W/m-k)
A_1	4.54	1.05E03	9.46E-05	1.80E-02
A_2	-2.32E-02	-3.51E-01	-1.02E-06	-1.68E-04
A_3	5.64E-05	5.84E-04	4.71E-09	1.38E-06
A_4	-6.28E-08	3.03E-07	-9.11E-12	-3.26E-09
A_5	2.36E-11	-5.2E-10	6.54E-15	2.75E-12

3.3.3 For inner tube

Here in this work copper is used for inner tube manufacturing, the properties of copper material is shown in the below table.

Table 3.3 Properties of copper material

Property	Value
Density (kg/m^3)	8978
Specific heat (J/kg-k)	381
Thermal conductivity (W/m-k)	387.6

3.3.4 For Outer tube

For outer tube it used plexiglas as a manufacturing material which act as thermal insulator. It prevents heat to go inside the tube.

Table 3.4 Properties of Plexiglas material

Property	Values
Density (kg/m^3)	1180
Specific heat (J/kg-k)	1466
Thermal conductivity (W/m-k)	0.000581

IV. RESULT AND DISCUSSION

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. To enhance the heat transfer from water to air baffles were placed in the outer surface of inner tube. Due to the baffles turbulence and contact time were increased which helps in increasing the heat transfer. In this work it considered three different shapes of perforated helical baffles that are triangular, square and circular perforated helical baffles to enhance heat transfer rate. Here it calculate the value of nusselt number for different Re and also calculate the value of friction factor for different nusselt number. To measure the heat transfer increasing due to baffles hear it also calculate the value of thermal performance for different perforated baffles. To complete the objective numerical model of the heat exchanger is develop in the below section.

4.2 Development of numerical model of heat exchanger

4.2.1 Development of solid model of heat exchanger

The solid model of heat exchanger is develop on the basis of geometry considered by Sheikholeslami et.al[21]considered during the experimental analysis the geometric specification of solid model of heat exchanger is given in the below table.

Table 4.1 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
Pitch ratio (PR)	1.83	
Open area ratio	0.0625	
Fin thickness (mm)	2	

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

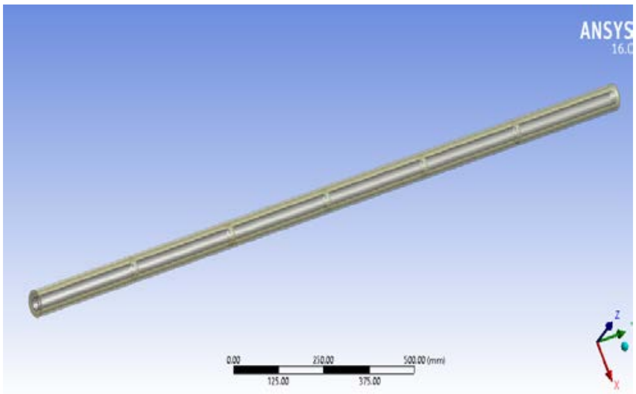

Fig. 4.1 solid model of the heat exchanger with perforated helical baffles

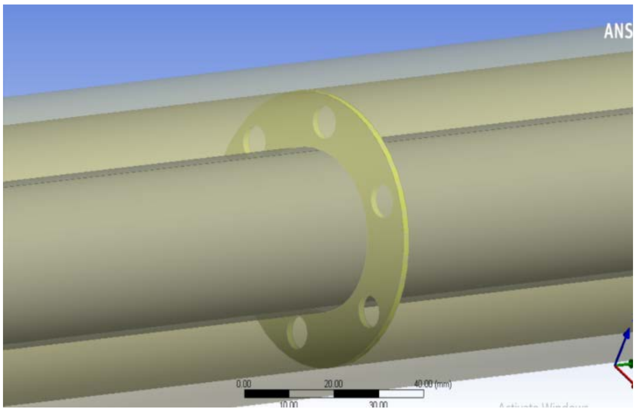

Fig. 4.2 shows the circular perforation helical baffles

For the initial analysis here it considered circular perforated helical discontinuous baffles. To corroborate the numerical model of heat exchanger, same geometric and boundary condition where considered for the initial analysis as considered in experimental analysis performed by Sheikholeslami et.al[21].

4.2.2 Meshing

To perform the numerical analysis here it has to discretize the solid model in to number of elements. To perform proper mesh different meshing tool where use for the refinement of mesh. Mesh of the helical baffles heat exchanger is shown in the below fig.

