Simulation of Helical Coil Double Tube Heat Exchanger with Baffles by Numerical Investigation

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Abstract - The project aims to study the comparison of nusselt number on the behalf of Reynolds number and baffles in spiral coil tube in tube device. A spiral coil tube in tube device with variety of turns adequate to two and that accommodates three ring formed baffles that area unit placed in annular space between these two spiral tubes is taken into account for study. The most aim of providing baffle is to extend the turbulence so that it increase the convection and the baffles are also provides to support and helps to keep up two coils concentric . The design was modeled exploitation Ansys 16. The hot fluid flows through the tube and cold fluid flows through annular space. The fluid considered is water. The analysis is completed exploitation Ansys fluent. The heat transfer in spiral coil device is analyzed by varied the rate of hot fluid and rate of cold fluid is kept constant.

The laminar and turbulent flows are considered for study. K–ε model is employed to model the turbulence within the flow and also the flow is analyzed for counter flow device setup. The variation of Nusselt number with the amendment in Reynolds number of hot fluid is studied. The coil diameter of the spiraling coil is additionally varied to check the result for each laminar and turbulent flow. The D/d magnitude relation is varied from ten to twenty five in steps of five

Keywords - Helical coil heat exchanger, Baffles, Nusselt number

I. INTRODUCTION

1.1. Heat Exchangers

Heat exchanger is that devices that square measure used for the transferring heat between totally different temperature fluids which can be directly in grips or could also be flowing severally in two tubes or in two channels. various applications of heat exchangers are often determined in our day these days life, to mention a number of square measure condensers and evaporators employed in refrigerators and air conditioners and just in case of thermal station heat exchangers square measure employed in, condenser, boilers, air coolers and chilling towers. Just in case of cars heat exchangers square measure within the sort of radiators or within the sort of oil coolers in engine. Giant scale method industries and chemical industries use heat exchangers for the transferring heat between totally different temperature fluids that square measure single section or two section. 1.2. Type of HEAT EXCHANGERS: Based on Heat transfer method 1. Direct Contact heat exchanger In direct contact heat exchangers two unmixable fluids are directly mixed and heat transfer happens between two fluids. The specialty of this kind of heat exchangers are the absence of wall separating the hot fluid stream and cold fluid stream. the appliance of this sort of heat exchangers are often found in several places like in air conditioners, water cooling, humidifiers, industrial predicament heating and compressing plants.

2. Transfer type of device

In Transfer style of device two fluid at the same time flows through two tubes separated by walls. This are the foremost usually used sort device owing to simplicity in its construction

3. Regenerators type device

A regenerative device is that style of device within which hot fluid heat is intermittently keeps during a thermal medium so it'll be transferred to the cold fluid. To realize this initial the new fluid is allowed to return in grips with the thermal medium that is sometimes the wall of heat transfer so the fluid is replaced with the cold fluid which can absorb the warmth from the medium.

Based on Constructional options

1. Tubular device

This type of heat exchangers contains two coaxial tubes within which one in all the fluid flows through the tubing and also the second fluid flows through the annulated area. Each the fluids square measure separated by the wall and heat transfer happens through the walls

2. Shell and Tube device

This type of heat transfer contains tube bundles that are ready of tubes and a shell. The fluid that is to be heated or cooled is contained in one set of those tubes. The second fluid flows over the tubes that have to be heated or cooled during this manner fluid are often either heated or absorb the warmth needed.

3. Finned tube device

The principle that is in cooperated during this style of heat exchanger are that with the introduction of fin within the heat money handler the heat transfer capability of the heat exchanger are often improved. This is often principally employed in gas to liquid style of device and whereas victimization this fin is employed in gas aspect.

4. Compact device

A compact device are often outlined as device that has space density (The magnitude relation of the heat transfer area of a device to its volume) for gas worth larger than 700 m2/m3 and for liquid or two-phase stream operation it's greater than 300 m2/m3. Compact device square measure usually cross flow sort wherever two fluid flow perpendicular to every different.

