CFD ANALYSIS OF CONCENTRIC CIRCULAR TUBE WITH INSERTS

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Abstract

In this paper tried to visualize the flow pattern inside the concentric circular tube equipped with combined wire coil and twisted tape as inserts under the laminar flow. ANSYS 12.0.16 version fluent is used for meshing, processing and post processing. And also the comparisons are made for plain circular tube and tube with inserts in terms of heat transfer and pressure drop. At last the obtained swirl flow pattern is visualized, the heat exchanger performance characteristics of heat transfer and pressure drop for tube equipped with combined insert is higher than plain circular tube alone.

Keywords: *CFD, twisted tape, rectangular cut, heat transfer, friction facto, wire coil*

1. Introduction

In some equipment heat needs to be transferred for proper running of applications, otherwise it will leads to malfunctioning. Example if we increase the heat transfer rate in heat exchanger, definitely we can reduce the size (length and cross section) of the heat exchanger, which leads to reduced equipment cost and able to make better shape and size based on our requirement. In concentric circular tube heat exchanger, heat transfer rate can be enhanced by use of some external aids. Generally two category of enhancement, one is active technique and another one is passive technique. Mostly passive technique is followed rather active technique, because for passive augment technique no need of any external power source. In this work described about augmentation of the heat transfer rate by following passive technique. Senthil kumar et al [1] numerically investigated convective heat transfer in concentric tube heat exchanger with spherical dimpled and elliptical dimpled tube. Obtained heat transfer rate for spherical and ellipsoidal dimpled tube with Al_2o_3 nanofluid were 40% and 46% higher than smooth tube with Al_2o_3 nanofluid. The friction factor was 52.7% and 87.27% for ellipsoidal and spherical dimpled tubes than smooth tube. Among these ellipsoidal dimpled tube with nanofluid is better than others. Sami et al [2] heat transfer and friction factor characteristics were made tube with classical and quadrant cut twisted tape with three different twist ratio and depth ratio. Concluded that decreasing twist ratio and depth ratio were given increased heat transfer coefficient and friction factor. Rajesh et al [3] made CFD analysis with ANSYS version 14.5 and found 10 to 15% heat transfer rate was increased by incorporating helical tape in double pipe heat exchanger and also concluded passive technique are better than active technique. Subramanian et al [4] investigated in turbulent flow the effect of dimples on both sides of tube for heat transfer and friction factor characteristics. Revealed that ellipsoidal with both side dimpled tube gives higher heat

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transfer rate and small amount of friction factor than plain tube. Naveen et al [5] made CFD analysis on concentric circular tube with three different twist ratios of twisted tape of plain, v cut and jagged v cut one by one and investigated the thermal performance and friction factor characteristics. Among these three varieties jagged v cut twisted tape gives better thermal performance factor.

Most research discussed only about individual enhancement devices and the results compared with plain tube but the combined insert area research is limited. So these experimental work concentrating combinations of insert for heat transfer optimization.

2. Analysis Procedure

- In this analysis used ANSYS 12.0.16 version fluent, geometries are imported from externally which is drawn from CREO by using extrude and helical sweep command.
- The numerical simulation has performed with a three dimensional Steady state laminar flow system. Pressure velocity Coupling and first order upwind scheme for momentum and energy equations are used for solving the problem. Governing equations for the flow and heat transfer are modified according to the conditions of the simulation setup.
- Imported geometries are freeze to draw the fluid path, then the Boolean operation are carried out to subtract the fluid flow from the insert.
- In meshing operation automatic meshes are used, named sections are given to the geometry to specify the boundary conditions such as wall, inlet and outlet of tube.
- In this wall act as a stationary wall that is no slip conditions, continuity equation, energy equations, momentum equations are used for solving and the fluid are selected from the fluent database, boundary conditions were modified according to our requirement.
- Initialize the solution to start the numerical calculations and then the converged solutions are taken from post processing.

