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HEAT TRANSFER THROUGH DOUBLE PIPE TYPE OF HEAT EXCHANGER BY USING INSERT OF CORRUGATED TWISTED TAPE AND ITS ANALYSIS

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ABSTRACT

The experimental investigation of the heat transfer and friction factor properties carried out by using the copper (wavy) corrugated twisted tape insert in double pipe heat exchanger. The enhancement of heat transfer rate is obtained by creating high rate turbulence in pipe, it also provides drop in pressure. This is achieved by inserting the twisted tape into the inside tube of heat exchanger. The tape consists of the corrugations and the twisting with various twist ratios (TR=10.7, 8.5, 7.1). Before going ahead, let us know, what is TR? TR is twisted ratio. It is the number of twists per meter .Mathematically, TR=Pitch/witdh(diameter). Here,we used TR of 10.7,8.5 and 7.1. The length and width of insert was 1 meter and 14 mm respectively. The bulk mean temperatures at various positions are used for different flow rate of water. From the obtained results, the new Correlation between Nusselt number and friction factor developed for insert of twisted tape. The twisted tape having wavy corrugated structure on it. By changing pitch size, different twist ratios obtained. The observations are noted for twisted tape and for without using twisted tape. Calculation of properties, Reynolds number and Nusselt number varied and it is observed that, it increases for insert of twisted tape, compared to without using twisted tape. From result, it is observed that ,Reynolds number increases from 5000-17000. The other factor Nusselt number was increased by 172% and friction factor value increased by 32.11% compared to smooth tube values. For modeling and predicting the experimentation and analysis of the result in double pipe heat exchanger having wavy corrugated twisted tape inserts. For Fuzzy Logic system the twist ratio, temperature and Reynolds Numbers were used as input functions and friction factor and Nusselt number were used as output functions. It is found that a fuzzy inference system named Mamdani, due to its low error in result. Also, thermal analysis is done by the CFD, which also represents increase in rate of heat transfer by inserting the twisted tape. In CFD analysis, variation parameters used are rate of mass flow and temperature of hot water and cold water.

Keywords: Double Pipe Heat Exchanger, The Working Fluid-Hot Water And Cold Water, Reynolds Number, Nusselt Number, Tempertaure, Flow Rate, Thermal Analysis.

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1. INTRODUCTION

In heat exchanger, the enthalpy is transferred between two or more fluids, at different temperatures. The use of heat exchangers are in various industrial processes for heating and cooling applications such as air conditioning and refrigeration systems, heat recovery processes, food and dairy processes, chemical process plants etc.

The important demand of designing the heat exchanger is to make apparatus more dense and to obtain the high rate of heat transfer by using the less pumping power. For special engineering purposes, different skills or techniques are developed for augmentation of heat transfer. Nowdays, due to increased expenditure of energy and materials, researchers are struggling with target of generating more productive and profitable equipment of heat exchangers. In unique application like space, there is requirement of miniaturization for heat exchangers. The problem of fouling occurs as the heat exchanger working span increases increases beyond limit, it resulted in resistance to transfer of heat. The rate of heat transfer need to increase is demand for some special applications. It is mostly, when thermal conductivity of fluid is low and plant desalination problem. This fouling problems happens in the chemical and marine industries. The rate of heat transfer enhanced by providing the disturbances between flow of fluid which collaps the viscous and thermal layer of boundary. In this process of increasing the rate of heat transfer, consumption of power for pumping rises conclusively. so, to obtain the aimed rate of heat transfer in current heat exchanger with economic power of pumping, different techniques have been suggested in recent years and focused under the classified section. The method for rising the rate of heat transfer are developed and enhancement of heat transfer is obtained. In many heat exchangers, methods used such as Use of insert of twisted tape and strip, insert of helical wire coil and coil wire and placing the devices for obtaining turbulent decaying swirl flow.

Recorded results shows that, improvement in efficiencies of heat transfer and friction factor for flow also increases. In this research, for enhancement of heat transfer, various twisted tape used with various twist ratios. The Twsited strip provides fast mixing and large turbulent flow resulted in excellent heat transfer rate.

For modeling the experiment, used method is fuzzy logic which is economical.

CFD is termed as technique of computational fluid dynamics. It provides analysis of fluid flow for numerical and thermal processes. It provides algorithm which analyse problem and solves it with calculations provides simulation of interaction between the gas and liquid defines by boundary layer condition. Better solutions and results are obtained with high speed super computers.

II LITERATURE SURVEY

Study on boundary layers and external flows have been categorized as flows influenced externally, flows with special geometric effects, compressible and high-speed flows, analysis and modeling techniques, unsteady flow effects, flows with film and interfacial effects and flows with special fluid types or property effects. External effects on boundary layers including swirl, oscillation, and unsteadiness imposed by forcing the flow, elevated external turbulence levels are included in literature below. Many papers deal with variations in geometry. Such geometric features include surface roughness elements, embedded micro channels or grooves, porous heat transfer walls(with suction or injection); baffles, solid and porous, vortex generators, turbulators, twisted tape, corrugations, fins of various shapes, cylinders of various shapes, spheres, rod bundles and rod bundle support structures are included in literature below.