Based on flow arrangement

1. Parallel Flow

In parallel flow heat exchangers the new and cold fluid flows parallel to every different which means within the same direction.

2. Counter Flow

In counter flow heat exchangers each the fluids flows in wrong way.

3. Cross Flow

In cross flow heat exchangers the two fluid flow perpendicular with relevance each other

1.3. Helical Coil Heat Exchangers

Helical coil device are recent development that has several blessings compared with straight tube heat exchangers.

Advantages:

a. Heat transfer rate of whorled coil is giant compared thereupon of straight tube device.

b. It's a compact structure and needs less floor space compared to different heat exchangers.

c. Self-cleaning.

d. surface area for heat transfer is massive

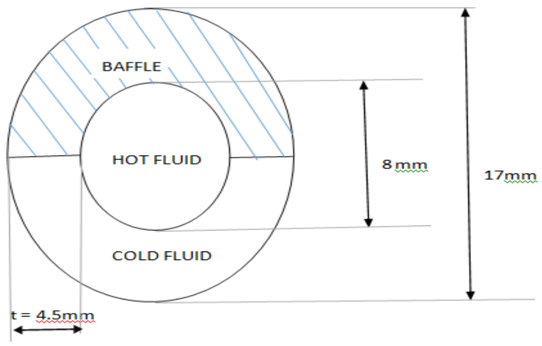
SI NO:	CASE NAME	VARIABLES	VALUE RANGE
1	D/d=10 Laminar	Reynolds number and baffle thickness	Re=1500,2000,2500,3000t (mm)=0,3.5,4,4.5
2	D/d=15 Laminar	Reynolds number and baffle thickness	Re=1500,2000,2500,3000 t (mm)=0,3.5,4,4.5
3	D/d=20 Laminar	Reynolds number and baffle thickness	Re=1500,2000,2500,3000 t (mm)=0,3.5,4,4.5
4	D/d=10 Turbulent	Reynolds number and baffle thickness	Re=5000,7500,10000,12500 t(mm)=0,3.5,4,4.5
5	D/d=15 Turbulent	Reynolds number and baffle thickness	Re=5000,7500,10000,12500 t(mm)=0,3.5,4,4.5
6	D/d=20 Turbulent	Reynolds number and baffle thickness	Re=5000,7500,10000,12500 t(mm)=0,3.5,4,4.5

The application of warmth exchanger covers following areas

1. Air conditioning
2. Power generation
3. Crude oil industry
4. Chilling towers in Thermal station
5. Refrigeration
6. for warmth recovery

II. SYSTEM MODEL

Cross section of helica l



coil tube in tube heat exchanger at the baffle

DIMENSIONS	
Coil diameter	variable
Inner tube diameter(d_1)	8 mm
Outer tube diameter(d_2)	17 mm
No: of turns(n)	2
Pitch(H)	30 mm

III. CREATION OF GEOMETRY

The geometry was created in Ansys workbench Design modeller.

3.1 Creation of Hot fluid region

Hot fluid is flowing in the inner helical coil. For creating the hot fluid zone the sweep option in the design modeler is used. For using sweep option a profile and a path is required. The profile and path is created in XY plane. The profile here is a circle whose diameter is the diameter of the helical pipe and which is at a distance equal to the radius of the coil from the origin. The path here is a straight line along the Y-axis and whose length is equal to the product of number of turns and pitch. The profile and path are created in different sketches in the XY plane. The helical coil is generated by giving profile, path and number of turns. In the details the type is changed to fluid from solid.