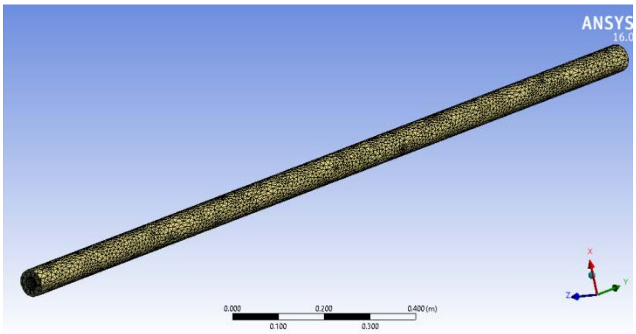

Fig. 4.3 shows the mesh of the helical baffle heat exchanger

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. The value of temperature of water at the exit for different number of element of mesh is shown in the below table

Table 4.2 Value of temperature for different number of elements

No. of elements	Temperature (K)
385563	318
404586	318.5
432486	319

From the above table it is found that the value of temperature of water at the exit is not depending on the number of mesh elements. So to minimize the computational time here it considered minimum number of elements to perform the analysis. Mesh with minimum optimum number of element is shown in the below fig.

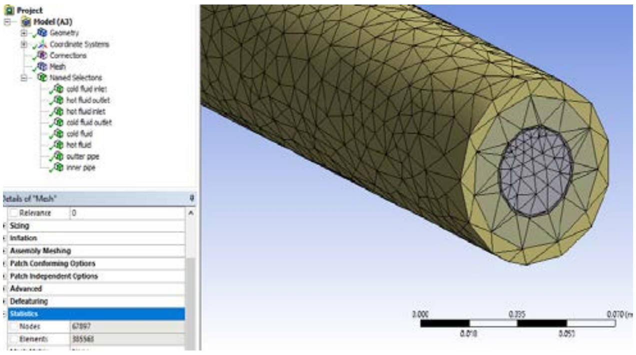

Fig. 4.4 showing the number of elements used for the numerical analysis

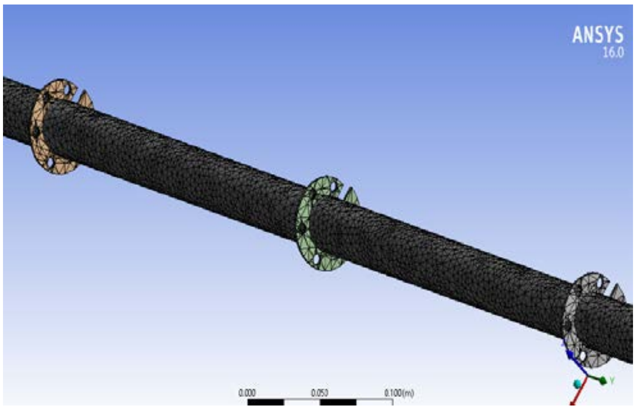

Fig. 4.5 showing the mesh of the helical baffle used in heat exchanger

4.2.3 Name Selection

Here in this section different component of heat exchanger is named to apply the boundary condition on that part of heat exchanger. The name selection of different component of heat exchanger is shown in the below fig.

Cold fluid

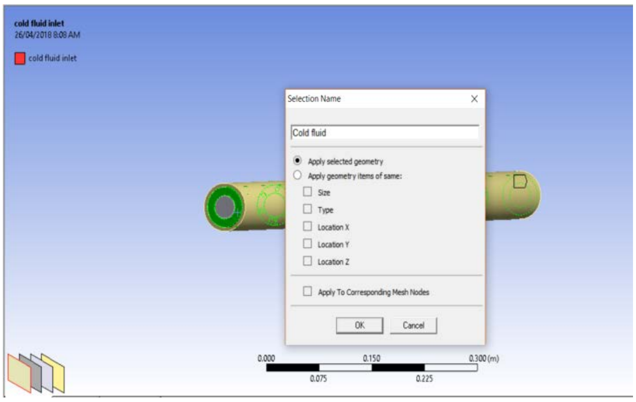

Fig. 4.6 showing the cold fluid (air) inlet

Hot fluid

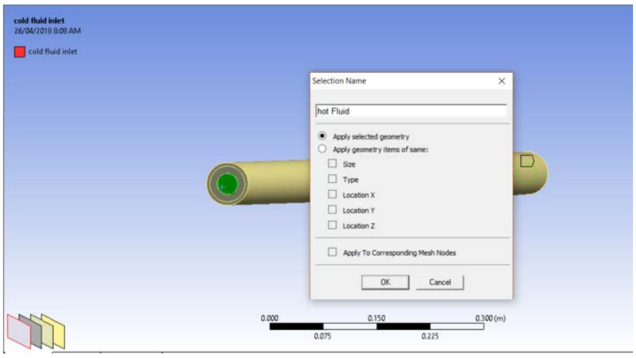

Fig. 4.7 showing the hot fluid body (water)