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Hsieh and Huang [1] studied for laminar flow in horizontal tubes to observe the heat transfer and pressure drop with/without longitudinal inserts. They announced that improvement of rate of transfer of heat as compared to a conventional bare/uncovered tube at the same Reynolds number to be a factor of 16 at Re >10000, while a factor of friction increases to 4.5. So, Sharma [2] proposed new method to predict coefficient of heat transfer with insert of twisted tape in a tube in which properly modification of the temperature gradients with wall shear through correlation of coefficient of friction provides augmentation of transfer of heat from the tube wall. It is observed that the criterion for performance evaluation was about 1.322–1.395 times compared to plain tube. characteristics of heat transfer and flow horizontal circular tube for turbulent flow of insert of strip type (insertion of Crossed and longitudinal Strip). Factor of friction increases due to inclusion of inserts observed by Hsieh [3] typically between 1.12 and 1.54 from low Re (=27000) to high Re (=55500) with respect to bare tube. Analysis drop in pressures and transfer of heat in horizontal double pipes with insertion of twisted tape experimented by Naphon [4]. By using conical ring work as turburator which proved characteristics of factor of friction, efficiency of enhancement and Heat transfer in a circular tubes and experimental analysis of a twisted-tape swirl generator by Promvonge and Eiamsaard [5]. Ozceyhan and Siebel Gunes [6] performed experiment of transfer of heat and drop in pressure in a tube with insert of coiled wire which is placed separately from the tube wall and they observed the ratio of enhancement about 1.5 as compared to the plain tube. Dasmahapatra and Rao [7] experimentally investigated growth in rate of heat transfer to viscous non-Newtonian fluids in laminar flow using twisted tapes with full width interrupted under the constant wall temperature conditions. Al-Fahed and Chakroun [8] studied the effect of tube-tape clearance on rate of transfer of heat inside the horizontal isothermal tube under fully developed turbulent flow conditions. Investigation of experiment were carried out in a horizontal tube by introducing twisted tape in viscous flow by Manglik and Bergles [9]. Experimental observation obtained as with insert of snug-fit tape of different kind of twist ratios y=3.0, 4.5, and 6.0 for water and ehtylene glycol; in each case , the tape thickness was 0.4832 mm.

Experimental data were obtained for water and ehtylene glycol with snug-fit tape inserts of three different twist ratios, y=3.0, 4.5, and 6.0; the tape thickness in each case was 0.483 mm. In continuation of their research, an extended review of the application of twisted-tape inserts in tubular heat exchangers and their thermal-hydraulic performance was discussed by Manglik and Bergles [10]. Twisted tapes promote enhanced heat transfer by generating swirl or secondary flows, increasing the flow velocity due to the tube partitioning and blockage. Experiments were conducted on compound heat transfer enhancement in a tube fitted with serrated twisted tape in the Reynolds number range of 10000 to 57000 by Chang [11]. Heat transfer and pressure drop characteristics of laminar flow in rectangular and square plain ducts and ducts with twisted-tape inserts were experimentally investigated by Saha and Mallick [12]. Experimental investigation of heat transfer and friction factor characteristics of circular tube fitted with full-length helical screw element of different twist ratio, and increasing and decreasing order of twist ratio set have been studied with uniform heat flux by Sivashanmugam and Suresh [13].Ozceyhan and Siebel Gunes [14] conducted experiments with equilateral triangle cross sectioned coiled wire inserts and they found the maximum performance evaluation of about 1.38 as compared to the plain tube. They performed their experiments for various Reynolds numbers and the obtained experimental data were then compared with those previously reported in the literature. They reported higher performance of the helical twisted insert in comparison with the twisted tape insert. Modification of twisted tape was made by

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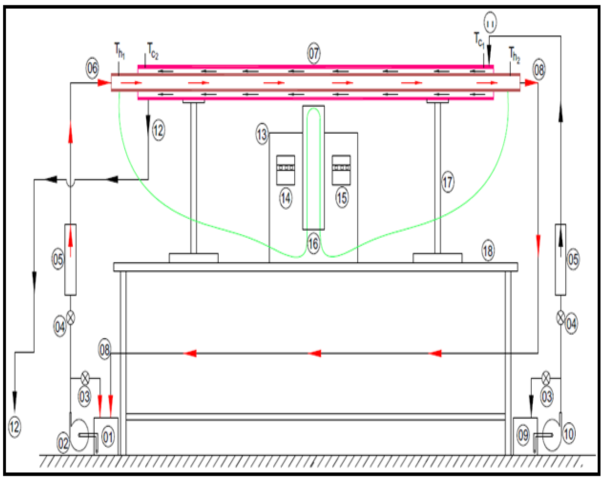
focusing on the increase of heat transfer rate rather than the reduction of friction loss by Rahimi [15]. The tapes in this group were designed to offer stronger swirl flow and better mixing than the typical one. However, the enhanced heat transfer by the use of the twisted tapes in the group was certainly accompanied by the rise of friction factor. In general, the performance factors of twisted tapes in this group were higher.

