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 it is identified as to perform simulation and experimental investigation of double pipe heat exchanger with inner twisted tape type insert at 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 insert with 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.

Keywords – CFD Analysis, Heat Exchanger, ANSYS etc

I. INTRODUCTION

Heat exchangers are broadly utilized in chemical, power generation and oil refining industry. Shell and tube heat exchanger can transfer vast measure of heat in moderately minimal effort, useful plans. The basic variable in reducing the size and cost of a heat transfer gadget are weight drop and heat transfer coefficient. Along these lines, it respects made procedure to improve the heat transfer coefficient. The twisted tape insert as stream turbulator's have been broadly connected because of their promising execution. Numerous analysts have detailed their impact of tube insert on heat transfer improvement.

The promising test for plan of heat exchanger is to reduce the pumping power while expanded heat transfer rate. In this manner it is fundamental to create hypothesis and technique about increased heat transfer in the double pipe heat exchanger to enhance the execution of heat exchanger. The presence of twisted tape brings down the hydrodynamic and thermal boundary layer thickness, prompting more noteworthy convective heat transfer. In spite of fact that pumping power may increment definitively and eventually it is seen the cost of pumping is more. In this way to accomplish a coveted heat transfer rate with least pumping power, the outline of twisted tape with legitimate geometry is important.

Twisted tapes are typically embedded into the tube to produce whirl movement of liquid for more prominent heat transfer this likewise prompts enhance flow speed, thermal boundary layer, hydrodynamic boundary layer, heat transfer rate, fluid mixing. Anyway all the more pumping power is required when twisted tapes are inserted inward tube.

A. *Improve method classification*

Heat expulsion change technique says the improvement of thermo water powered execution of heat exchanger. This improvement method is categorized in generally three categories. They are as below:

1. Active method
2. Passive method
3. Compound method

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 imperative technique is the one wherever more than one of the above expressed strategy is utilized in blend by the motivation behind further progressing the rate of heat transfer.

II. METHODOLOGY

1. Work being considered is to perform experimental examination and recreation of double pipe heat exchanger with and without twisted tape insert
2. The studies of the heat transfer performance of heat exchanger with and without insert twisted tape different geometry.

Calculation of its heat transfer performance at different men flow rate involving

a. Heat transfer coefficient for all cases.

b. Nusselt number for all cases.
c. Reynolds Number for all cases.

3. compare in mode of the result of found from experimental analysis and simulation

Fig. 1 twist tape inserts

A. Proposed experimental set-up

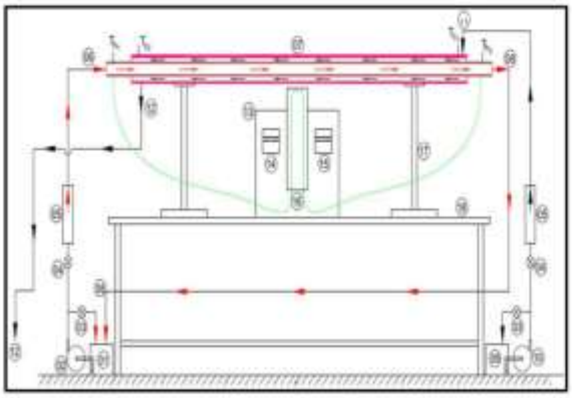


Fig. 2 experimental setup

a. Hot water tank
b. Hot water pump
c. By pass valve
d. Flow control valve
e. Rotameter
f. Hot water inlet
g. Test section
h. Hot water outlet
i. Cold water tank
j. Cold water pump
k. Cold water inlet
l. Cold water outlet
m. Control panel
n. Temperature indicator
o. Temperature controller
p. Inverted u- tube manometre
q. Stand
r. 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

Dimension of heat exchanger

Outside Pipe Material:	Steel
Length	1.4 m
Inside Pipe	
Inside	
pipe Dia	0.0198 m
Inside Pipe thickness:	0.0028 m
Outside Pipe Diameter:	0.038 m
Outside Pipe thickness:	0.003 m
Hot water	
Pass	1
Water	
Pass	1

2. Valve

Ball Valves

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

3. Temperature indicating controller

Display: 31/2 digit red led 13 mm Height

Accuracy: 1%F.S.

Set point: 1 Potentiometric

Output: INO/NC, 3A

$$Tbh = \frac{Th1 + Th2}{2} \quad \text{in } °C$$

Where

Tbh = mean bulk temperature hot water in °C

$Th1$ = inlet temperature of hot water in °C

$Th2$ = outlet temperature of hot water in °C

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. C.