Outer pipe

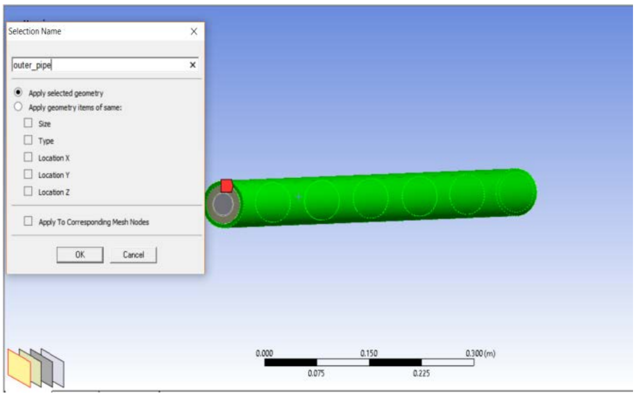

Fig. 4.8 showing outer pipe body

Hot fluid inlet

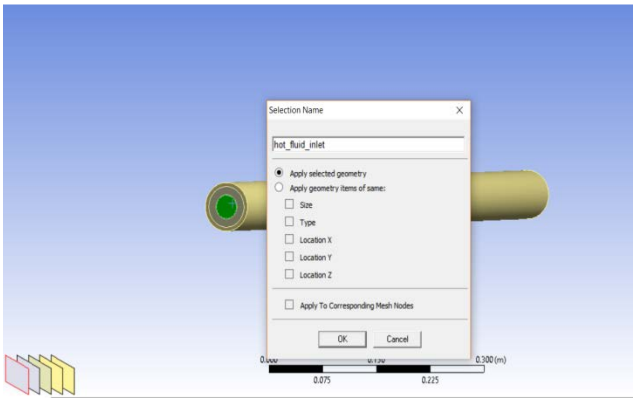

Fig. 4.9 showing the hot fluid (water) inlet

4.2.4 Material Selection

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. The properties of all material is mention in chapter 3, the selection of different material for different components is shown in the below section.