In continued research process, review of the insert of twisted tape resulted increase in the heat transfer rate.

III EXPERIMENTAL SETUP

Experimental Set up



01 Hot water tank	07 Test Section	13 Control pannel
02 Hot water pump	08 Hot water outlet	14 Temperature Indicator
03 By pass valve	09 Cold water tank	15 Temperature controller
04 Flow control valve	10 Cold water pump	16 Inverted U-tube manometer
05 Rotameter	11 Cold water inlet	17 Stand
06 Hot water inlet	12 Cold water outlet	18 Table

Schematic diagram of forced convection set up of experimentation

The set up of experiment and various measuring devices were shown in figure. It consisted of tube in tube type heat exchanger. The material of inside tube was of Copper and outside tube was of Mild Steel.For the measurement of temperature of inlet and outlet of cold and hot water the thermocouples are are used. Here four thermocouples were used; at the inlet and outlet of cold and hot water, two at each placed, respectively. Rotameters were used for measurement of the rate of flow at inlet of hot and cold water. Two centrifugal pumps were used to circulate the cold and hot water.

Two tanks were used for storing the hot water and cold water. Electric heater was attached to the hot water tank having capacity of 1500 watt. Inverted U-tube manometer was used to measure the change of pressure between inlet and outlet of test section of hot fluid the velocity of flow through inserted tube was measured by using current meter. The control valves and bypass valves were provided at inlet of both the rota meters.

Remarks are noted and results are calculated. The graphs are plotted permitting to the attained results.

IV EXPERIMENTATION

4.1 Modified Experimental procedure

The different mass flow rates and temperature variations are used along with changes in TR ratio.In the

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experiment, initially the cold water filled in water tank and maintained its temperature up to 80 ^{0}C by using water heater. Then, through the rota meter by opening the flow control valve with help of hot water pump and through the inner pipe of heat exchanger, this high tempertaure water was flowed. Now,low temperature water from the cold water tank was allowed to enter the heat exchanger through rota meter by flow control valve & cold water pump. Adjust the flow rate of cold water at 100 LPH and made it constant during whole experiment. The flow rate of hot water was modified at 300 LPH and kept it constant. When the steady state was reached, the thermal reading of cold and the hot watersat the inlet and outlet and decrease in pressure across the test tube was measured for plain tube without inserts. Thereafter repeat same procedure with wavy twisted tapes having twist ratio (TR=10.7, 8.5, 7.1) for various flow rates of hot water like 400, 500, 600, 700, 800, 850, 900 & 950 LPH. The figure shows the terminology of wavy twisted tape and figures shows the wavy tape inserts with twist ratio 10.7, 8.5, 7.1 respectively.

4.2 Experimental work carried out on inserts

The literature that has been discussed above deals with active as well as passive techniques used for heat transfer augmentation, but maximum researchers have used passive technique as it doesn't require any external agency for heat enhancement, hence it is advantageous over the active techniques thus giving ample of room for experimental studies.

By using twisted tape of different pitch sizes,it is observed that increase in factor of friction about 25%to 45 % ,which is need to decrease,so then they tried to make hollow pattern of twisted tape along with varying material types. The inserts used for the research are twisted corrugated tape with different thickness and pitches as there is no work done on such type of insert.

The work includes the following:

1. To obtain the factor of friction and Nusselt number for plain tube and for tube with insert of Wavy Corrugated twisted tape with different pitches
2. The graph are plotted for the plain tube and tube with copper twisted tape insert for the characteristics result obtained such as of Reynolds number, factor of friction, criteria of Performance evaluation and compared .
3. In same manner, characteristics shown above for insert of twisted tape made of copper are plotted on the graph and compared with the values for the plain smooth tube.
4. for the investigation purpose of effect variation with twist variations, another set of graphs are plotted for insert of copper.
5. The Fuzzy Logic system and CFD thermal analysis used to validate the result of experiment for heat transfer in double pipe heat exchanger equipped with the wavy corrugated twisted tape inserts**.**

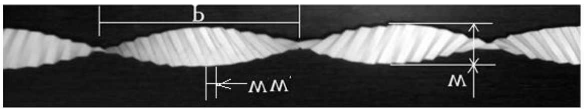

Fig.1 Terminologies of wavy twisted tape

Before going ahead,let us know,**what is TR?**

TR is twisted ratio.Its the number of twists per meter

Mathematically,

TR=Pitch/witdh(diameter)

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Here,we used TR of 10.7,8.5 and 7.1 of twisted tape used for experimentation.

4.3 Fabrication Procedure

1. Take copper sheet of desired width, length & thickness 14mm, 1000mm & 2 mm respectively.
2. The cut tapes are then given corrugations on die for required wave-widths, on both sides.
3. Twisted tape can be made with torsion machine, Lathe machine. I have made twisted tape on Lathe machine.
4. Hold one end of strip in chuck and hold other end in tail stock.
5. Rotate tail stock slowly (manually) to get desired pitch.