2.1 Assumptions

The following assumptions are made in this analysis,

- ❖ The density and molecular viscosity of the fluid do not change with respect to temperature and time.
- ❖ The flow is steady state conditions.
- ❖ The Thermal conductivity of the fluid is uniform over the entire length of the tube.
- ❖ Specific heat of the fluid does not change with respect to time and temperature.

2.3 Models of Insert

There is a plain tube of 1 metre length, 14 and 16 mm inner and outer diameter of copper tube. In that one by one placing the inserts the readings are taken.

Table.1 wire coil details

Material	Copper
Wire diameter	1 mm

Pitch ratio	2
Length	1 m
Diameter of wire coil	11 mm

Table.2 Twisted tape details

Material	Copper
Width of twisted tape	9 mm
Length of twisted tape	1 m
Thickness of twisted tape	1 mm
Twist ratios (h/W)	10, 12.22
Cut of depth ratios (E/W)	0.33, 0.55
Cut of width ratio (w/W)	0.11

Fig.1 Wire coil

Fig.2 Plain twisted tape

Fig.3 Combined wire coil and plain twisted tape

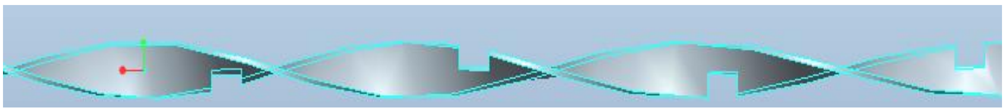


Fig.4 Rectangular cut twisted tape

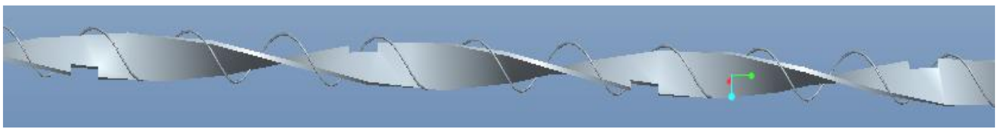


Fig.5 Combined wire coil and rectangular cut twisted tape

Above Figure shows the combined wire coil and plain twisted tape of twist length 90 mm and uniform wire coil pitch of 28 mm. Which is drawn by using extrudes and sweep command in CREO software.

2.3 Meshing and Boundary Conditions

Fluent meshing is generated for tube with combined wire coil and plain twisted tape. The generated nodes and element details are shown in table 3.

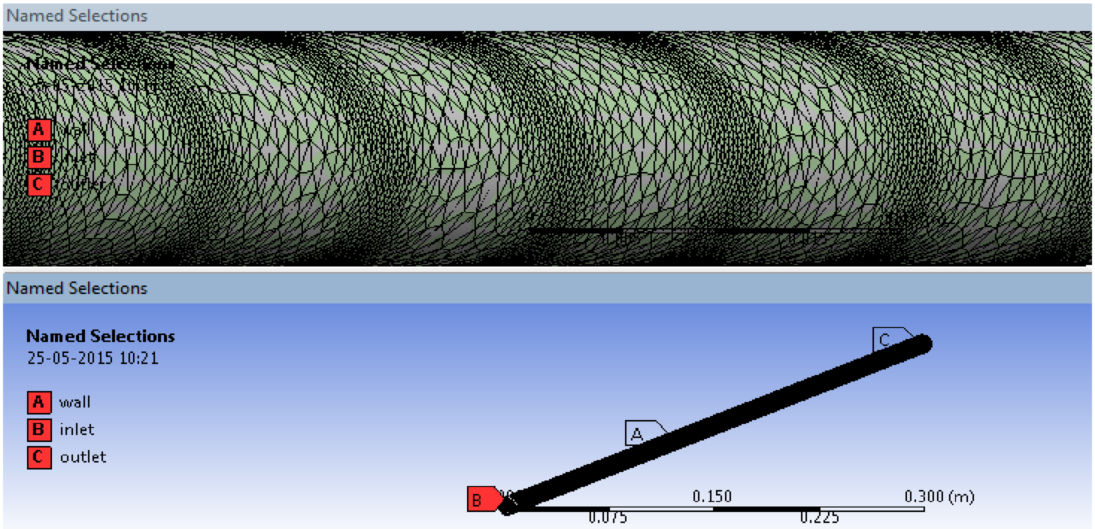


Fig. 6 Mesh of the tube with combined insert

Above figure shows the generated mesh and named selections of the test sections for the given input. This has 3143395 elements and 1522419 for the whole domain.

