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Experimental Investigation and CFD Analysis on Effect of Turbulaters on Performance of Heat Exchanger

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Abstract: Heat exchanger is an important device in all the thermal systems. The heat exchanger is widely used equipment in different industries such as process, petroleum refining, chemicals, pharmaceutical and paper etc. After studying different literature about heat exchanger and double pipe heat exchanger problem is identified as to perform simulation and experimental investigation of double pipe heat exchanger with inner twisted tape inserted different mass flow rate. The system has followed different types of flow arrangement and geometric dimension with circular tape to attain heat transferred in experimental result and compare with simulation result. The objective of these experiments is Performance analysis of double pipe heat exchanger with inner and outer twisted tape at different mass flow rate. The experimental set up consists of double pipe heat exchanger experiment. The apparatus includes tube-within-a-tube heat exchangers and twisted tape type inserted threaded thermocouple at each end, a water pump and electric motor. These methods used to find out the heat transfer rate from the surface and related temperature of fluid motions also used to find the effectiveness..

I. INTRODUCTION

Heat exchangers are widely used in chemical, power generation and petroleum refining industry. Shell and tube heat exchanger have the ability to transfer large amount of heat in relatively low cost, serviceable designs. The important variable in reducing the size and cost of a heat transfer device are pressure drop and heat transfer coefficient. Therefore, it is good to developed method to improve the heat transfer coefficient. The twisted tape insert as flow turbulator's have been widely applied due to their promising performance. Many researchers have reported their influence of tube insert on heat transfer improvement.The promising challenge for design of heat exchanger is to reduce the pumping power while increased heat transfer rate. Therefore it is essential to develop theory and technique about increased heat transfer in the double pipe heat exchanger to optimize the performance of heat exchanger. The presence of twisted tape lowers the hydrodynamic and thermal boundary layer thickness, leading to greater convective heat transfer. Though pumping power may increase meaningfully and ultimately the cost of pumping is more. Therefore to achieve a desired heat transfer rate with minimum pumping power, the design of twisted tape with proper geometry is necessary.Twisted tapes are normally inserted into the tube to generate swirl motion of fluid for greaterheat transf This also leads to improve flow velocity, thermal boundarylayer,hydrodynamic boundary layer, heat transfer rate, fluid mixing. However more pumpingpower is required when twisted tapes are inserted to inner tube. Classification of improvement method- Heat removal improvement method mention to the development of thermo hydraulic performance of heat exchanger .These improvement method is categorized in generally three categories. They are as below

A. Active method

In these Methods, exterior power is used to effect the need flow statementand related important in rate of heat transfer.

B. Passive Method

These methods do not necessary have any direct input of exterior power.

C. Compound Method

A compound important method is the one wherever more than one ofthe above stated method is used in mixture by the purpose of further improving the rate of heat transfer.

II. METHODOLOGY

Work being considerd is to perform experimental investigation and simulation of double pipe heat exangerwith and without twistd tape inserted

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The study the heat transfer performance of heat exchanger with and without insert twisted tape different geometry.
Calculation of its heat transfer performance.
Heat transfer coefficient for all cases.
Nusselt number for all cases.
Reynolds Number for all cases.
.compare in mode of the result of found from experimental analysis and simulationtwisted tape type insert