4.4 Specifications of inserts

1. Material = Copper
2. Width of twisted tape (W) = 14 mm
3. Twist ratio (TR) = 10.7, 8.5, 7.1.
4. Length of insert = 1000 mm
5. Thickness of inserts = 2 mm
6. Wave-width (WW) = 10 mm
7. Depth of wave = 10 mm

Before going ahead,let us know,**what is TR?**

TR is twisted ratio.Its the number of twists per meter

Mathematically,

TR=Pitch/witdh(diameter)

Here,we used Tr of 10.7,8.5 and 7.1.

The actual photographs of twisted tape for varying wave-widths but same twist ratio are shown below from Fig.2. (a) to 2. (c)

Fig.2(a) Wavy corrugated twisted tape with TR– 10.7

Fig.2.(b) Wavy corrugated twisted tape with TR – 8.5

Fig.2.(c) Wavy corrugated twisted tape with TR – 7.1

Instrumentation

Specifications of set up

The following is a list of all pieces of equipment and their specifications for the double-pipe heat exchanger.

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1. Double-Pipe Heat Exchanger

Inside Pipe Material: Copper

Outside Pipe Material: Mild steel

Length: 1.4 m

Inside Pipe Diameter: 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

Cold Water pass: 1

2. Valves

Ball Valves

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

3. Temperature Indicating Controller

Input: RTD-PT100 3 wire

Range: 0 to 200Deg C

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. C.

Channels: 4

Selection: Rotary Switch

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

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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. Rotameter

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

V. MATHEMATICAL ANALYSIS

5.1 Mathematical Model

Conclusively, developed interrelationship between the parameters, which represents a new correlation based on the experimental observation for predicting the pressure loss in coiled wire inserted tubes. The correlation is given as follows

$$Nu = 0.81 Pr^{\frac{1}{3}} Re^{.661} \left\{ \frac{\left(\rho_1/\rho_m\right)_{in}^{0.5} + \left(\rho_1/\rho_m\right)_{out}^{0.5}}{2} \right\}^{0.90} (X\ D/L)^{0.29} \quad [2]$$

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5.2 Sample Calculations

Hot Water flows through copper tube .The cold water flows through annular space the flows of fluids are in opposite direction and it is counter flow arrangement The heat transfers from hot water to cold water we will calculate heat given by hot water, heat absorbed by cold water and average heat transfer as follows –

1. Properties of Water
   a) Properties of hot water – calculated at mean bulk temperature

$$T_{bh} = \frac{T_{h1} + T_{h2}}{2}$$

   b) Properties of cold water

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

2. Heat given by hot water

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

3. Heat given by cold water

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

4. Average heat transfer

$$Q_{avg.} = \frac{Q_h + Q_C}{2}$$

5. Overall heat transfer coefficient

$$Q_{avg.} = U \times As \times \Delta Tm$$

a) Surface area of tube

$$A_s = \pi d_i L$$

b) Logarithmic mean temperature difference

$$T_m = \frac{(\Delta T_1 - \Delta T_2)}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

$$T_1 = T_{h1} - T_{c2}$$

$$T_2 = T_{h2} - T_{c1}$$

6. Nusselt Number of cold water flowing through the annular space.

$$Nu_o = 0.023(R_{eo})^{0.8} (P_r)^{0.3}$$

$$Re_o = \frac{\rho U_o D_h}{\mu}$$

$$D_h = D_i - d_o$$

Continuity equation –

$m_c =$ □ $A_o U_o$

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7. coefficient of heat transfer for cold water flowing through the annular space.

$$Nu_o = \frac{h_o D_h}{K}$$

$$h_o = \frac{Nu_o K}{D_h}$$

8. coefficient of Heat transfer for hot water flowing through the tube.

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_o}$$

$$h_i = \frac{1}{\left(\frac{1}{U} - \frac{1}{h_o}\right)}$$

9. Experimental Nusselt Number of hot water flowing through the tube.

$$Nu_i = \frac{h_i d_i}{K}$$

10. Theoretical Nusselt Number of hot water flowing through the tube (Dittus Boelter equation).

$$Nu_i = 0.023(R_{ei})^{0.8} (P_r)^{0.3}$$

11. Experimental Friction Factor

a) $\Delta P = \rho g h$

b) $\Delta P = \dfrac{f L \rho U_i^2}{2 d_i}$

$$f = \frac{2 g d_i h}{L U_i^2}$$

12. Theoretical Friction Factor (John Nikuradse equation)

$$f = 0.0055 \times \left(1 + \left(50 + \left(\frac{10^6}{\mathrm{Re}_i}\right)\right)^{0.33}\right)$$

The procedure for calculating the various parameters for with and without inserts is given below. The experimentation was done at constant heat supply; hence the calculations are done at constant heat supply. A sample observation table is shown below to understand the parameters need to be observed during experimentation.