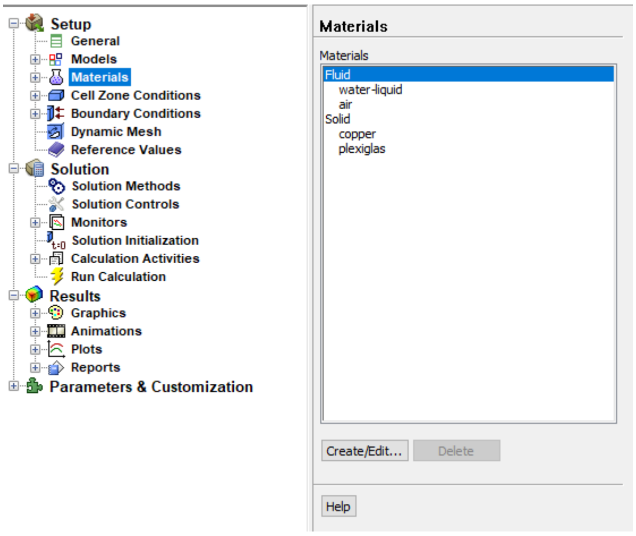

Fig. 4.10 selection of material for different components of heat exchanger

4.2.5 Solution method

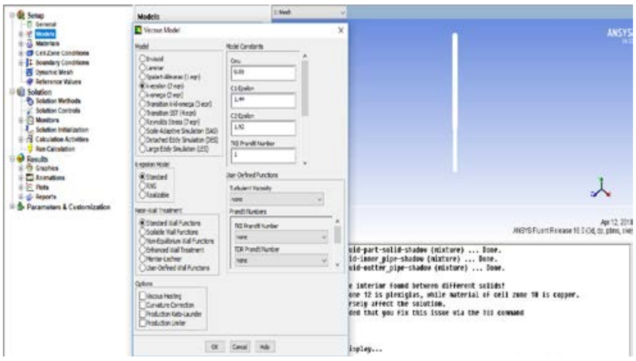

Fig. 4.11 use of K-epsilon model for the numerical analysis of heat exchanger

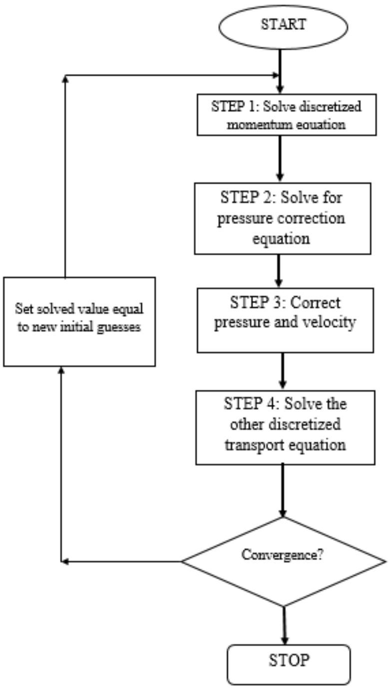

Fig. 4.12 Block diagram of solution method used during the analysis

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. 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.

4.2.6 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 and temperature of cold fluid at inlet 301.16 K as considered during the experimental analysis performed by Sheikholeslami et.al[21].The fig. showing the boundary conditions are shown below

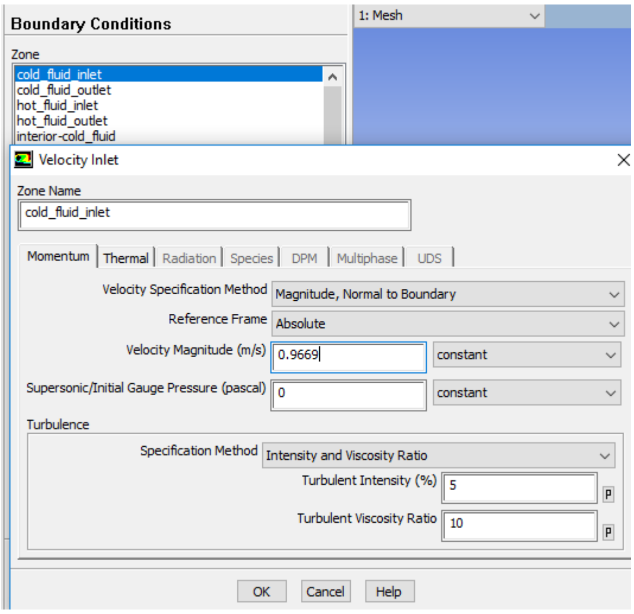

Fig. 4.13 showing the boundary condition of cold fluid

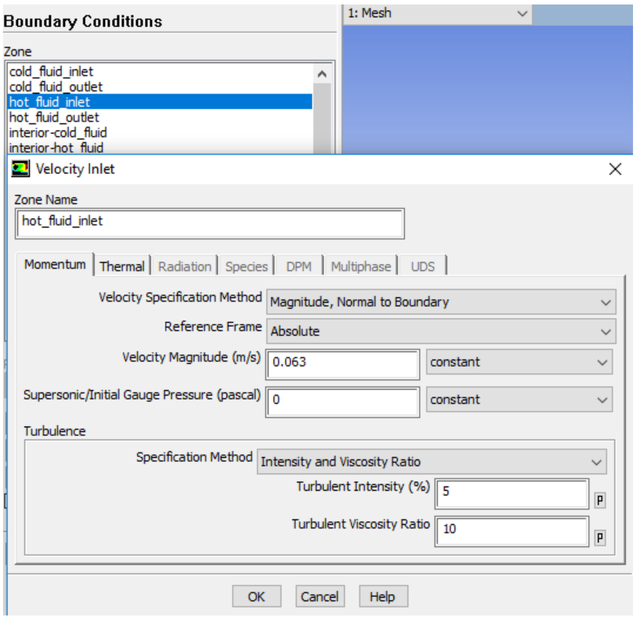

Fig. 4.14 showing the boundary condition of hot fluid

4.2.7 Result

Here in this work, through numerical investigation it has calculated the value of Nusselt number for altered Re number. It also calculated the value of Darcy friction factor for with respect to different Re number of heat exchanger having different types of shape of perforation. To analyze the effect of different perforation of helical baffles on heat transfer here in this work three different type of perforation were considered. For analyzing the effect circular, square and triangular shape perforations where considered during the analysis. To calculate the heat transfer enhancement due to different types of perforation here it has calculated the value of thermal performance for different geometry of heat sink. During the analysis the velocity of hot fluid remain constant whereas the velocity of cold fluid Changes that is Re number varies 6000, 8000, 10000, 12000.