A. Proposed Experimental Set-Up

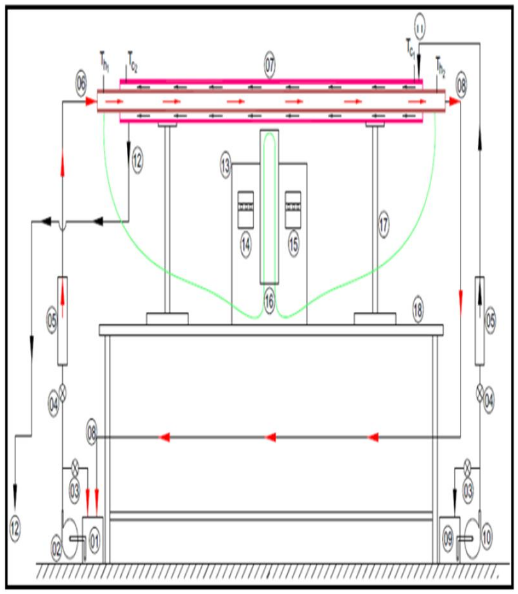

Fig 3.5

1) Hot water tank 7. Test section 13. Control panel
2) Hot water pump8. Hot water outlet 14. Temperature indicator
3) By pass valve 9. Cold water tank 15. Temperature controller
4) Flow control valve 10 . Cold water pump16. Inverted u- tube manometre
5) Rotameter 11. Cold water inlet 17. Stand
6) Hot water inlet 12. Cold water outlet 18. Table

B. Components With Specification
The following is a list of all pieces of equipment and their specifications for the double-pipe heat exchanger.
1) Double-Pipe Heat Exchange
Inside pipe Material copper
Outside pipe matrial steel
Length 1.4m
INSIDE PIPE
inside pipe dia 0.0198m
outside pipe dia 0.0028 m
outside pipe thickness 0.003m
HOT WATER
Pass 1

COLD WATER
Pass 1

2) Valves

Ball Valves
Location: Process Valves, Tank Valve, Drain Valve, Bypass valves

3) Temprature indicating controle

Input ; RTD –PT100
wire range 0 to 200degc
Display: 31/2 digit red led 13 mm Height
Accuracy: 1%F.S.
Set point: 1 Potentiometric
Output: INO/NC, 3A
Control mode: ON/OFF
Power: 230VAC 50Hz +/- 10%
Size: 96 x 96 x 85 mm DIN ABS Cabinet
Panel cutout: 92 x 92mm

4) Multipoint Temperature Indicator

Input: RTD-PT100, 3 Wires
Display: 3 1/2 Digit Red Led 3mm Height
Range: 0 to 400 Deg.
Power: 230V AC, 50 Hz.
Size: 96 x 96 x 80 mm DIN
Panel Cutout: 92 x 92 mm
Model: MPTI

5) Electrical Heater

Type: Emersion type
Body: SS304
Capacity: 1.5KW
Power: 230VAC 50Hz

6) Pumps

Type: Centrifugal
Capacity: 1/5HP
Discharge: 2000LPH
Foot mounting
Power: 250VAC 50 Hz
Size: 1”

7) U tube manometer

MOC: Acrylic
Range: 250 – 0- 250mm WC

8) Temperature Sensor

Type : RTD-PT100 3 wire
Assembly: Transition type
Range: 0 to 300Deg C
Diameter: 6mm
Length: 100mm
Cable:3mtr. Teflon/Teflon Cable

9) Rota meter

MOC: Acrylic
Range: 100-1000LPH
Media: Water
Connection: ½”