5.3 Sample observation table

Sr. No	Cold water mass flow rate (LPH)	Cold water inlet temp. (^oC)	Cold water outlet temp. (^oC)	Hot water mass flow rate (LPH)	Hot water inlet temp. (^oC)	Hot water outlet temp. (^oC)	Manometer reading (diff.) (m)
	m_c	Tc_1	Tc_2	m_h	Th_1	Th_2	h_w
1							
2							
3							
4							
5							
6							
7							
8							
9							

As per the methodology discussed above the experimental calculations are to be carried out and the sample observation tables for with and without inserts are also used to carry out the result.

5.4 Validation of parameters:

(i.e Nu and Re number with mass flow rates)

For Nusselt number,we have Theoretical values and experimental values.

Nusselt Number of cold water :

$$Nu_o = 0.023(R_{eo})^{0.8} (P_r)^{0.3}$$
$$= 0.023(4589.98)^{0.8} (7)^{0.3}$$
$$= 35.05$$

Experimental Nusselt Number of hot water flowing through the tube.

$$Nu_i = \frac{h_i d_i}{K}$$
$$= \frac{4189.66 \times 0.0198}{0.6}$$
$$= 138.26$$

Theoretical Nusselt Number of hot water flowing through the tube equation)

$$Nu_i = 0.023(R_{ei})^{0.8} (P_r)^{0.3}$$
$$= 0.023(10713.21)^{0.8} (5.42)^{0.3}$$
$$= 63.95$$

Below,The experimental Nu number are provided.

Also,Reynolds Number with different mass flow rates are provided.

Plain tube:

Sr. No.	Mass flow rate (m) (kg/s)	Reynolds Number (Re)	Nusselt Number (Nu)	Friction factor (f)
1	0.0833	5356.60	39.46	0.03615
2	0.1112	7150.71	54.39	0.03687
3	0.1388	8925.53	64.55	0.03248
4	0.1667	10713.21	67.56	0.03123
5	0.1945	12507.32	78.18	0.03074
6	0.2223	14295.00	87.56	0.02936
7	0.2361	15182.41	94.98	0.02932
8	0.2500	16076.25	96.78	0.02843
9	0.2638	16963.66	94.75	0.02824

With twisted tape:

Sr. No.	Mass flow rate (m) (kg/s)	Reynolds Number (Re)	Experimental Nusselt Number (Nu)	Experimental Friction factor (f)
1	0.0833	5356.60	69.13	0.05349
2	0.1112	7150.71	97.27	0.05232
3	0.1388	8925.53	115.18	0.04822
4	0.1667	10713.21	138.26	0.03973
5	0.1945	12507.32	148.4	0.03771
6	0.2223	14295.00	153.1	0.03672
7	0.2361	15182.41	161.8	0.03582
8	0.2500	16076.25	165.4	0.03455
9	0.2638	16963.66	171.8	0.03432

VI. RESULTS AND CONCLUSION -DISCUSSIONS

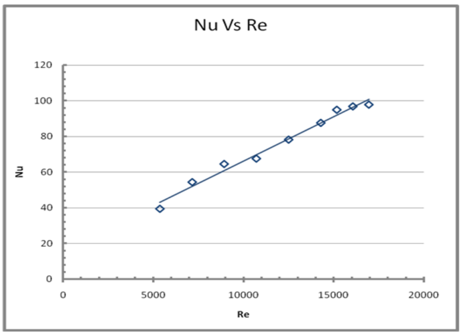
Introduction and Validation of the Experimental Programme :

The validation of the experimental programme is described followed by a detailed discussion on the various results obtained.

6.1 The purpose

The accuracy with which the friction factor and Nusselt number checked out for trials of experiment with current set up analysed by performing experiment with plain tube and with insert and results compared with standard experimental relationships and earlier work of research. To check the accuracy of the equipment.

1. By MATLAB FUZZY LOGIC ANALYSIS



Nu v/s Re number for plain tube

Fig.2 (a)

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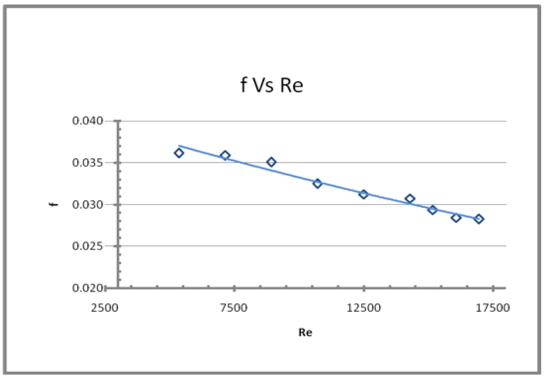


f v/s Re number plot for plain tube

Fig.2 (b)