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

sr. No	cold water mass FLOW	cold water Inlet temp(°c)	Coldw ater ut let emp °c)	Hot ater ass FLOW	Hot ater nlet temp °c)	Hot ater ut let emp °c)
1	.0833	00	08	.0833	35	25
2	.1112	00	08	.1112	35	25
3	.1388	00	08	.1388	35	25
4	.1667	00	08	.1667	35	25
5	.1945	00	08	.1945	35	25
6	.2223	00	08	.2223	35	25
7	.2361	00	08	.2361	35	25
8	.2561	00	08	.2561	35	25
9	.2638	00	08	.2638	35	25

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
    Powder coating Size: 400 x 350 x 350mm

C. Formulae used

1. Properties of hot water

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

= 330°C

2. Properties of cold water

$$T_{bc} = \frac{T_{c1} + T_{c2}}{2}$$

U= 8984.295KW/m^2°C

Reynold number

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

p =density of water
v= velocity of water
μ = viscosity of water

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

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

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

Sr.	Mass flow n) (kg/s)	Reynolds number(Re)	Nusselt number(N	Friction (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

=12052.67

1) Plain tube

For mass flow rate =0.1667kg/s

Re=12052.67

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

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

f = 16/Re

= 16/12052.67=0.00132

Same as calculate for all mass flow rate

twisted tape inserted

For mass flow rate =0.1667kg/s

Re=12052.67

$$Nu_i = \frac{hxd_i}{k}$$

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

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

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

= 0.03197

Same as calculate for all mass flow rates

Sample observation table

Plane tube

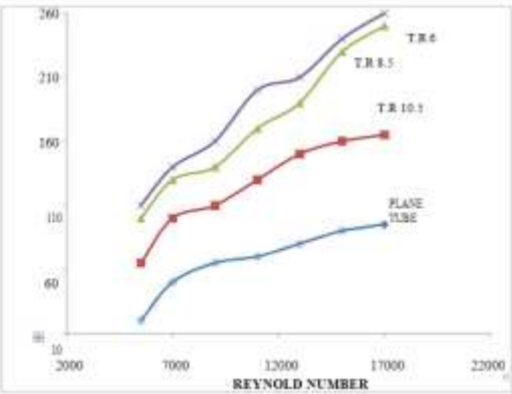
With twist tape

Sr.no	Mass flow rate(m)	Reynolds	Nusselt	Friction factor
G	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

Graph represent between Reynolds number and nusselt number of twist tape or without twist tape in sertedin heatexchanger

In below figureT.R represent the twist ratio

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

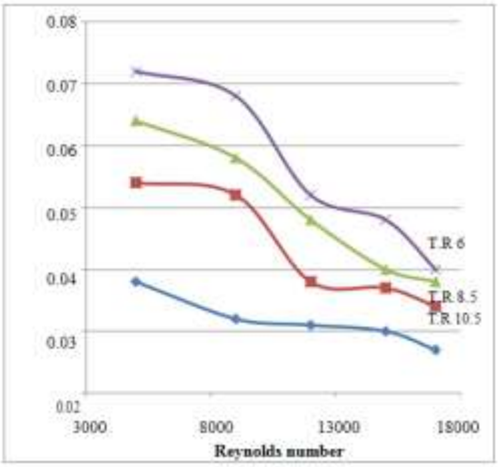


Above figure

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 reasoned that, twisted tapes with higher contort (with lesser turn proportion) give increment nusselt number for specific reynolds number. Heat transfer rate is hitter with twisted tape of lower contort proportion.

Graph between renold number and fraction factore is shown below

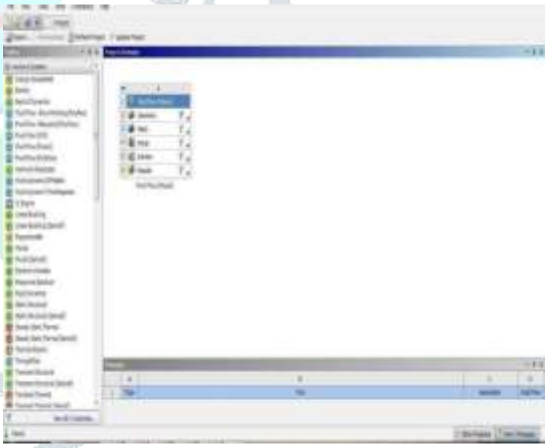


Above figure plot drawn between factor of friction and **Reynolds** number with varying twisted tape ratio ,one can easily observe the change fraction factor with varying twisted ratio with increase in fraction , **Reynolds** number also increase.