4.3 Validation of CFD model

For validating the CFD model of heat exchanger having helical discontinuous turbulator, here in this work it examine the heat exchanger having helical discontinuous turbulator with circular perforation were consider during the experimental analysis performed by Sheikholeslami et.al [21].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

For Re 6000

The temperature contours for 6000 Re number is shown below

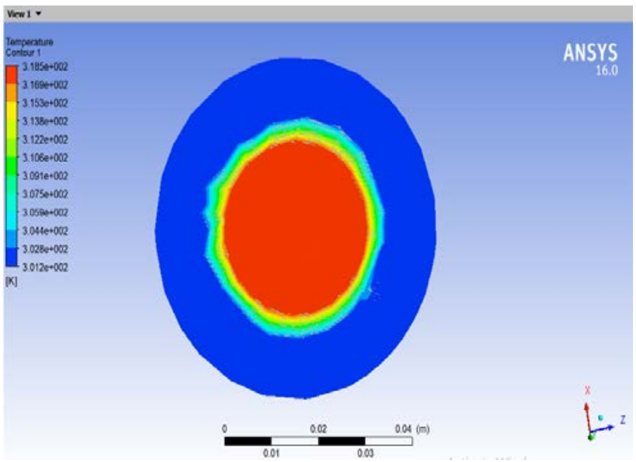

Fig. 4.15 Temperature contour of hot fluid outlet for Re 6000

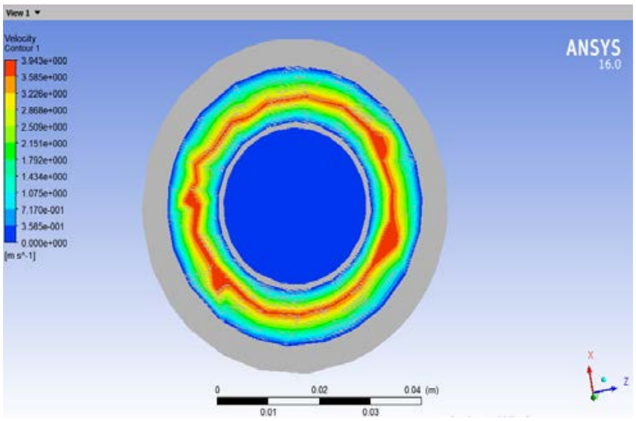

Fig. 4.16 Velocity contours of hot and cold fluid for Re 6000

For Re 8000

The contours of temperature for Re 8000 at the exit of heat exchanger is shown in the below fig.

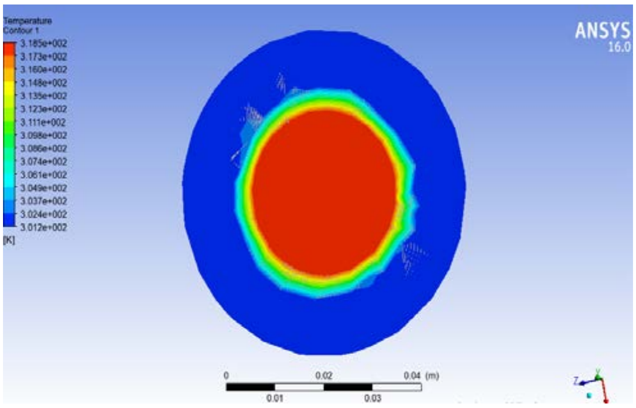

Fig. 4.17 Contour of temperature at the hot fluid exit of heat exchanger

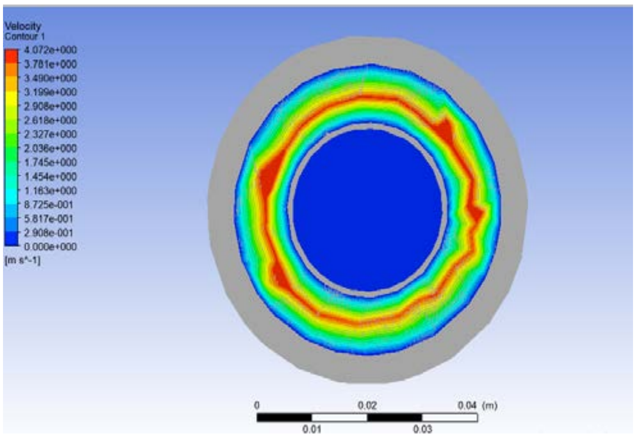

Fig. 4.18 Velocity contours to hot and cold fluid for Reynolds number 8000

Form the above graph it is found that the turbulence is maximum at the perforation, which helps in increasing the heat transfer from the cold fluid.