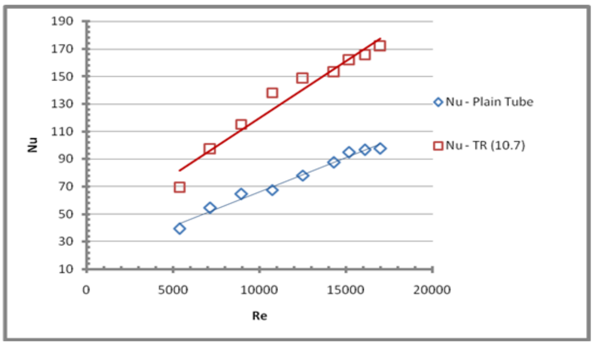
6.2 Friction factor results for smooth tube

Figure 2.b shows the relation between the factor of friction and Reynolds number for flow of turbulence in the tube without twisted tape insert, that is smooth tube flow conditions. The results agree with the range of Reynolds number is 5000 to17000. This proves that the experimental test rig is validated and in addition experimentation can be carried out.

The theoretical value of f can be calculated y

$$f = 0.0055 \times \left(1 + \left(50 + \left(\frac{10^6}{\mathrm{Re}_i}\right)\right)^{0.33}\right)$$

6.3 COMPARISION BETWEEN "PLAIN TUBE" & "WAVY CORRUGATED TWISTED TAPE INSERTS"



(a) Nu v/s Re number for plain tube and tube with wavy tape (TR – 10.7)

Fig 3.(a)

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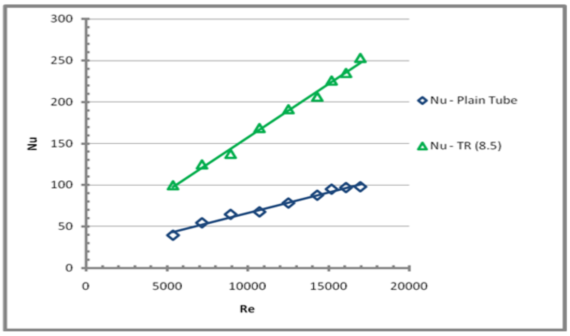

Nu v/s Re number for plain tube and tube with wavy tape (TR – 8.5)

Fig 3.(b)

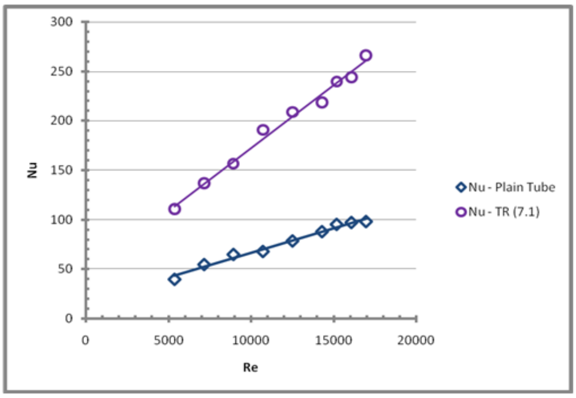

Figure 5.5.1 (c) Nu Vs Re for plain tube and tube with wavy tape (TR – 7.1)

Fig 3.(C)

6.4 Heat Transfer Analysis

Figures 3(a), 3(b) and 3(c) show the relation of Nusselt number and Reynolds number for plain wavy corrugated tape having twist with ratio of twist 10.7, 8.5, 7.1 respectively. In the increasing range of Reynolds number, there was a continuous improvement in Nusselt number with by using plain twisted tapes. The rise in Nusselt number with rise in Reynolds number and fall down off ratio of twist. At maximum Reynolds number of 17000 and for smallest twist ratio of 7.1, the Nusselt number was 3 times that of plain tube without insert.

6.5 Friction Factor Analysis

Figures 4(a), 4(b) and 4(c) show the relation between friction factor and Reynolds number, for plain wavy corrugated twisted tapes with twist ratio 10.7, 8.5 and 7.1 respectively.Figures are showing that the friction factor reduces with rise in Reynolds number and rise in twist ratio. At maximum Re of 17000 for smallest twist ratio of 7.1, the friction factor increased nearly 14 times to that of plain tube without insert because of the obstruction caused by the insert.

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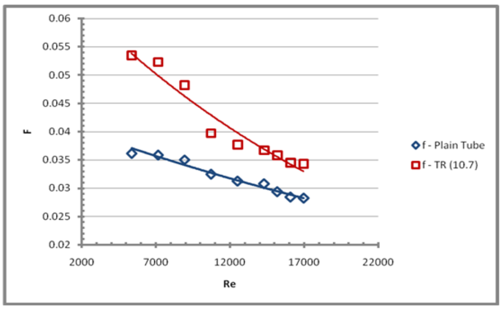
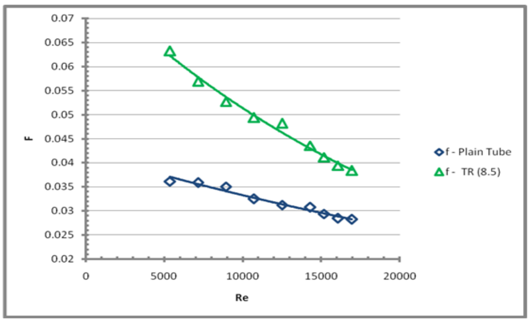
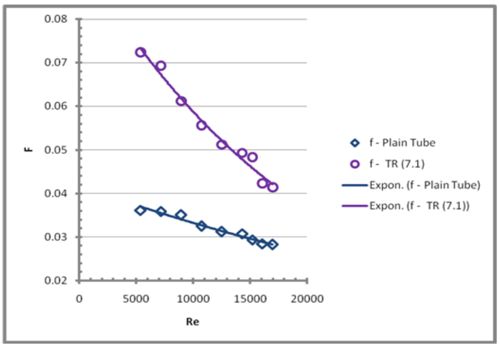