CFD ANALYSIS

Modelling

Start ANSYS WORKBENCH



Heat exchanger modelling and analysis are carried out on ansys workbench

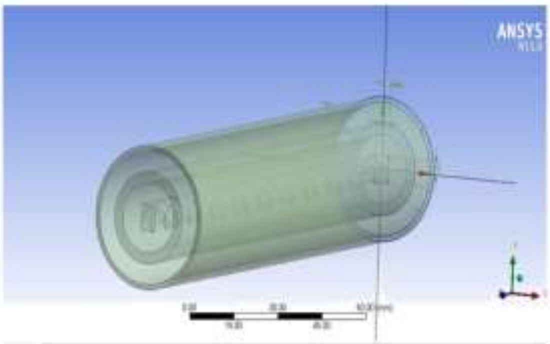


Fig 3.:model of heat exanger

First we describe part of model with Dimension

(A)Twisted tape

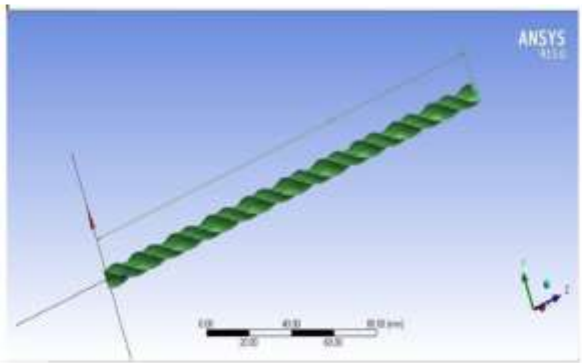


Fig 4

Dimension of twisted tape

Length of twisted tape	14m
Pitch of twisted tape	42mm
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, then generate

(B)For inner tube

Dimension of inner tube

diameter of the tube	0.0198m	:
tube thickness	0.0028m	:

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

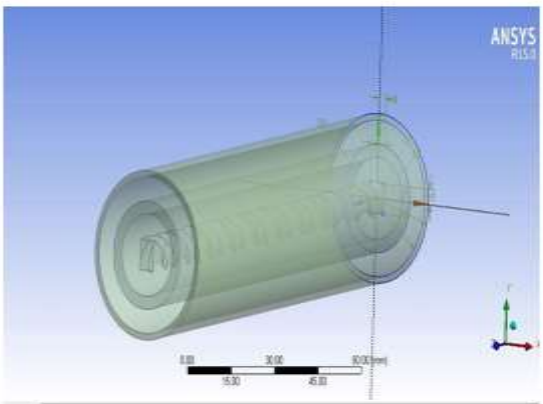


Fig5 outer pipe with inner pipe and twist tape

(C) Dimension of outer tube

diameter of the tube	0.038m
tube thickness	0.003m

PROCEDURE

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

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 below

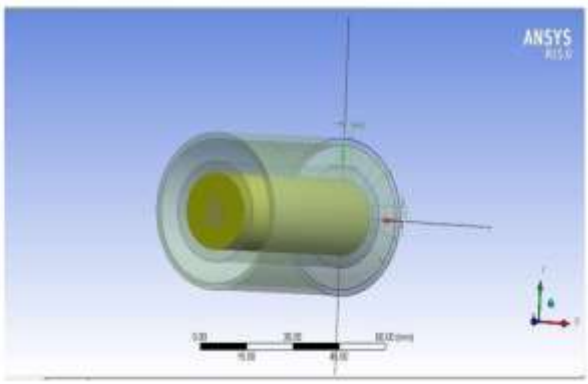


Fig 6 model of inner tube with hot fluid filling

Fluid filing in outer tube

Then we fill outer tube with cold fluid as shown below

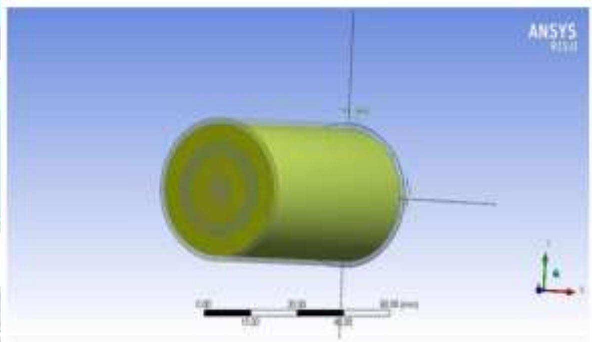


Fig 7 model of outer tube with cold fluid filling

Use Boolean operation

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

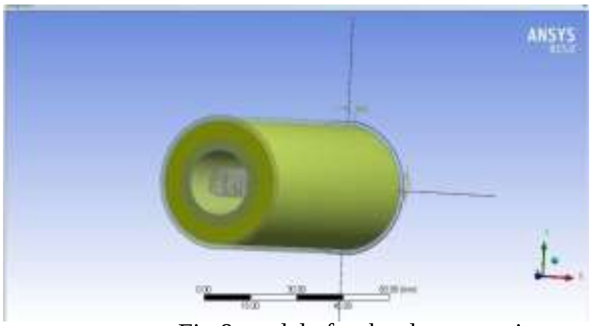


Fig 8 model after boolen operation

Meshing

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

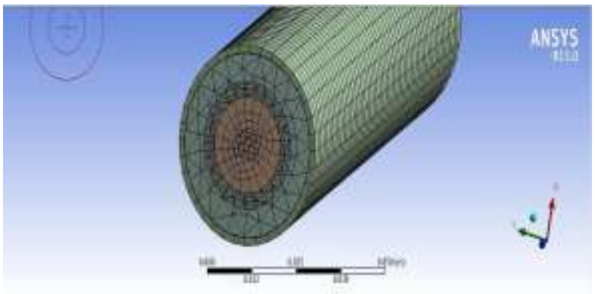


Fig 9 meshing of model

Meshing of outer edge

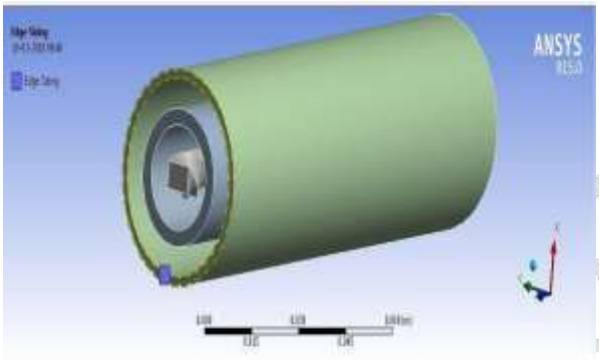


Fig 10 Mesing of outer Edge

All part meshing shown below

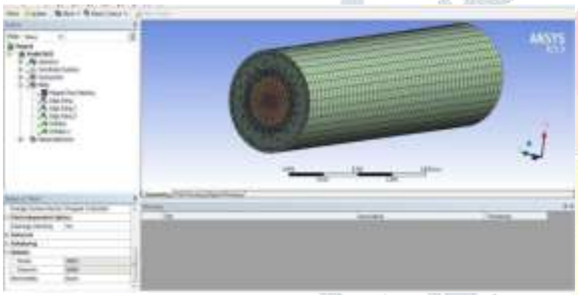


Fig 11 mesing of whole model

NO of nodes - 30933
NO of elements - 58496

3.6.3 processing

After the completion of meshing the design in ANSYS Fluent. Familiar boundery conditions are given according to necessity and arrangement is instated and estimation are iterated After the count is met the forms 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)