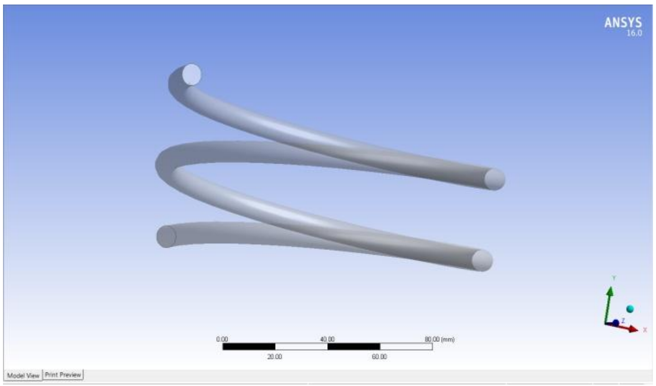


Figure 3.1: Geometry showing hot fluid region

3.2 Creation of Baffles

For creating baffles also we are using sweep option. Semi-circular ring baffles are used in the heat exchanger for creating that the cross section of the baffle in created in a new sketch in the XY plane. The newly created sketch act as the profile .Another straight line in a new sketch is created along the Y-axis this will act as the path .Two such line are created, the length of the line is equal to product of number of turn and pitch after doing two sweep operations we will get two solid bodies then Boolean operation is used .The subtract option in Boolean operation is used and the tool body is not preserved. The same procedure is carried out for making the other two baffles also

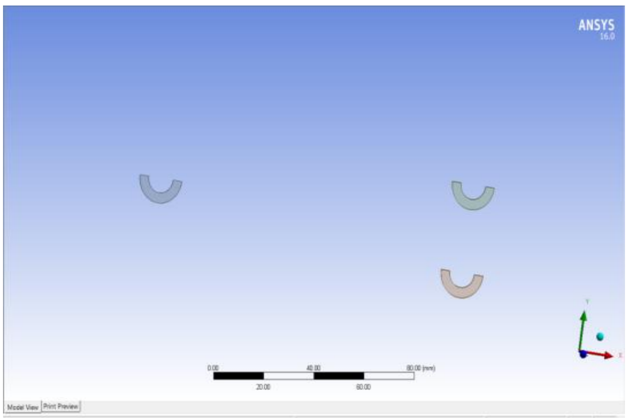


Figure 3.2: Geometry showing Baffles

3.3 Creation of Cold fluid region

For creating cold fluid region the outer helical coil is made. Sweep option is used for this, the profile used is circular shape with diameter equal to the diameter of the outer helical pipe and the centre is at a distance which is equal to radius of helical coil from the origin .The cold fluid region is obtained by using the Boolean subtraction, the baffles and the hot fluids region are subtracted from the larger helical coil to obtain the cold fluid region

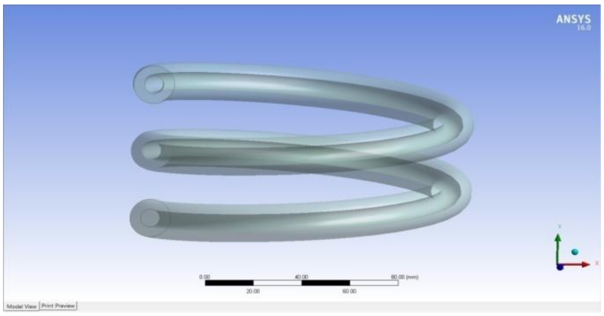


Figure 3.3: Geometry showing cold fluid region

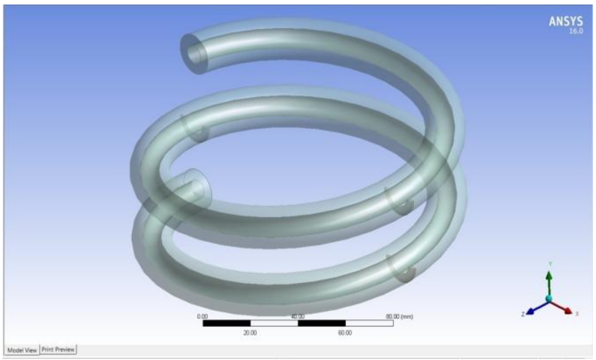


Figure 3.4: Geometry showing hot fluid region, cold fluid region, Baffles

3.4 Mesh Generation

The geometry should be made sweep able before generating mesh .We can check whether a body is sweep able or not by right clicking on the mesh then go to show option and in that go to sweep able bodies then it will show the sweep able bodies in green colour. Our geometry is not sweep able because it has the imprints of baffles on the hot fluid region and cold fluid region .So now we have to use the slice option (available under create) in design modeler and we should slice the geometry along the planes where the imprints are formed which help us to separate the hot and cold fluid into different small pieces and the body can be made sweep able.