Table.3 Mesh information

Domain	Nodes	Elements
part fluid	276966	1452285
part twisted tape	14112	6167
part wire coil	23317	63967
All Domains	314395	1522419

Table.4 Domain physics

Domain - part fluid	
Type	Cell
Domain - part tt	
Type	Solid

Domain - part wire coil	
Type	Solid

The boundary conditions used are,

- Inlet fluid temperature is 312 K.
- Inlet velocity is 0.03791326 m/s (laminar flow)
- Wall heat flux is 436.8 w/m^2
- Outlet pressure of fluid is zero Pascal.

Table.5 Boundary physics

Domain	Boundaries	
part fluid	**Boundary – inlet**	
	Type	VELOCITY-INLET
	Boundary – outlet	
	Type	PRESSURE-OUTLET
	Boundary – wall	
	Type	WALL
	Boundary - wall part fluid part twisted tape shadow	
	Type	WALL
	Boundary - wall part fluid part wire coil	
	Type	WALL
part twisted tape	**Boundary - wall part fluid part twisted tape**	
	Type	WALL
	Boundary - wall part twisted tape	
	Type	WALL
part wire coil	**Boundary - wall part fluid part wire coil shadow**	
	Type	WALL
	Boundary - wall part wire coil	
	Type	WALL

2.4 Post-Processing

In post processing the velocity streamline flow and velocity vector of the combination of insert for the given boundary conditions are shown in figure. Figure 6 shows the velocity streamline of tube with combined insert for given boundary conditions. Based on twist length and geometry of design the reverse flow caused by the wire coil and swirling intensity of the fluid inside the tube is varying. Because of swirling flow the travelling time of fluid inside the tube is high and therefore there may be chances of absorbing more amount of heat from the wall than plain tube. This swirling flow intensity is the main reason for heat transfer enhancement.

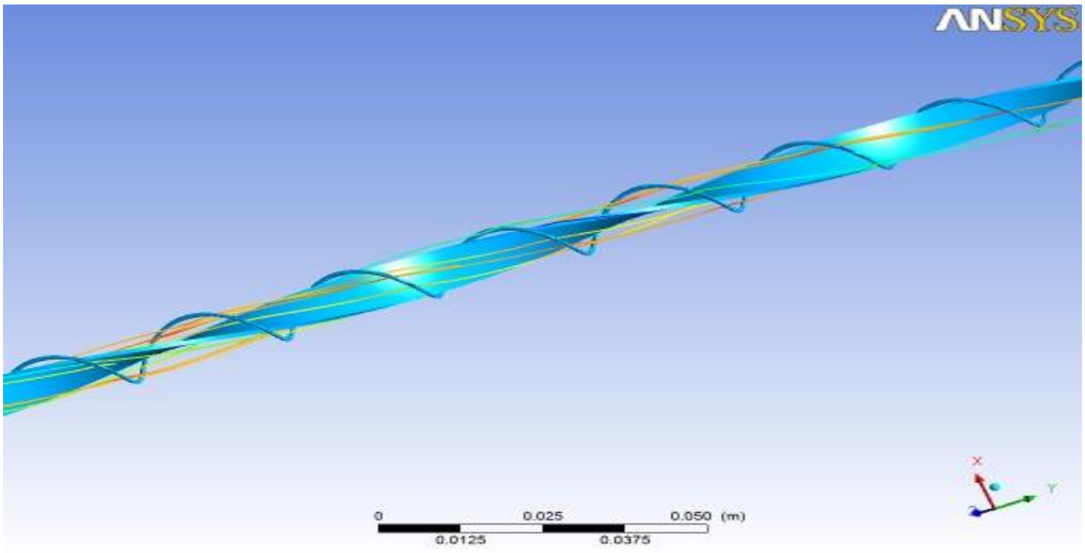
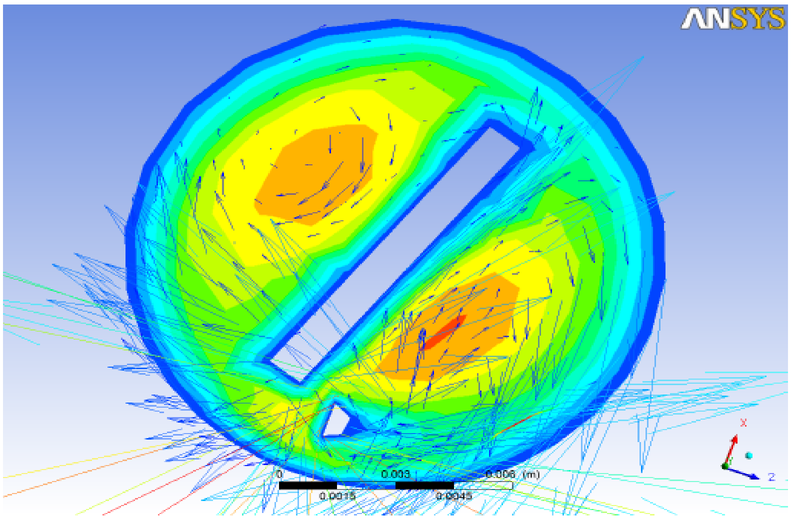