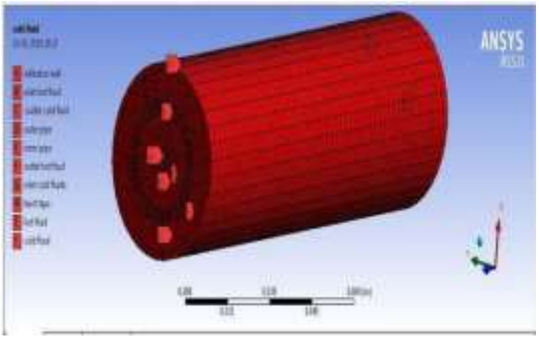


Fig 12 Boundary condition

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

post processing

RESULTS AND DISCUSSION

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

With twist tape

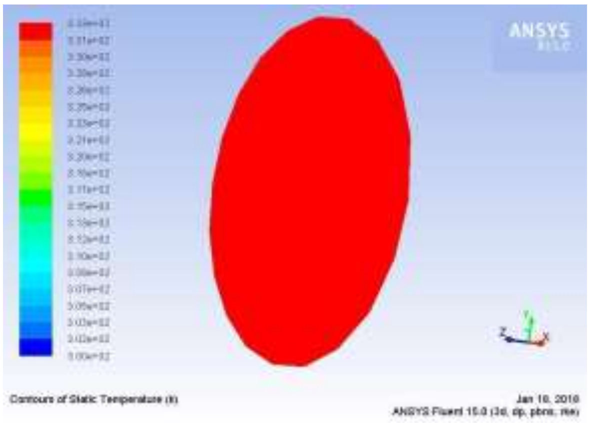


Fig 13 temperature of Cold fluid outlet with twisted tape inserted

Without twist tape

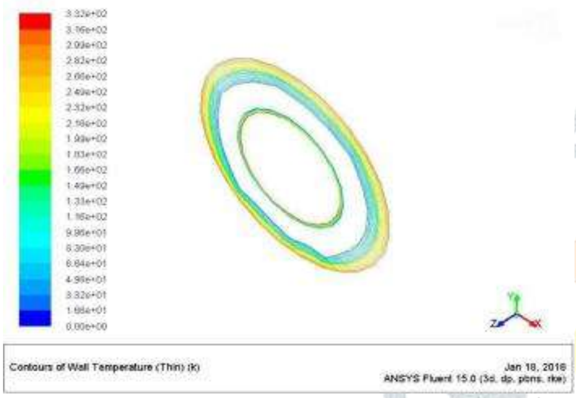


Fig 14 Temperature of cold fluid outlet without twisted tape

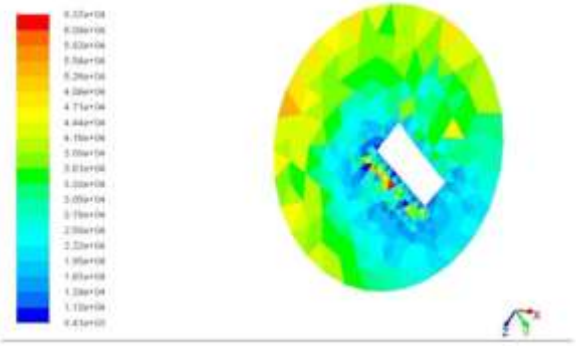


Fig 14 Reynolds number at inlet in heat exchanger with twist tape

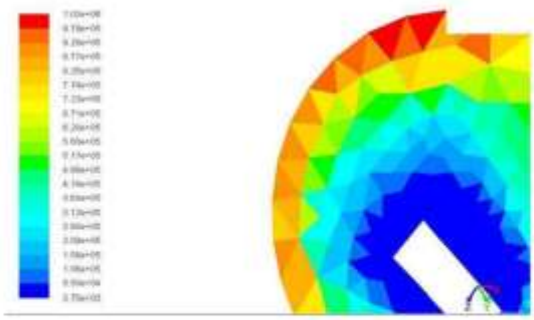


Fig 15 Reynolds number at outlet in heat exchanger with contort tape

In the above figure we can see that the Reynolds number is expanding from delta to outlet of the heat exchanger to the outlet of heat exchanger .this the in light of the reason that amid the stream of liquid over the twisted tape an unsettling influence is made in stream hence disturbance is made this outcome is increment of the Reynolds number

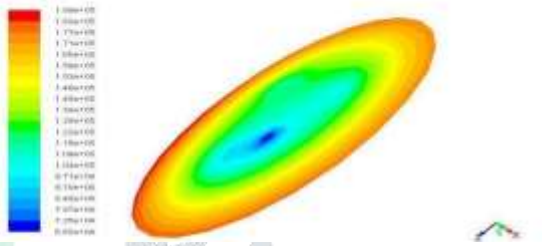


Fig16 Reynolds number at inlet in heat exchanger without twist tape

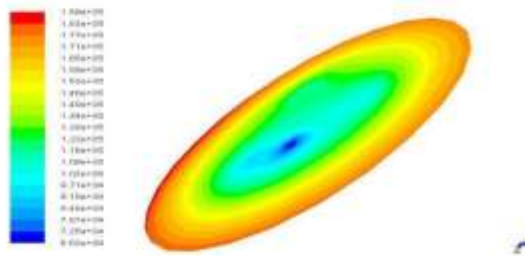


Fig 17 Reynold number at outlet in heat exchanger without twist tape

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

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

.this is due to no turbulent in the flow

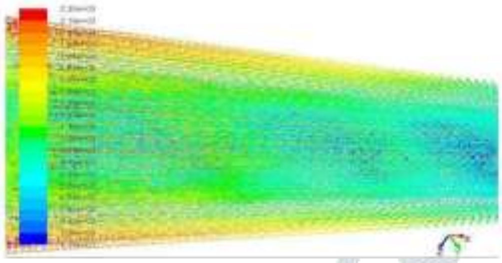


Fig 18 velocity vector of heat exchanger with twisted tape

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.

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

After Cfd find the table with twist tape are shown in below

Table 4.2 CFD result with inserted twisted tape

It is noted that the result of CFD and experimental analysis are comparable without much devation. Hence CFD analysis is validated

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.

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