The size of the mesh can be adjusted under the sizing option which is available in details of mesh. We can adjust the min size, max face size and max size to adjust the size of the mesh and the number of elements of the mesh. In the details of the mesh statistics we can check the number of elements and number of node, Element quality, orthogonal quality, skewness whose values are to be within a specified range in order to obtain a good mesh.

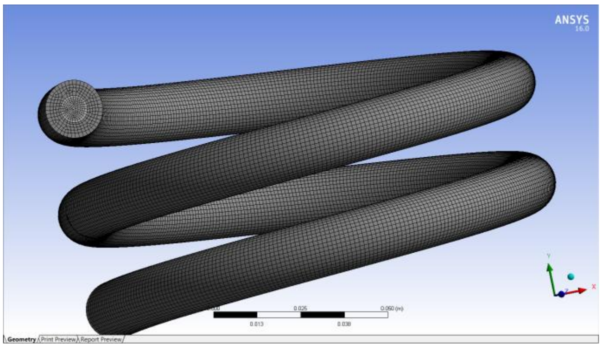


Figure 3.5: Image of geometry which is meshed fully

To apply inflation layer in hot and cold fluid region we have to use inflation option select geometry as hot fluid and boundary as hot fluid wall. In the same way in the cold fluid region inflation layer can be provided

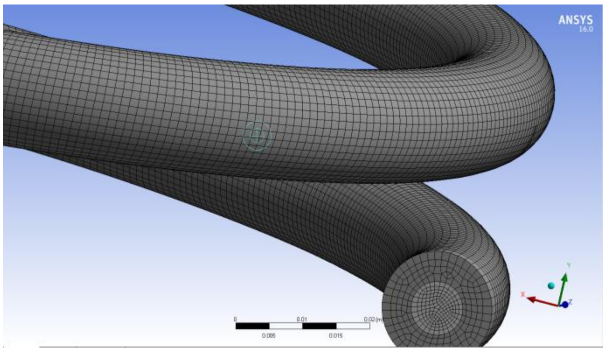


Figure 3.6: Image showing the inflation layer

3.5 Governing Differential Equations

➢ The Continuity Equation

$$\frac{\partial \rho}{\partial t} + \nabla.\left(\rho \vec{v}\right) = 0$$

➢ The Momentum Equation

$$\frac{\partial}{\partial t}\left(\rho \vec{v}\right) + \nabla.(\rho \vec{v}\vec{v}) = -\nabla p + \nabla.[\mu(\nabla \vec{v} + \nabla \vec{v}^T)] + \rho \vec{g} + \vec{F}$$

➢ Energy equation

$$\rho c_p \left(\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial Z} \right) = k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) + \phi$$

Where is viscous dissipation factor

$$\phi = 2\mu \left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2 + \frac{1}{2}\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2 + \frac{1}{2}\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)^2 + \frac{1}{2}\left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right)^2 \right]$$

➢ Turbulence presence in the domain has been modeled using standard k-ε model

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k + G_b - \rho\varepsilon - Y_m + S_k$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k + C_{3\varepsilon}G_b\right) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon$$

Gk= Turbulence kinetic energy generation as a result of the mean velocity gradients.

Gb= Turbulence kinetic energy generation as a result of buoyancy.

YM= fluctuating dilatation contribution in compressible turbulence to the overall dissipation

C2Ɛ, C3Ɛ = Constants.

Sk & Se = The User-defined source terms.