Float : SS316

10) Power relay

Power: 250VAC 50Hz

Output: 1NO

Size: Wall mounting

11) Tanks in MS with powder coating Size: 400 x 350 x 350mm

C. Formulae use

1) Properties of hot water : Calculated at mean bulk temperature

$$Tbh = \frac{Th1 + Th2}{2}$$

Where

Tbh = mean bulk temperature hot water in °c

Th1 = inlet temperature of hot water in °c

Th2 = outlet tempratue of hot water in °c

$$T_{bh} = \frac{335+325}{2}$$

= 330°c

2)Properties of cold water

$$Tbc = \frac{Tc1 + Tc2}{2}$$

Where

Tbc = mean bulk temperature cold water in °c

Tc1 = inlet temperature of cold water in °c

Tc2 = outlet tempratue of cold water in °c

$$T_{bc} = \frac{300+308}{2}$$

= 304°c

3) Heat given by hot water

$Q_h = m_h \cdot C_{ph}(T_{h1} - T_{h2})$

Where

Q_h= heat given by hot water in kw

m_h= mass flow rate of water in k_g/s

c_p= specific heat of water at constent pressure in k j/k_g°c

T_{h1}= inlet temperature of hot water in °c

T_{h2}= outlet temperature of hot water in °c

Q_h= 0.1667x4.187(335-325)= 6.9797kw

4) Heat given by cold water

$Q_c = m_c \cdot C_{pc}(T_{c2} - T_{c1})$

Where

Q_c= heat given by cold water in kw

m_c= mass flow rate of water in k_g/s

c_p= specific heat of water at constent pressure in k j/k_g°c

T_{c1}= inlet temperature of cold water in °c

T_{c2}= outlet temperature of cold water in °c

Q_c= 0.1667x4.187(308-300)= 5.5837 kw

5) Avrage heat transfer

$$Qavg = \frac{Q_h + Q_c}{2}$$

Q_h= heat given by hot water in kw

Q_c= heat given by cold water in kw

$$Q_{avg} = \frac{6.9797+5.5837}{2}$$

$= 6.2817$ kw

6) *Overall heat transfer coefficient*

$Qavg = U.As.\ \Delta T_m$

Where

U=overall heattransfer coefficient between two fluide w/m^2 °c

A_S= effective heat transfer area m^2

$\Delta^T{}_m$ = approprimate means of temperature difference

$A_S = (\pi/4) \times d_i^2$

$$\frac{3.14\ (0.0198)^2}{4} = 0.0003077$$

$$\Delta T_{m=}\ \frac{(\Delta T_{1-}\ \Delta T_2)}{\ln(\Delta T_1/\ \Delta T_2)}$$

$$= \frac{(335_-\ 325)}{\ln(335/\ 325)} = 2.2723°c$$

$Qavg = U.As.\ \Delta T_m$

6.2817 kw =Ux0.0003077x2.2723

U= 8984.295KW/m^2°c

7) *Reynolds number*

$$Re = \frac{pvd_i}{\mu}$$

p= density of water

v= velocity of water

d_i= diameter of inner pipe

μ = viscosity of water

$$v = \frac{m}{PA_S}$$

$$V = \frac{0.1667}{1000x0.0003077} = 0.5417m/s$$

$$Re = \frac{1000x0.05417x0.0198}{8.90x10^{-4}}$$

=12052.67

$\Delta p = pg\Delta h$

= 1000x9.8x0.132

=1293.6N/m^2

For mass florate =0.1667kg/s

Re=12052.67

$Nui = 0.023(Re)^{0.8}\ (Pr)^{0.3}$

$Nui = 0.023(12052.67)^{0.8}(5.42)^{0.3} = 70.27$

$f = 16/R_e$

= 16/12052.67=0.00132

Same as calculate for all mass flow rate

For mass florate =0.1667kg/s

Re=12052.67 $Nui= \frac{h*d_i}{k}$

$$= \frac{4189.66x0.0198}{0.6} = 138.26$$

$$f= \frac{\Delta pd_i}{2PLv^2}$$

$$f= \frac{1294.6x0.0198}{2x1000x1.4x0.5417^2}$$

$$= 0.03197$$

Same as calculate for all mass flow rate

Sample observation table1.1

Sr.no	Cold water Mass flow rate	Cold water Inlet temp (°c)	Cold water outlet temp (°c)	Cold water Mass flow rate	hot water Inlet temp (°c)	hot water outlet temp (°c)
1	0.0833	300	308	0.0833	335	325
2	0.1112	300	308	0.1112	335	325
3	0.1388	300	308	0.1388	335	325
4	0.1667	300	308	0.1667	335	325
5	0.1945	300	308	0.1945	335	325
6	0.2223	300	308	0.2223	335	325
7	0.2361	300	308	0.2361	335	325
8	0.2561	300	308	0.2561	335	325
9	0.2638	300	308	0.2638	335	325

TABLE 1.2 Plain tube

Sr. no	Mass flow rate(m) (kg/s)	Reynolds number(Re)	Nusselt number(Nu)	Friction factor (f)
1.	0.0833	6022.53	40.34	0.00256
2.	0.1112	8039.93	50.83	0.00199
3.	0.1388	10035.45	60.69	0.00159
4.	0.1667	12052.67	70.27	0.00132
5.	0.1945	14062.65	79.50	0.00113
6.	0.2223	16072.63	88.47	0.00099
7.	0.2361	17070.39	92.83	0.00093
8.	0.2561	18516.42	99.07	0.00086
9.	0.2638	19073.15	101.26	0.00083