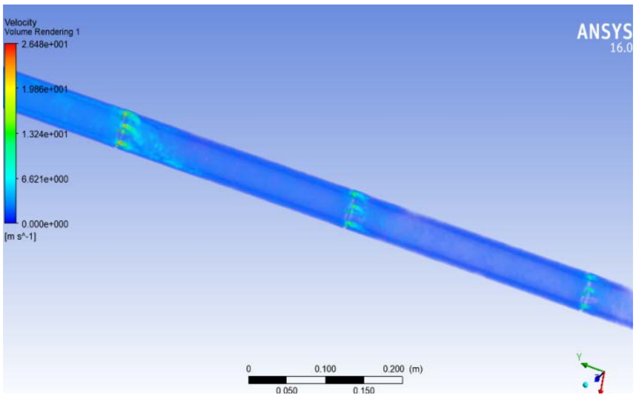

Fig. 4.19 Shows the flow of air from the perforated baffles

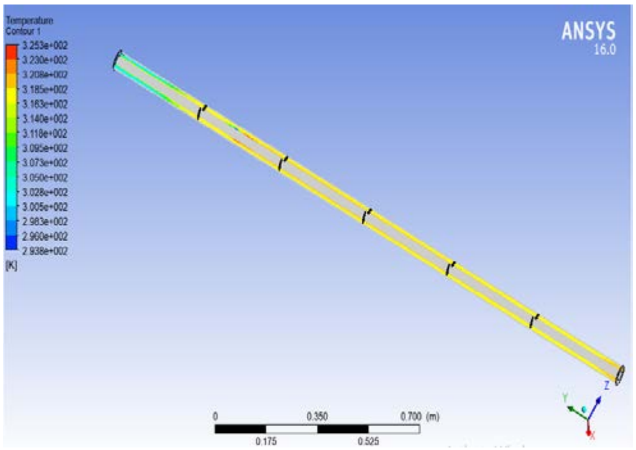

Fig. 4.20 Shows increase of air temperature from inlet to outlet

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.

With the support of numerical investigation we have calculated the value of nusselt number for different Re number and through calculation we have calculated the evaluate of Darcy friction factor and Thermal performance. The evaluate of nusselt (Nu) for circular perforation discontinuous helical baffles is shown in the below table

Table 4.3 Value of Nu number for circular perforation calculate through numerical analysis

Reynolds Number	Nusselt (Nu) number for numerically analysis
6000	44.32
8000	53.98
10000	67.79
12000	76.44

Comparison of Nu calculated through numerical analysis and experimental perform in base paper

Table 4.4 Shows the comparison of Nu number

Reynolds Number	Nusselt number from base paper	Nusselt number from numerically analysis	Error (%)
6000	43.65	44.32	1.53
8000	51.5	53.98	4.81
10000	64.06	67.79	5.82
12000	74.01	76.44	3.28

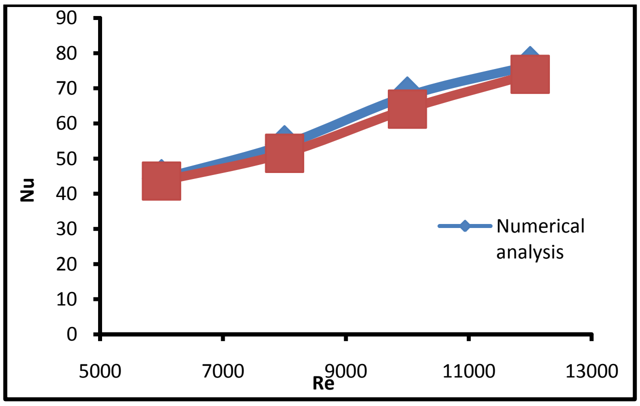

Fig. 4.21 Shows comparison of Nu value

Form the above comparison graph it is initiate 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

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

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. 2 we can calculate the value of friction factor for different Re numbers. The value of friction factor for different Re number is shown in the below table.