➢ Turbulent viscosity

$$\mu = \rho C_\mu \frac{k^2}{\varepsilon}$$

➢ Critical Reynolds number as per the Schimidt correlation (1967)

Re cr = 2300[1+ 8.6 (d/D)0.45]

➢ The heat transfer coefficient can be obtained by the following relation

$$h = \frac{-k\frac{\partial T}{\partial x}}{T_w - T_f}$$

➢ Local Nusselt number is given by

$$Nu_x = \frac{hl}{k}$$

Another representation is as follows

➢ Local Nusselt number is given by

$$Nu_x = \frac{-\frac{\partial T}{\partial x}\text{dh}}{T_w - T_f}$$

➢ Then the average Nusselt number can be found by following relation

$$Nu_{avg} = \frac{1}{L}\int_0^L Nu_x dx$$

➢ Reynolds number value is given by formula

$$\text{Re} = \frac{\rho V D}{\mu}$$

3.6. Values of Parameters Used

Table 3.1: Properties of Water

DESCRIPTION	VALUE	UNITS
VISCOSITY	0.001003	kg/m-s
DENSITY	998.2	kg/m^3
SPECIFIC HEAT CAPACITY	4182	J/kg-K
THERMAL CONDUCTIVITY	0.6	W/m-K

Table 3.2 Properties of Copper

DESCRIPTION	VALUE	UNITS
DENSITY	8978	kg/m^3
SPECIFIC HEAT CAPACITY	381	J/kg-K
THERMAL CONDUCTIVITY	387.6	W/m-K

3.7. Boundary Conditions Used

The following are the boundary conditions considered.

- The counter flow configuration is considered for helical coil heat exchanger.
- The flow rate of cold fluid has been kept constant.
- The flow rate of hot fluid was varied
- For laminar flow the velocities are as flows

For hot fluid Uz= 0.18846, 0.25329, 0.31911, 0.37493m/s and

For cold fluid Uz= -0.37493 m/s

- For turbulent flow the velocities are as follow

For hot fluid Uz= 0.5582, 0.837340, 1.11645, 1.39556m/s and For cold fluid Uz= -1.39556 m/s

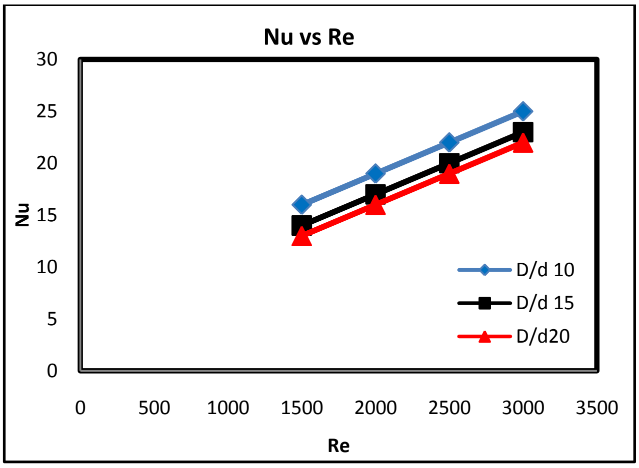
The inlet temperature of hot fluid is 355 K and inlet temperature of cold fluid is 290 K The cold wall is considered to be at constant temperature T= 330K

IV. RESULT

Variation of Nusselt number with Reynolds number for different curvature ratio :

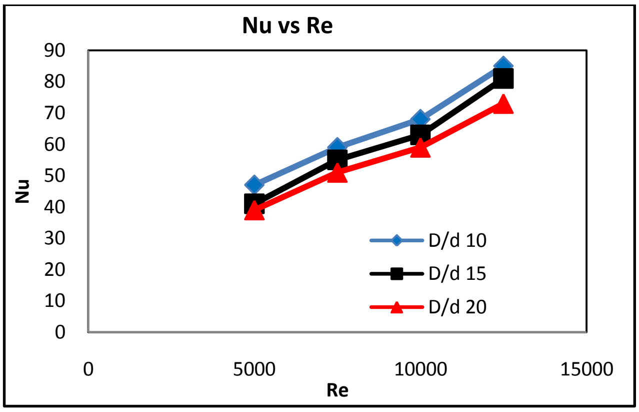
4.1 Laminar case:

With the increase in value of D/d ratio the value of average Nusselt number is decreasing that is for a particular value of Re the value of Nu will be maximum for D/d = 10 as the value of D/d ratio increases the effect of curvature decreases and the action of the centrifugal force reduces and that is the reason for the decrease in the Nu value. The effect of curvature is the main reason for increase of centrifugal force as the centrifugal force increases it will accelerate the particle and thus results in the increase in velocity of fluid in the helical coil heat exchanger.