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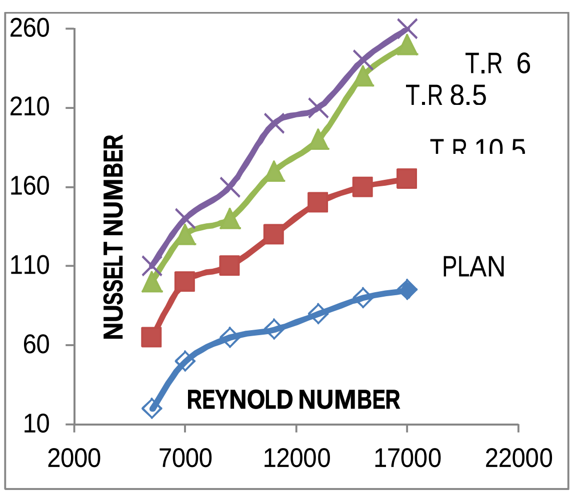
Sr. no	Mass flow rate(m) (kg/s)	Reynolds number(Re)	Nusselt number(Nu)	Friction factor (f)
1.	0.0833	6022.53	69.13	0.12489
2.	0.1112	8039.93	97.27	0.07012
3.	0.1388	10035.45	115.18	0.045004
4.	0.1667	12052.67	138.26	0.03197
5.	0.1945	14062.65	148.4	0.0227
6.	0.2223	16072.63	153.1	0.017548
7.	0.2361	17070.39	161.8	0.011548
8.	0.2500	18516.42	165.4	0.0132
9.	0.2638	19073.15	171.8	0.01245

Table 1.3 Twist tape

Graph represent between Reynolds number and nusselt number of twist tape or without twist tape inserted in heat exchanger
In below figure
T.R represent the twist ratio

$$\text{Twist ratio} = \frac{\text{pitch}}{\text{Width of tape}}$$

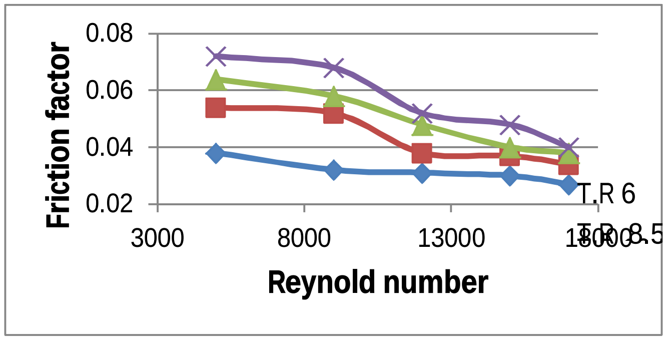


Above figure

C. Above Figure

plot between Nusselt number and Reynolds number for without twist tape and twisted tape with various twisted ratio inserted ,concludes that nusselt number and Reynolds number . Nusselt number rise with rise in reynolds number .hence rate of convective heat transfer is more with higher reyonlds number . Further ,it can concluded that , twisted tapes with higher twist (with lesser twist ratio) give increase nusselt number for particular reynolds number . heat transfer rate is batter with twisted tape of lower twist ratio.

Graph between renold number and fraction factore is shown below



Heat exchanger modelling and analysis are carried out on ansys workbench Above figure plot drawn between factor of friction and Reynolds number with varying twisted tape ratio ,one can easily observe the change fraction factor with varying twisted ratio with increase in fraction , Reynolds number also increase.