f v/s Re for plain tube and tube with wavy tape (TR – 10.7)



(b) f v/s Re for plain tube and tube with wavy tape (TR – 8.5)



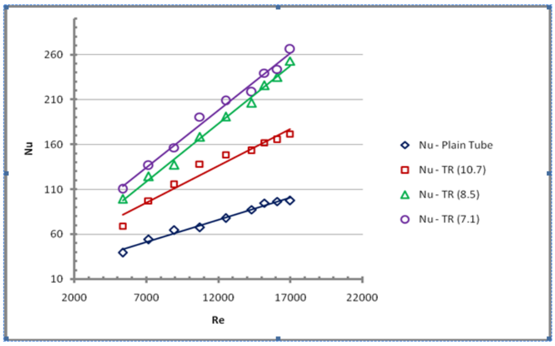
(c) f v/s Re for plain tube and tube with wavy tape (TR – 7.1)

Fig.4(a)(b)and(c)

6.6 COMPARISON OF "PLAIN TUBE" AND "TUBES WITH VARIOUS WAVY CORRUGATED TWISTED TAPES"

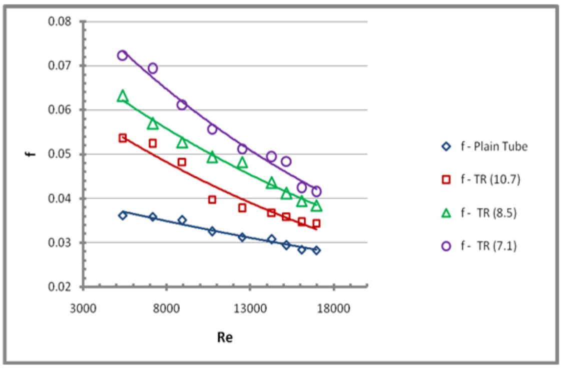
Figure 5.(a) shows the plot between Nussult number and Reynolds number for plain tube and tube with various inserts, the Figure concludes that the Nusselt number is function of Reynolds number. Nusselt number rise with rise in Reynolds number. Hence, rate of convective heat transfer is more with higher Reynolds number.

Further, it can be concluded that, twisted tapes with highter twist (with lesser twist ratio) give increased Nusselt number for a particular Reynolds number. Heat transfer rate is better with twisted tapes of lower twist ratio.



Nu Vs Re number for plain tube and tube with TR =10.7, 8.5, 7.1

Fig.5(a)



f Vs Re number for plain tube and tube with TR =10.7, 8.5, 7.1

Fig 5.(b)

Figure 5 b shows ,plot drawn between factor of friction and Renolds number with varying twisted ratio,one can eaily observe the change friction factor with varying twisted ratio.wirth increase in friction, Reynolds number also increases.

2.CFD Analysis

Why CFD analysis?

For obtaining the results of thermal analysis,i.e.the temperature variation takes place at different point along the fluid flow line and changes in temperature of hot and cold fluid at various points. This analysis provides graphical representation as well as accuracy in thermal analysis.

Objective: Calculate temperature drop for counter flow double pipe heat exchanger through experimental & CFD analysis

1. Double Pipe HE without twisted tape:

Geometry :

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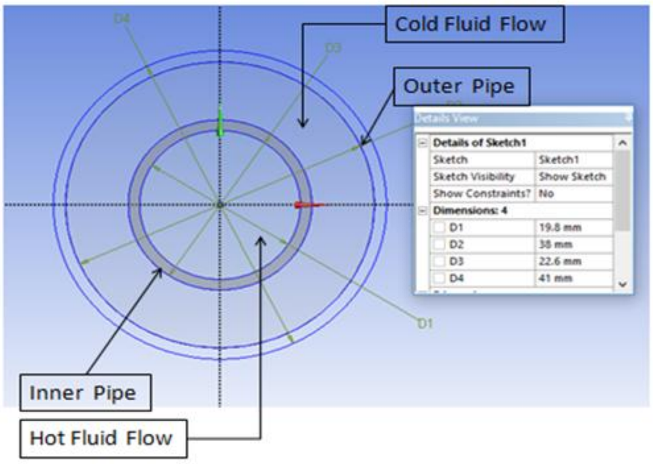
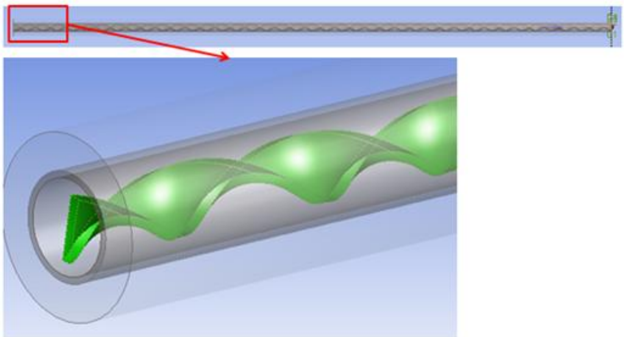