Fig. 6 Velocity streamline for tube with combined insert

Figure 6 shows the velocity swirling and velocity vector of the combined inserts for the given boundary conditions. Because of insertion of inserts velocity get increasing near the wall region as well as better mixing of water molecules so that temperature of fluid goes on increasing from the inlet to outlet there is a heat transfer take place along the test tube. Figure 7 and 8 shows the variaion of flow direction inside the tube because of inserts the layer by layer flow are converted into swirling flow, due to this most of the fluids get chance to meet and touch the heated wall surfaces.



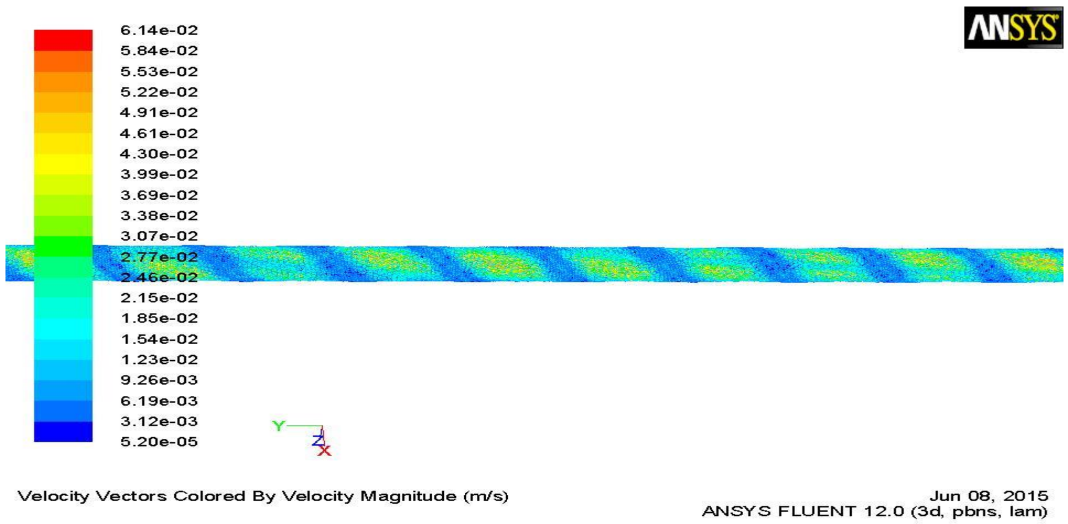


Fig.7 Velocity vectors of combined insert, side and front view

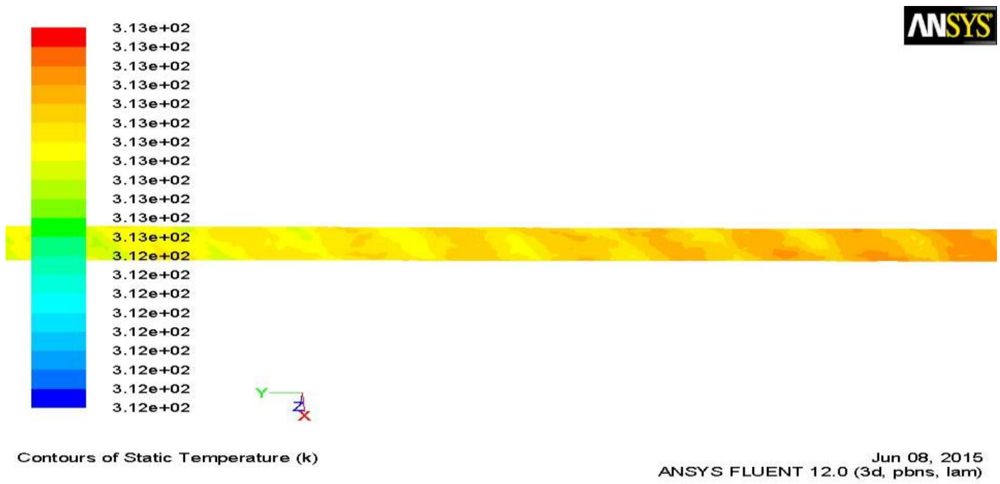


Fig.8 Temperature contour

3. Results and Discussion

3.1 Heat Transfer Characteristics

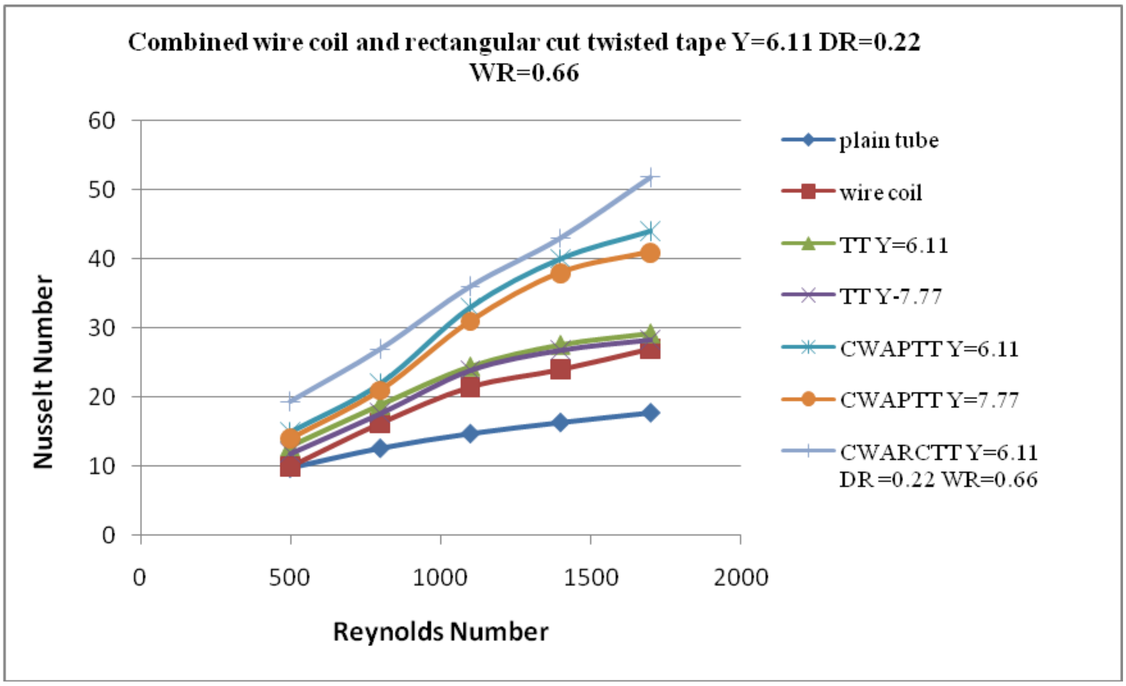


Fig.9 variation of Nusselt number with Reynolds number

Compare to combined wire coil and rectangular cut twisted tape, the combined wire coil and plain twisted tape of Y=6.11, DR=0.22 and WR=0.66 increased the Nusselt number in the ranges of 23% to 16%

