Experimental Investigation & CFD Analysis on Effect of Tarbulators 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.

Key words: CFD Analysis, Heat Exchanger

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 greater heat transfer this also leads to improve flow velocity, thermal boundary layer, hydrodynamic boundary layer, heat transfer rate, fluid mixing. However more pumping power is required when twisted tapes are inserted to inner tube.

A. *Classification of Improvement Method*

Heat removal improvement method mention to the development of the RMO hydraulic performance of heat exchanger .These improvement method is categorized in generally three categories. They are as below

1) *Active Method*

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

2) *Passive Method*

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

3) *Compound Method*

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

II. METHODOLOGY

1) Work being considerd is to perform experimental investigation and simulation of double pipe heat exanger with and without twisted tape inserted
2) 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.
3) compare in mode of the result of found from experimental analysis and simulation

Fig. 3.1: Twisted Tape Type Insert

A. *Proposed Experimental Set-Up*

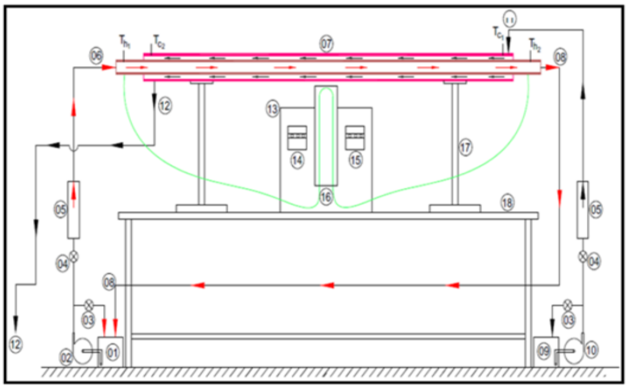

Fig. 2:

1) Hot water tank
2) Hot water pump
3) By pass valve
4) Flow control valve

5) Rotameter
6) Hot water inlet
7) Test section
8) Hot water outlet
9) Cold water tank
10) Cold water pump
11) Cold water inlet
12) Cold water outlet
13) Control panel
14) Temperature indicator
15) Temperature controller
16) Inverted u- tube manometre
17) Stand
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 Exchanger
- Inside pipe Material: copper
- Outside pipe material: steel
- Length: 1.4 m
- Inside pipe diameter: 0.0198m
- Outside pipe thickness: 0.0028m
- Outside pipe thickness: 0.003m
- Hot water
- Pass 1
- Cold water
- Pass 1

2) Valves
- Ball valve
- Location: process valves, Tank valve, drain valve, bypass valves

3) U Tube Manometer
- MOC: Acrylic
- Range: 250-0- 250mm WC

4) Temperature Sensior
- Type: RTD-PT100 3 wire
- Assembly: Transition Type
- Range: 0 to 300 deg C
- Diameter: 6mm
- Length: 100 mm
- Cable: 3 mtr. Teflon/Teflon Cable

5) Rota meter
- MOC: Acrylic
- Range: 100-1000LPH
- Media: Water
- Connection: ½"
- Float: SS316

6) Power Relay
- Power: 250VAC 50 Hz
- Output: 1 NO
- Size: Wall mounting

7) Tanks in MS with Powder Coating
- Size: 400x350x350 mm

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

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

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

4) 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

Δp= pgΔh

= 1000x9.8x0.132

=1293.6N/m^2

a) Plain Tube

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

b) Twisted Tape Inserted

For mass florate =0.1667kg/s

Re=12052.67

$$Nu_i = \frac{h*d_i}{k}$$

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

$$f = \frac{\Delta p d_i}{2PLv^2}$$

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

$$= 0.03197$$

Same as calculate for all mass flow rate, mass value is given

0.2638	0.2638	0.2638	0.2638
0.2638	0.2638	0.2638	0.2638

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

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

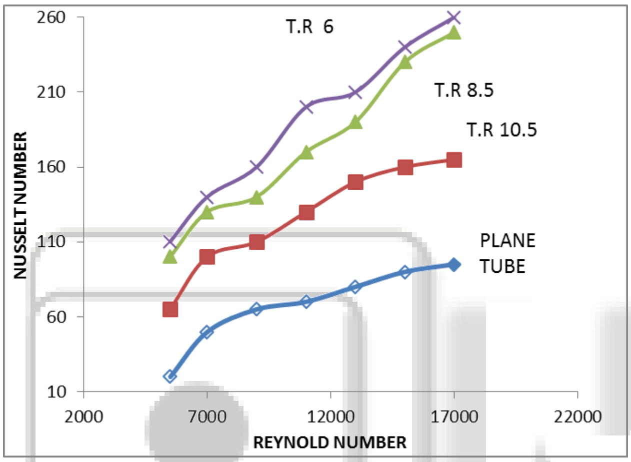

Fig. 3:

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

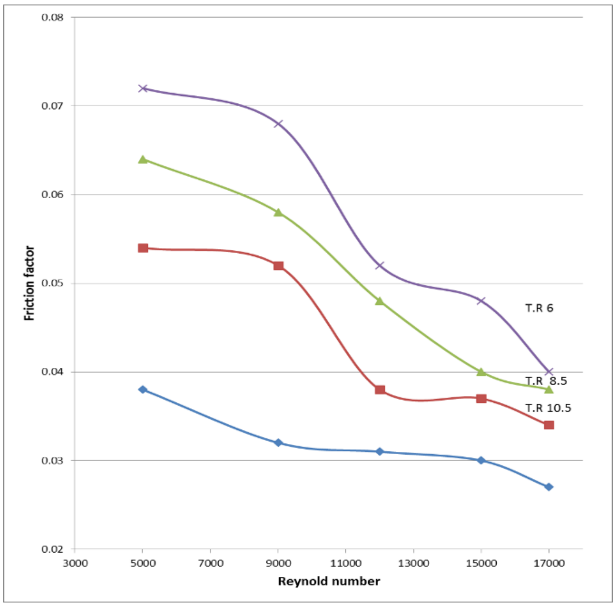

Fig. 4:

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*

a) Ansys Workbench

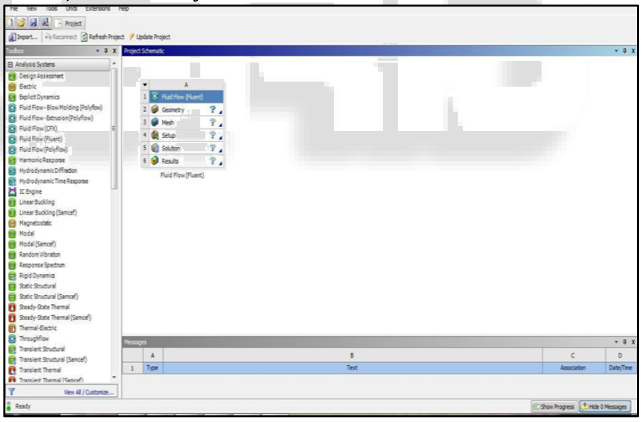

Fig. 5:

Heat exanger modeling and analysis are carried out on First we describe part of model with Dimension

c) Twisted Tape

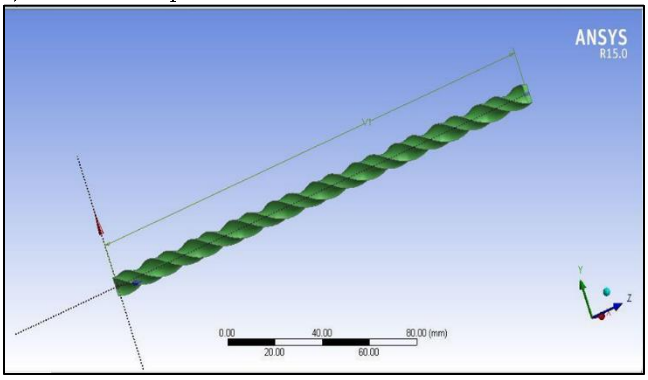

Fig. 6:

2) Model of Twisted Tape Insert

a) Dimension of Wisted Tape

- Length of twist: 1.4 m
- Pitch of twisted tape: 0.42mm
- Cross section of twisted tape: rectangular (0.7x0.5)

3) 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

- Dimension of the tube: 0.0198m
- Tube thickness: 0.0028m

III. 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

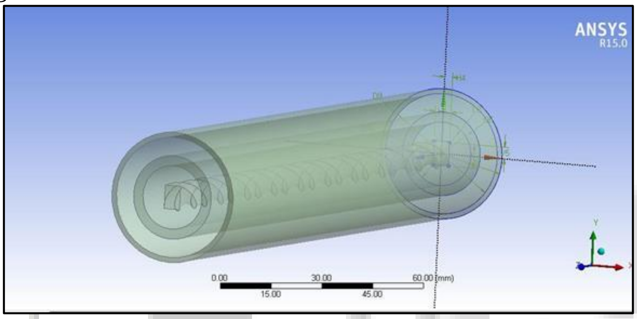

Fig. 7:

For this select x-y plane and making circle with diameter is 0.038m ,again drawing circle with diameter 0.041m in same sketch, the extrude with frozen with height 1.4m then generate .this is complete geometry of twist tape

A. *Fluid Filling in Inner Tube*

After completing the modelling, we need do fluid filling in inner and outer tube fill inner tube with hot fluid as shown

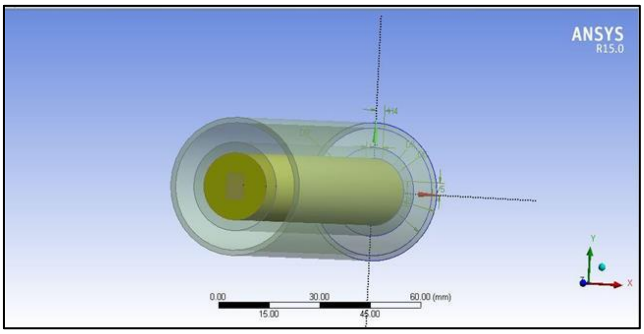

Fig. 8:

B. *Fluid Filing in Outer Tube*

Fill outer tube with cold fluid as shown as below

Then we describe of outer tube filling fluid figure shown in below

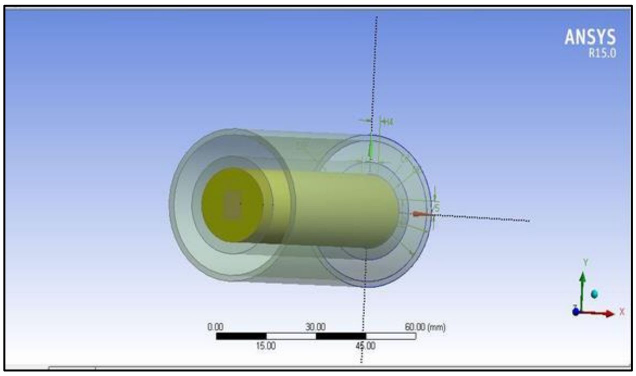

Fig. 9:

C. *Use Boolean Operation*

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

1) Meshing

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

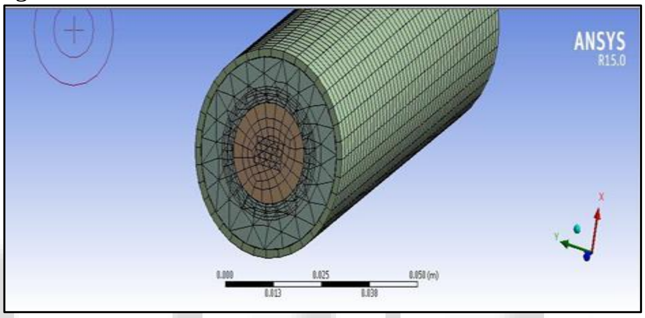

Fig 10:

D. *Meshing of whole model*

1) No of node s30933
2) Elements no 58496

1) Processing

After the completion of meshing the design in ANSYS Fluent .in fluent boundary 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

Boundary condition

- At inlet
- Hot fluid – water (335k)
- Cold fluid – water (300k)

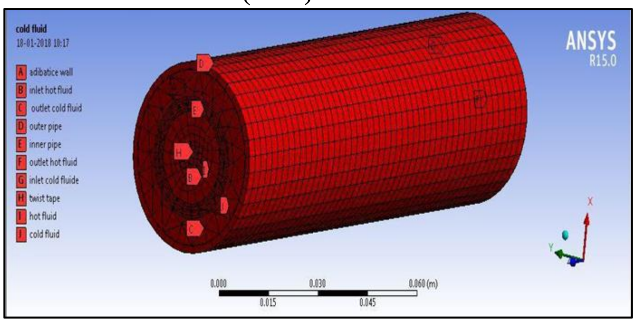

Fig. 11:

E. *Boundary Condition*

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

1) 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

IV. RESULTS & DISCUSSION

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

A. With Twist Tape

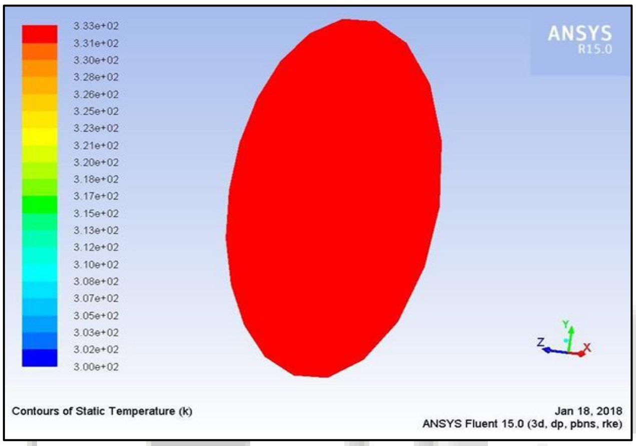

Fig. 12:

B. With Twist Tape

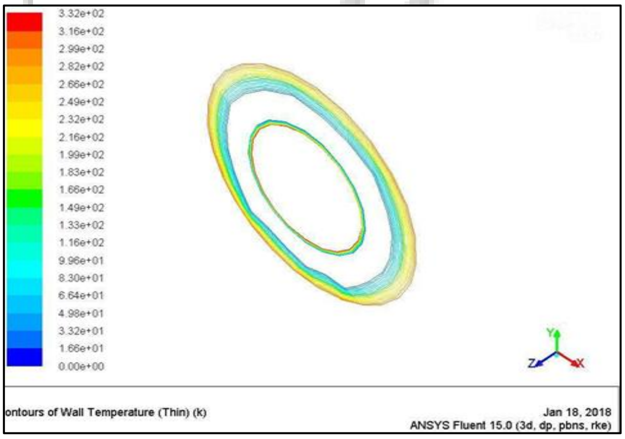

Fig. 13:

C. Reynolds number at inlet in heat exchanger with twist tape

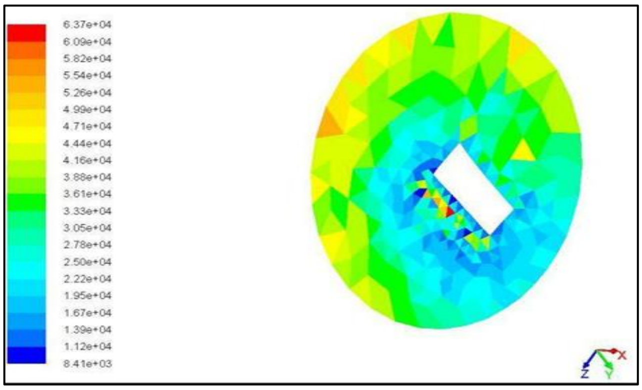

Fig. 14:

D. Eynolds number at outer in heat exanger with twist tape

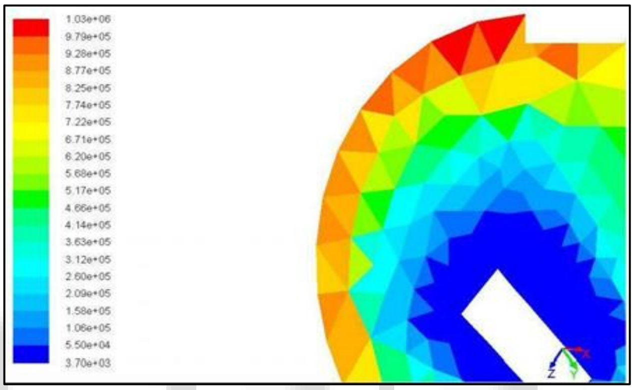

Fig. 15:

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

E. Reynolds number at inlet in heat exchanger without twist tape

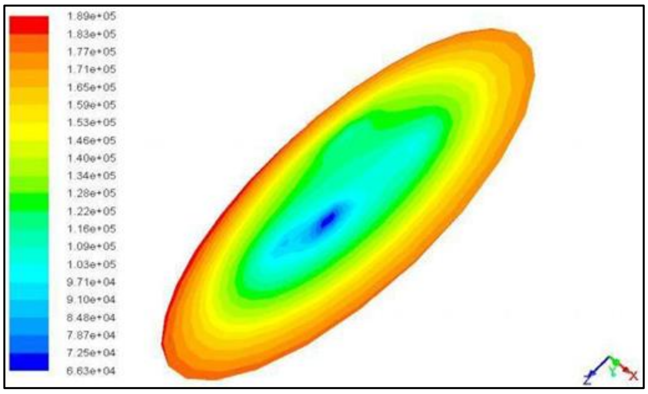

Fig. 16:

F. Reynold number at outlet in heat exchanger without twist tape

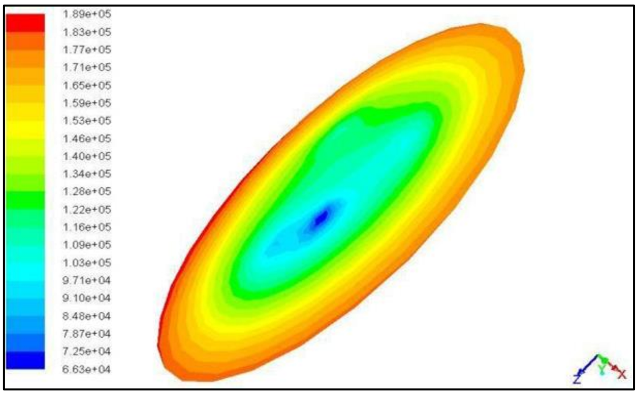

Fig. 17:

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 velocity vector of heat exchanger with twisted tape

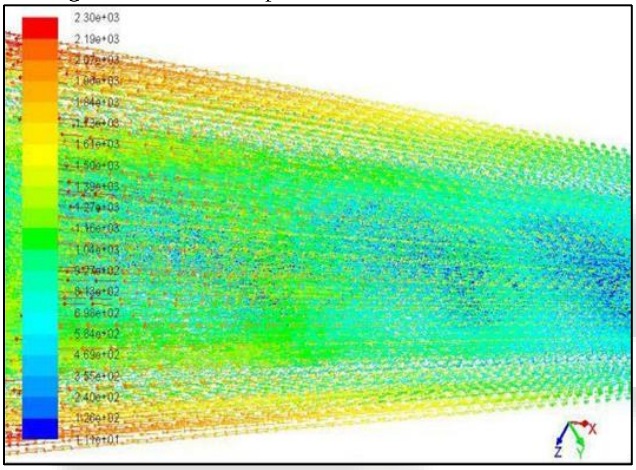

Fig. 18:

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

V. 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:

1) Combination of techniques may be used to enhancement of heat transfer coefficient by compound techniques.
2) Reduce the width of twist tape inserts with low Reynolds number.
3) By varying low Reynolds numbers check the Heat transfer enhancement coefficient

REFERENCE

[1] Aha s.k, Heat Transfer Intensification in U-bend Double Pipe Heat Exchanger using Twisted Tape Inserts International Journal of Innovative Research in Science, Engineering and Technology, Augest 2015 ,vol 5 1333-1341
[2] ard Eiamsa- experimental investigations of heat transfer enhancement in double pipe heat exanger using twisted tape dense wire mesh insert, 2012 5 -9
[3] Ebru Kavak Akpina Modeling of Climatic Parameters and Determination of Climatic Differences in the City of Elazig-Turkey and its Close Regions *Journal of Environmental Protection*, 2010, 1, 41-52
[4] Kannan .M rainfall Forecasting using data mining technigue international journal of engineering & Technology, t 2010 vol 2 , 397-401
[5] Kiran K. Lalit, CFD Analysis on Twisted Tape Heat Exchanger with Hybrid Nano Particle, International Journal for Research in Applied Science & Engineering echnology (IJRASET) April 2017 Volume 5
[6] Maddah Heydar Effect of Twisted-Tape Turbulators and Nanofluid on Heat Transfer in a Double Pipe Heat Exchanger Journal of Engineering, 2014
[7] Mangtani Mukesh, EFFECT OF TWISTED-TAPE INSERTS ON HEAT TRANSFER IN A TUBE—A REVIEW international journal of mechanical engineering and robotic research , April 2015 Vol. 4
[8] Naveen. S CFD Analysis of Concentric Tube Heat Exchanger Using Twisted Tapes, International Journal of Advance Research, Ideas and Innovations in Technology.,2017, 870 -879
[9] Prajapati Om Shankar Heat Transfer Behaviour of Nano-fluid at High Pressure Journal of Materials Science Surface Engineering Vol. 1 2013, pp. 1-3. Vol. 1
[10] Sommers and Jacobi A review on polymer heat exchangers for HVAC&R applications, international journal of refrigeration (2009) 763–779