Table 4.5 Value of Friction Factor for different Re number

Reynolds Number	Darcy friction factor from base paper	Darcy friction factor for Numerically analysis	Error (%)
6000	0.055	0.0587	6.72
8000	0.0475	0.0503	5.89
10000	0.0413	0.0441	6.77

12000	0.037	0.0395	6.75

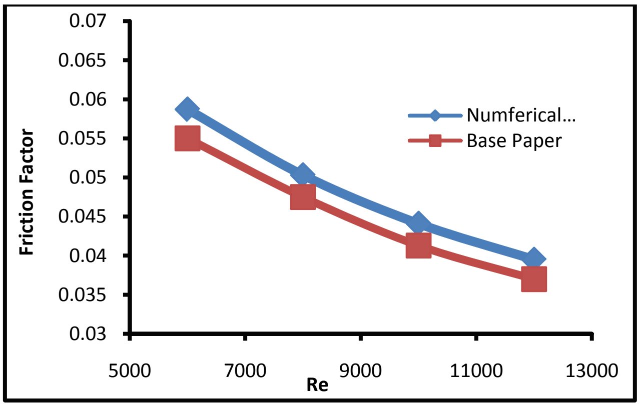

Fig. 4.22 Comparison of friction factor

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 fins is correct. After validation of the numerical model of discontinuous helical baffle heat exchanger, effect of dissimilar types of perforated baffles on the heat transfer were calculated in the below section.

For calculating the result of perforated baffle shapes on heat transfer, here in this work three different shapes of perforation were used. The cross section area of the peroration remain same, triangular, square and circular shape perforations were considered during the analysis. The dimension of the perforation were mention in the below section.

Table 4.6 Geometric dimension of different perforations

Perforation shape	**Geometric parameter**	**Values**
Circular perforate	Diameter (mm)	6
Square perforate	Side (mm)	5.31
Triangle perforate	Side (mm)	8

For circular perforation analysis were performed in the above section, now CFD analysis of heat exchanger having Rectangular and triangular perforation were performed in the below section.

4.4 For Square Shape Perforation

Here shape of the perforation on discontinuous baffles is of square shape, during the analysis the boundary condition were same as considered during the analysis of heat exchanger having circular perforations. The velocity and temperature of hot and cold fluid will remain same as considered in circular perforation. The solid model of discontinuous helical baffles having square shape perforation were shown in the below fig.

V. CONCLUSION

5.1 Conclusion

From the above analysis following conclusion were drawn

1. From the numerical investigation of discontinuous helical perforated baffles, it is determine that the heat transfer rises with increase in Re number.
2. The value of Nu number rises with rise in Re number of cold fluid flowing in the outer pipe.
3. The value of Nu number is greater for heat exchanger having discontinuous helical baffles with square perforation as compared to the heat exchanger with circular and triangular perforation.
4. Darcy friction factor is reducing with increase in Re Number. Whereas the value of Friction factor is supreme for square perforation as compared to the other perforation shapes.
5. Thermal performance was calculated to measure the overall thermal enhancement in heat exchanger having different shapes of perforations.
6. Through calculation it is found that the value of thermal performance of heat exchanger having discontinuous helical baffles with square perforation is maximum as compared to the circular and triangular perforations.
7. Form the numerical analysis it is determine that the heat transfer is supreme in case of heat exchanger having discontinuous helical baffles with square perforation.

VI. FUTURE SCOPE

6.1 Future Scope

1. Researcher can work on the helix angle to increase the performance of heat exchanger.
2. People can work on the continuous turbulator and different shapes of perforation.

Researchers can work on the thickness of baffles placed inside the heat exchanger for enhance the turbulence.

REFERENCES

[1] Camilleri R, Howey D.A, McCulloch M.D., "*Predicting the flow distribution in compact parallel flow heat exchangers*". Applied Thermal Engineering 2015; 90: 551-558.

[2] Hassan H, Zahra H., "*Investigating the effect of properties variation in optimum design of compact heat exchanger*

using segmented method". Chemical Engineering Research and Design 2016; 112: 46-55.

[3] J.J. Brandner, E. Anurjew, L. Buhn, E. Hansjosten, T. Henning, U. Schygulla, A. Wenka, K. "*Schubert, Concept and realization of microstructure heat exchangers for enhanced heat transfer"*, Experimental Thermal and Fluid Science 30 (2006) 801–809.