3.2 Pressure Drop Characteristics

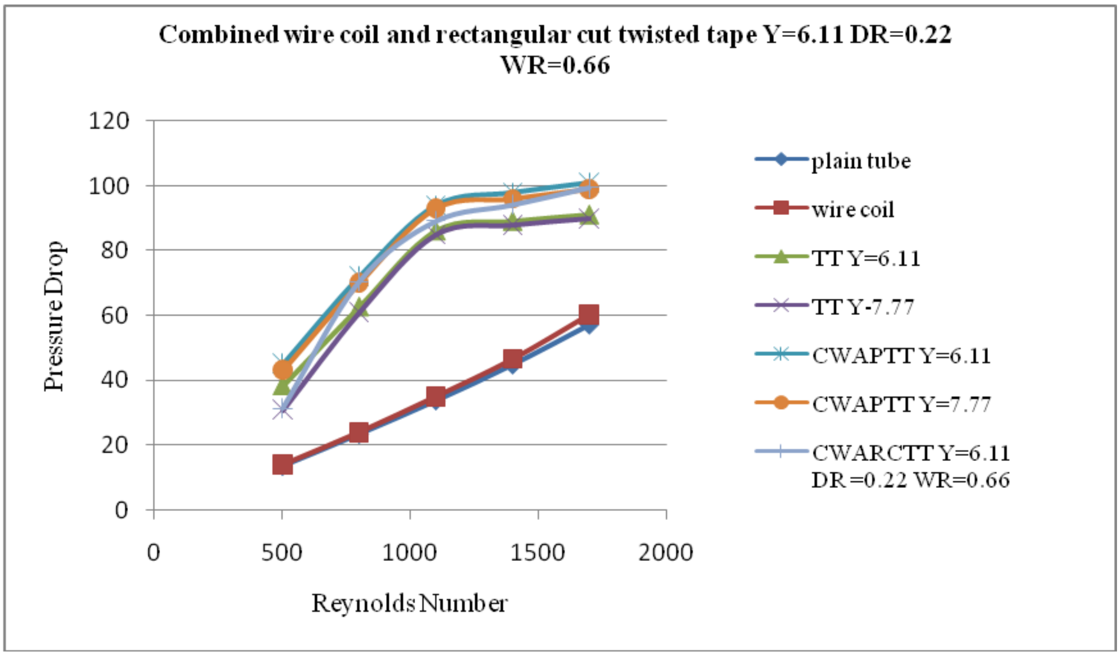


Fig. 10 variation of pressure drop with Reynolds number

Compare to combined wire coil and plain twisted tape, the combined wire coil and rectangular cut twisted tape of Y=6.11, DR=0.22 and WR=0.66 decreased the pressure drop in the ranges of 43.3% to 1.7%

4. Conclusions

From the analysis work made on concentric circular tube equipped with combined inserts the following observation are made, Inserts cause rapid mixing of molecules and the twisted tape creates swirl flow based on the shape of the geometry. Because of the thorough mixing of fluid molecules, the heat is transferred easily from one place to another place. So the exit fluid temperature increases due to rapid contact with the heated wall surface because of the disturbance created by inserts. Decreasing twist ratio and increasing depth of rectangular cut gives higher heat transfer and friction factor than all other inserts. Combination of the wire coil and rectangular cut twisted tape gives a more or less similar Nusselt number and friction factor with a combined wire coil and plain twisted tape. In overall whatever may be the insert, the heat transfer rate for the tube with insert is higher than the fluid flow in the plain tube.

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Notations

DR- depth ratio

WR- width ratio

Y- Twist ratio

TT- twisted tape

CWAPTT- combined wire coil and plain twisted tape

CWARCTT- combined wire coil and rectangular cut twisted tape