D. Cfd analysis

1) *Modelling:* Start ANSYS WORKBENCH

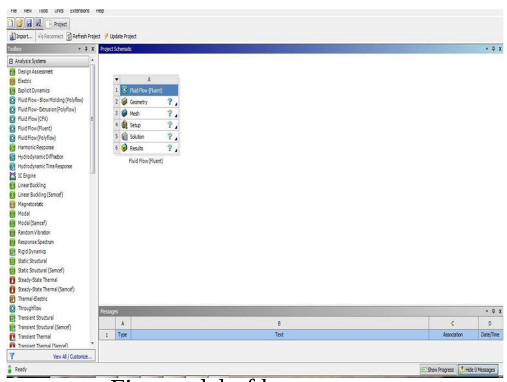


Fig model of heat exanger

First we describe part of model with dimension

2) *wisted Tape*

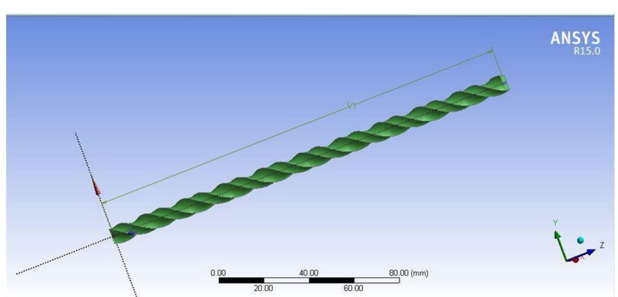


Fig model of heat exanger

Dimension of twisted tape

Length of twist tape 1.4m

Pitch of twisted tape 4.2mm

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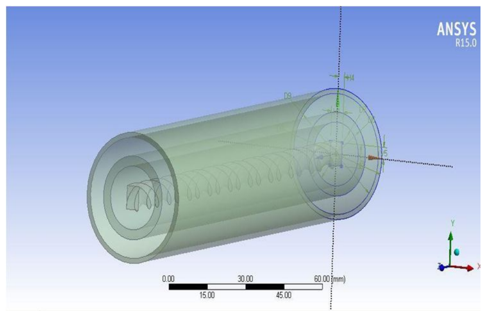
Cross section of twisted tape rectangular(0.7x0.5)
Procedure for twisted tape For this open the Ansys workbench ,and select the x-y plane ,then drawing rectangle 0.7*0.5 ,after that again taken y-z
plane making second sketch drawing line start with centre of rectangle with length is 1.4m and exist 2d work bench go modelling sweep command use , for this select the first profile as rectangle then select line as path, then go twist and given the pitch 40 mm, the generate

diameter of the tube : 0.0198m

tube thickness : 0.0028m

D. Procedure

For this select x-y plane and making circle with diameter is 0.0198m,again drawing circle with diameter 0.0226m in same sketch ,then extrude with frozen with height 1.4m the generate



Fluid filing in outer tube Fill outer tube with cold fluid as shown as belo Then we describe of outer tube filling fluid figure shown in below

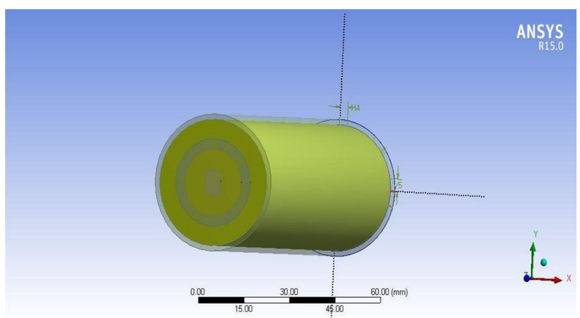


Fig 3.1211 model of outer tube with cold fluid filling

E. Use Boolean operation

Here subtract Boolean Operators is used from outer fluid to inner fluid as shown in below

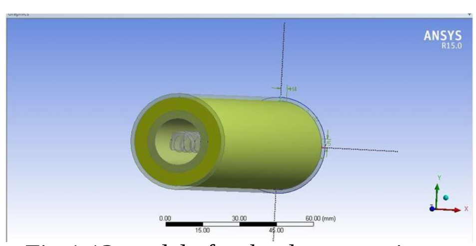


Fig 1.13 model after boolen operation

F. Meshing

After complete geometry , we need to mesh of the model
figure shown in below

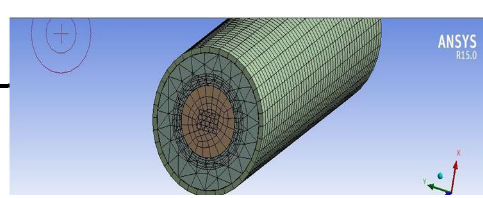


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Fig 3.14 meshing of model Mesh outer edge