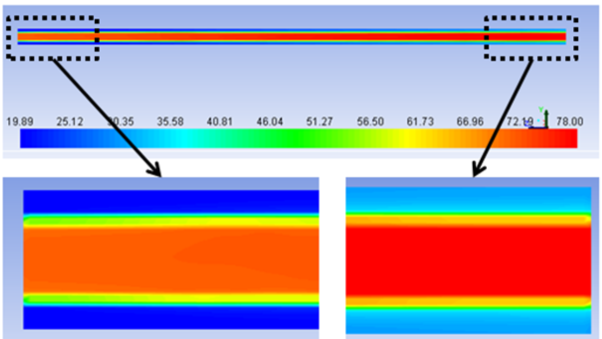
Double pipe HE without twisted tape geometry



twisted tape insert

Thermal Analysis :

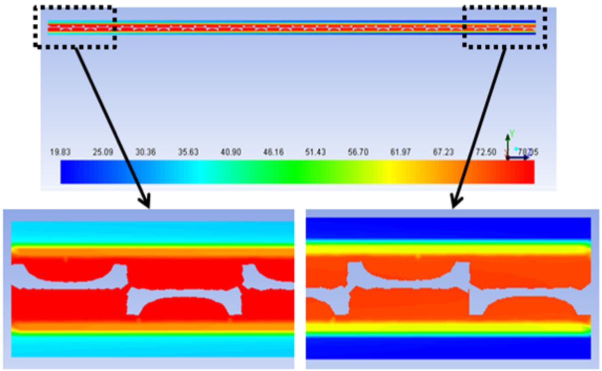
Temperature Plot(Case-1) at Center Plane:



Temperature Plot(Case-1) at Center Plane plot

Above graph shows the color indication of the temperature variation. Blue color is at low temperature and it turns to red as it increases the temperature.Its without twisted tape,thermal plot obtained from CFD.

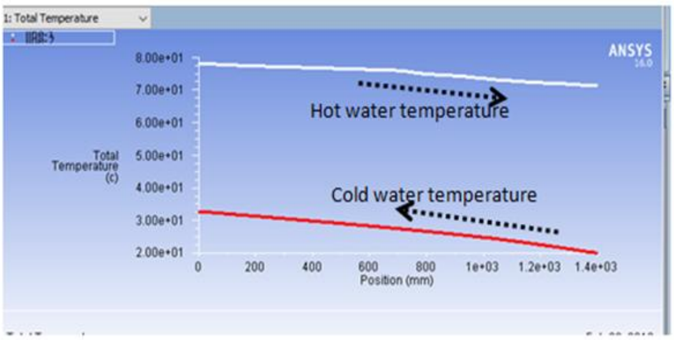
Temperature Plot(Case-1) at Center Plane:



Thermal analysis plot

Above Graph shows the temperature distribution plot when twisted tape inserted.Color code shows the temperature variation at center plane in CFD.

Temprature distribution of cold & hot temprature



Temprature distribution of cold & hot temprature plot

Above graph shows that,hot water transferred the heat to cold water.The temperature variation plotted against the position from left to right.Hot and cold water temperature variation at different region,obtained in graph of temperature variation by CFD thermal analysis.

By using insert of twisted tape ,the rate of heat transfer increases more than without insert.

Nomenclatures

A_s Lateral surface area of tube (m^2)

Cp *Air* Specific heat , (J/kg K)

Di Inside diameter of the inner tube

f Friction factor

h Coefficient of Heat transfer (W/m^2K)

w Width of wavy tape insert,(mm)

k Thermal conductivity, (W/mK)

L Length of inner tube, (m)

$\dot{m}$ Mass flow rate of water, (Kg/sec)

Nu Nusselt number (experimental) for plain tube

Pr Prandtl number

ΔP Drop in pressure across the test section, (Pa)

Q Total heat transferred to water (W)

Re Reynolds number, ($\rho\ V\ D/\mu$)

V Mean velocity of water

Th1 hot water temperature at the inlet (°K)

Th2 hot water temperature at the outlet (°K)

Tc1 cold water Temperature at the inlet (°K)

Tc2 cold water Temperature at the outlet (°K)

T_b Bulk temperature, (°K)

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