4.1 Variation of Nu with Re for different D/d ratio for laminar flow

As the Re increases the value of Nu increases for a particular D/d ratio. The more velocity of the flow will be toward the outer walls in case of helical coil and for less D/d ratio the secondary flow which is the main mechanism of heat transfer in helical coil heat exchanger is also enhanced. As the coil diameter increases the behaviour of Helical coil is tending to that of a straight tube heat exchanger.

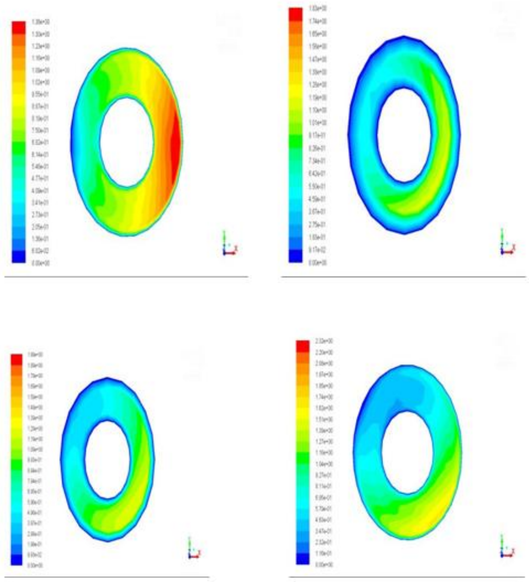


4.2 Variation of Nu with Re for different D/d ratio for turbulent flow

For turbulent flow also with the increase in D/d ratio the Nu value is decreasing for the same flow rate of the hot fluid as in the case of laminar flow. The reason for reduction in Nusselt number can be explained in the same way as explained for laminar case.

Velocity Contours of Outlet Cold Fluid for Laminar Flow Laminar Case

Re =2000 D/d =10

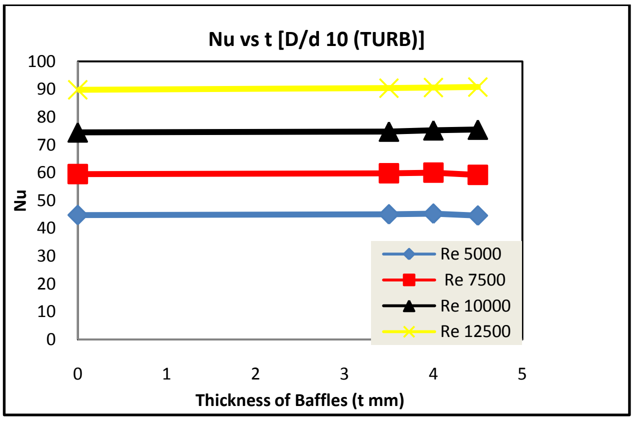


4.3 Velocity contour for cold fluid outlet in the increasing order of thickness of baffle

4.2 Laminar case:

For the turbulent case with the introduction of baffle the value of Nu is increasing slightly for moderate values of Re. For low values of Re the Nu value is slightly decreasing for baffle thickness of t = 4.5 mm and for high values of Re the Nu values are slightly increasing.

The percentage decrease of Nu for Re = 5000 is 0.238% and percentage increase in Nu for Re = 12500 is 0.4508%



4.4 Variation of Nu with thickness of baffle t (mm) for D/d=10 turbulent flow for various Re values.

For the turbulent case with the introduction of baffle the value of Nu is increasing slightly for moderate values of Re. For low values of Re the Nu value is slightly decreasing for baffle thickness of t = 4.5 mm and for high values of Re the Nu values are slightly increasing.