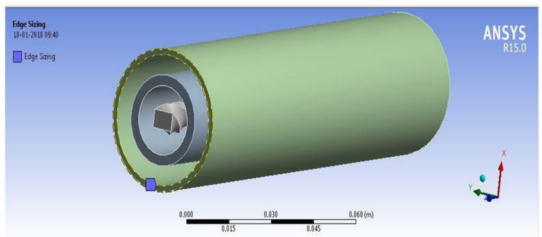

Fig 3.15 Mesing of outer Edge

All part meshing shown below

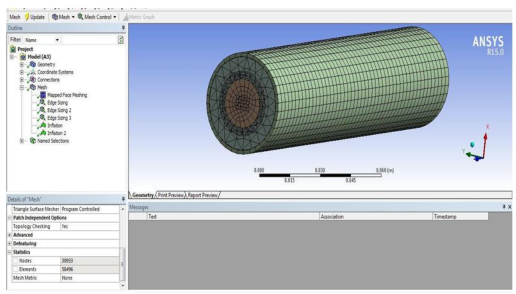

Fig 3.16 mesing of whole model 1.no of node s30933 2. elements no 58496

G. Processing

After the completion of meshing the design in ANSYS Fluent .in fluent boundery conditions are given as per requirement and solution is initialized and calculation are iterated After the calculation is converged the contours are to be plotted

The Boundary conditions are under taken below

Fluid domain is to be specified

Temperature

At inlet

Hot fluid – water (335k)

Cold fluid – water (300k

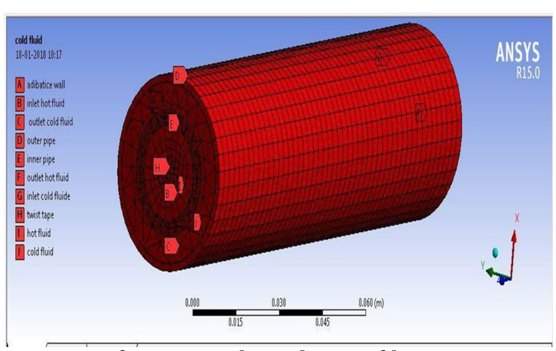

figure 3.17 boundaries of heat exanger

In the analysis report the mainly reynolds number, pressure, velocity, temperature contour to be viewed the result obtain are to be tabulated

Boundary specifications

Outer surface: **Adiabatic** outer wall

Twist tape: wall

Outer pipe: :wall

Inner pipe : : wall

Cold water inlet: : velocity

Hot water inlet : : velocity

Cold water outlet : : pressure outlet

Hot water outlet : : pressure outlet

Cold domain : :mass flow

Hot domain : :mass flow

II. RESULTS AND DISCUSSION

First we compare temperature of cold fluid outlet with twist tape and without twist tape shown in below