[4] Kyoungmin Kim, Min-Hwan Kim, Dong Rip Kim, Kwan-Soo Lee, "*Thermal performance of microchannel heat exchangers according to the design parameters under the frosting conditions"*, International Journal of Heat and Mass Transfer 71 (2014) 626–632

[5] Erika Y. Rios-Iribe , Maritza E. Cervantes-Gaxiola, Eusiel Rubio-Castro,Oscar M. Hernández-Calderón, '"*Heat transfer analysis of a non-Newtonian fluid flowing through a Plate Heat Exchanger using CF"* Applied Thermal Engineering 101 (2016) 262–272

[6] V. Pandiyarajan[a], M. ChinnaPandian[b], E. Malan[a], R. Velraja[*], R.V. Seeniraja "*Experimental investigation on heat recovery from diesel engine exhaust using finned shell and tube heat exchanger and thermal storage system*" Applied Energy, Elsevier 88 (2011) 77-87.

[7] PaisarnNaphon, "*Study on the heat transfer and flow characteristics in a spiral-coil tube*" International Communications in Heat and Mass Transfer, Elsevier 38 (2011) 69-74.

[8] Rahul Kharat, NitinBhardwaj[*], R.S.Jha,"*Development of heat transfer coefficient correlation for concentric helical coil heat exchanger*" International Journal of Thermal Sciences, Elsevier 48 (2009) 2300–2308.

[9] He Huang, Louis J. Spadaccini and David R. Sobel., "*Fuel-Cooled Thermal Management For Advanced Aero Engines*", Proceedings of ASME TURBO EXPO 2002, GT- 2002-30070 .

[10] Herchang Ay., JiinYuh Jang., Jer-Nan Yeh., "*Local heat transfer measurements of plate finned-tube heat exchangers by infrared thermography*", International Journal of Heat and Mass Transfer 45 (2002) 4069–4078.

[11] C. C. Wang, W. L. Fu, C. T. Chang, "*Heat Transfer and Friction Characteristics of Typical Wavy Fin-and-Tube Heat Exchangers*", Elsevier, Experimental Thermal and Fluid Science, 14 (1997) 174-186.

[12] Jiin-Yuh Jang, Mu-Cheng Wu, Wen - Jeng Chang, "*Numerical and experimental studies of three dimensional plate-fin and tube heat exchangers*", Pergamon, lnternational Journal of Heat and Mass Transfer, Vol. -39 (1996) 3057- 3066.

[13] J.J. Brandner, E. Anurjew, L. Buhn, E. Hansjosten, T. Henning, U. Schygulla, A. Wenka, K. Schubert, "*Concept and realization of microstructure heat exchangers for enhanced heat transfer"*, Experimental Thermal and Fluid Science 30 (2006) 801–809.

[14] L.H. Tang, M. Zeng, Q.W. Wang, "*Experimental and numerical investigation on air-side performance of fin-and-tube heat exchangers with various fin patterns*" Experimental Thermal and Fluid Science 33 (2009) 818–827

[15] Zhen Yang., Zhao Zhenxing., Liu Yinhe., Chang Yongqiang., Cao Zidong., "*Convective heat transfer characteristics of high-pressure gas in heat exchanger with membrane helical coils and membrane serpentine tubes"*, Experimental Thermal and Fluid Science, vol.-35 (2011) 1427–1434.

[16] Yakar, G &Karabacak, R, " *Investigation of thermal performance of perforated finned heat exchangers*", Experimental Heat Transfer vol.28, (2015): pp.354-365.

[17] Jayakumar J.S., Mahajani S.M., Mandal J.C., Vijayan P.K., BhoiRohidas., "*Experimental and CFD estimation of heat transfer in helically coiled heat exchangers"*, International journal of Chemical Engineering Research and Design, Vol.-86 (2008):221-232.

[18] G. Venugopal, C. Balaji, S.P. Venkateshan, "*Experimental study of mixed convection heat transfer in a vertical duct filled with metallic porous structures*", International Journal of Thermal Sciences 49 (2010) 340–348.

[19] LingdongGu[a], Jingchun Min[a*], XiaominWu[b], LijunYang[c]; "*Airside heat transfer and pressure loss characteristics of bare and finned tube heat exchangers used for aero engine cooling considering variable air properties*" ; International Journal of Heat and Mass Transfer, Elsevier 108 (2017) 1839 - 1849.