The percentage decrease of Nu for Re = 5000 is 0.238% and percentage increase in Nu for Re = 12500 is 0.4508%

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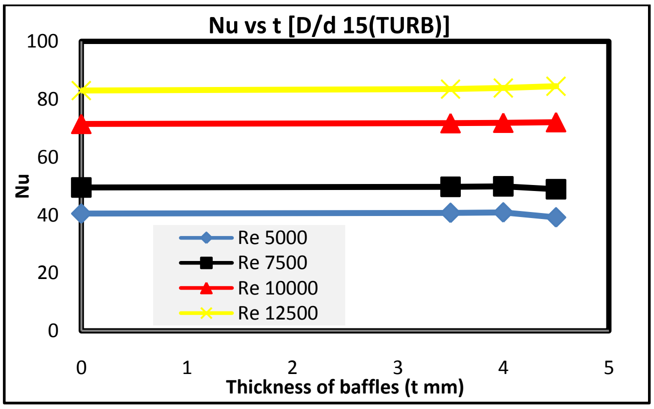
The results obtained shows that for low Re values the baffle with thickness t = 4.5 mm is obstructing the flow that is why the Nu values are decreasing slightly and for large values the baffle helps to enhance the turbulence and that is why the Nu values are increasing.



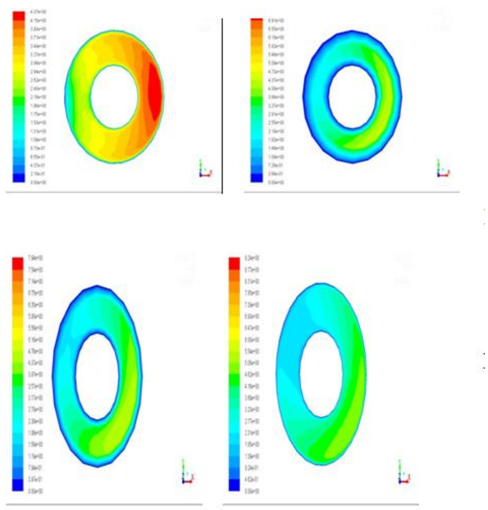
4.5 Variation of Nu with thickness of baffle t (mm) for D/d=15 turbulent flow for various Re values

The percentage decrease in Nu value for Re = 5000 is 2.254% and for Re = 7500 is 1.135% the value of reduction in Nu is decreasing with increase in Re. For high Reynolds number the value of Nu is increasing with increase in baffle thickness. The percentage increase in Nu value for Re = 10000 is 2.627%

Velocity Contours of Outlet Cold Fluid For Laminar Flow

Turbulent Case

Re =10000 D/d=10



4.6 Velocity contour for cold fluid outlet in the increasing order of thickness of baffle

V. CONCLUSION

Numerical simulation of helical coil tube in tube heat exchanger has been done with Ansys fluent and the variation of Nusselt number with different baffle thickness and for various D/d ratio and different flow rate of hot fluid has been plotted.

The conclusion drawn are as follows

I. With increase in D/d ratio the Nusselt number is decreasing, the Nusselt number is maximum for D/d=10 for a particular value of Re this is due to the effect of centrifugal force which is more for small D/d ratios and for high D/d ratio the behavior of helical coil tends to that of straight tube.

II. For laminar case with baffle thickness of t=3.5 mm and t=4 mm the Nusselt number is increasing compared to case without baffle and thickness of t=4.5 mm.

III. For Laminar flow for different D/d ratios the Nu variation with Re follow the same pattern.

IV. For turbulent case with baffle thickness of t=3.5 mm and 4mm the Nusselt number is slightly increasing and for thickness of t=4.5mm for low Reynolds number the value of Nu is decreasing and for high Reynolds number Nu value is increasing.

VI. FUTURE SCOPES

Along with numerical simulation experimental validation can also be done to check whether the results obtained are correct or not.

With the study we were not able to finalize the thickness of the baffle .The thickness of baffle can be optimized for obtaining maximum value of Nusselt number

Now the shape of the baffle is ring shape this shape can be modified. The shape of baffle can be optimized so that less obstruct will occur for the flow.

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