With twist tape

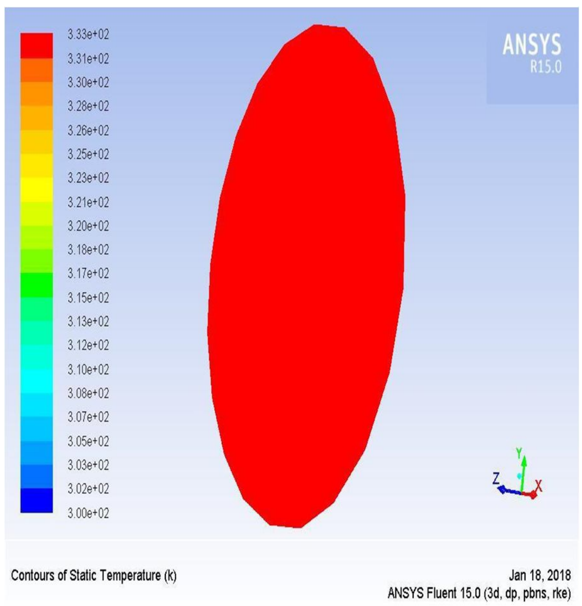

Fig 4.1 temprature of hot fluid outlet with twisted tape inserted

B. Without twist tape

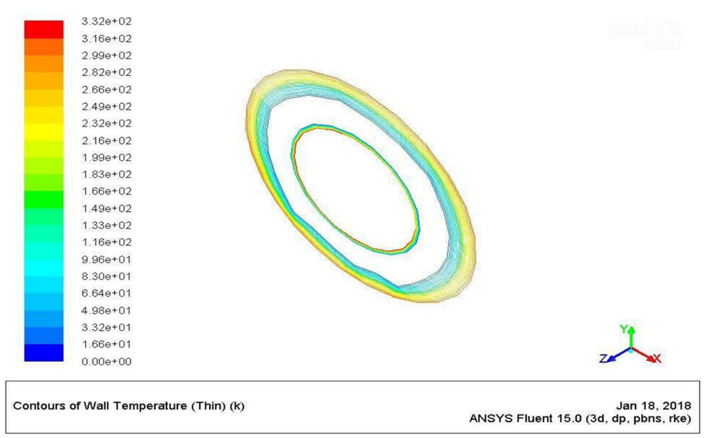

Fig 4.2 Temprature of hot fluid outlet without twisted tape

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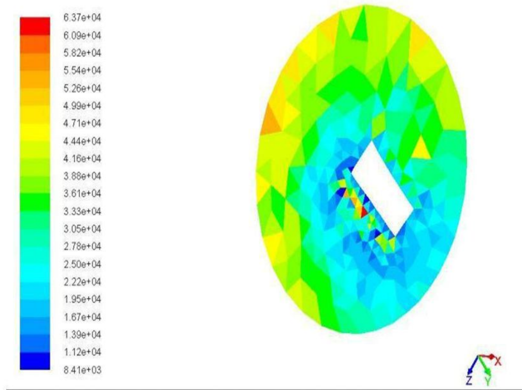

Fig 4.3 Reynolds number at inlet in heat exchanger with twist tape

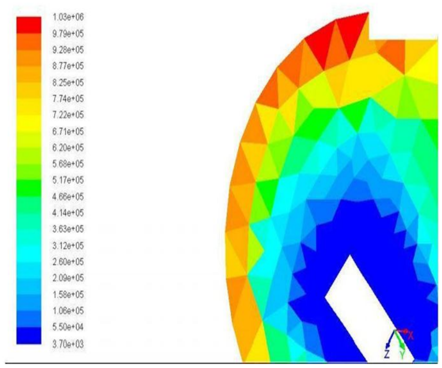

Fig 4.4 Reynolds number at outlet in heat exchanger with twist tape

in the above figure we can **observe** that the Reynolds number is increasing from inlet to outlet of the heat exchanger to the outlet of heat exchanger .this the because of the reason that during the flow of fluid over the twisted tape a disturbance is created in flow thus turbulence is created this result is increase of the Reynolds number

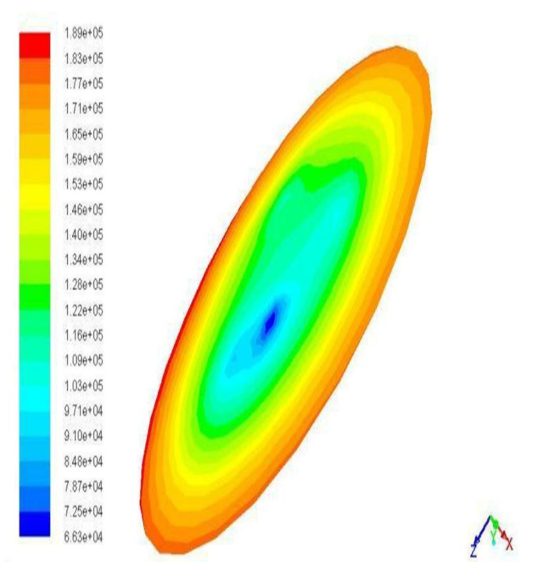

Fig4.5 Reynolds number at inlet in heat exchanger without twist tape

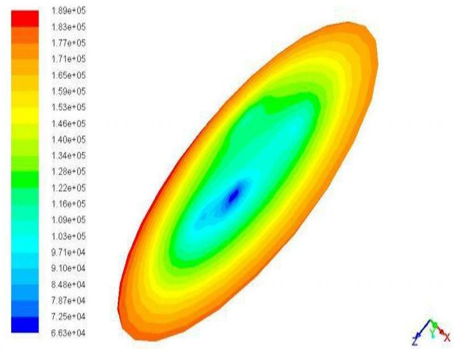

Fig 4.6 Reynolds number at outlet in heat exchanger without twist tape

Sr.no	Mass flow rate(m)	Reynolds	Nusselt	Friction factor
	(kg/s)	number(Re)	number(Nu)	(f)
1.	0.0833	6022.53	69.13	0.12489
2.	0.1112	8039.93	97.27	0.07012
3.	0.1388	10035.45	115.18	0.045004
4.	0.1667	12052.67	138.26	0.03197
5.	0.1945	14062.65	148.4	0.0227
6.	0.2223	16072.63	153.1	0.017548
7.	0.2361	17070.39	161.8	0.011548
8.	0.2500	18516.42	165.4	0.0132
9.	0.2638	19073.15	171.8	0.01245

In above two figure the reynolds no of the hot fluid at inlet and outlet of heat exchanger .we observe that there is no much difference in the value , they remain almost constant .this is due to no turbulent in the flow

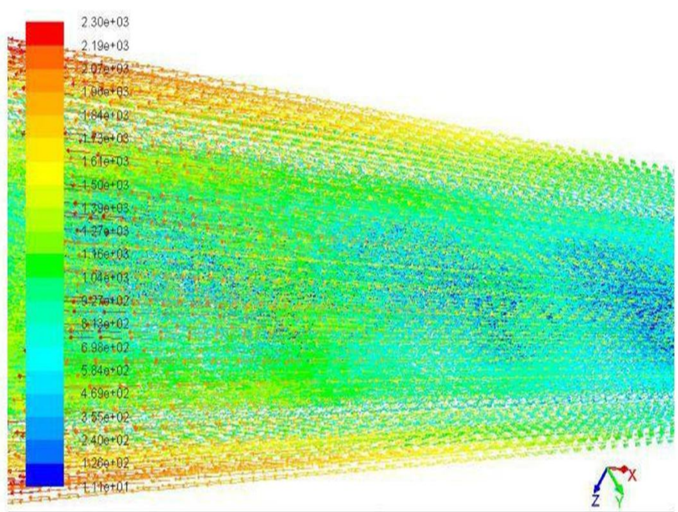

Fig 4.8 velocity vector of heat exchanger with twisted tape

The above figure shown that the velocity & direction of the fluid element during the flowing of heat exchanger (with twist tape). We can observe that there is a rise in velocity of the fluid element when moving from inlet to the outlet this is due to the swirl created by the twisted tape.

The result obtain from CFD analysis are shown below

Table 4.1 Plain tube:result without twist tape inserted

Sr. no	Mass flow rate(m)	Reynolds	Nusselt	Friction factor
	(kg/s)	number(Re)	number(Nu)	(f)
1.	0.0833	6022.53	40.34	0.00256
2.	0.1112	8039.93	50.83	0.00199
3.	0.1388	10035.45	60.69	0.00159
4.	0.1667	12052.67	70.27	0.00132
5.	0.1945	14062.65	79.50	0.00113
6.	0.2223	16072.63	88.47	0.00099
7.	0.2361	17070.39	92.83	0.00093
8.	0.2561	18516.42	99.07	0.00086
9.	0.2638	19073.15	101.26	0.00083

Comparision is made between CFD analysis and experimental analysis for with and without twisted tape inserted

III. CONCLUSION

CFD analysis is carried out by taking double pipe heat exchanger with cold and hot fluids with different boundary conditions by incorporating twist tape inserts .It can be concluded as follows: By using passive techniques that is by inserting twist tape inserts the heat transfer enhancement increased by 10-15% with the cost of reasonable allowable pressure drop .In this report we achieved enhancement of heat transfer effectively. Future work may be extended to:

A. Combination of techniques may be used to enhancement of heat transfer coefficient by compound techniques
B. Reduce the width of twist tape inserts with low Reynolds number
C. By varying low Reynol

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