HEAT TRANSFER ENHANCEMENT IN A TUBE USING PLAIN FIN & TWISTED TAPE INSERTS

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Abstract - *The heat exchangers are vastly used in almost every heat transfer applications. To make the heat exchangers less oversized its efficiency needed to be increased. In my experimental investigation effort has been made to increase the heat transfer rate from my heat exchanger in order to make the compact heat exchangers. For the secondary flow or swirling in fluid a twisted tape had been used with changing the twist ratio 2, 3 and 5. The flow velocities were varied from 0.5 to 2.5 l/min at a gap of 0.5. The result predicted that when the twisted tape is inserted it gives very high heat transfer rates if compared to a normal one. The annular cylindrical fins have been used on the outer periphery of the cylindrical tube. The increasing value of Reynolds number shows the increasing value of heat transfer rates.*

***Key Words*: Heat Exchangers, Heat Transfer Rate, Twisted Tape, Flow Velocities, Cylindrical Fins, etc.**

1. INTRODUCTION

The present era is the era of the energy and each country in the world is attempting to produce as more energy as possible. Heat exchangers are of great use in the power plants whether they are thermal power plants, hydraulic power plants, solar energy power plant or any other power plant. The main use of heat exchangers is in the process intensification, chemical industry, refrigerators, air conditioning equipment etc. The heat exchangers are used for exchanging of heat between two fluids. Generally the heat exchangers are overdesigned by 70-80% of its actual capacity of which about 50% is only attributed to fouling. So from the present point of view the heat exchangers must be made highly effective so that its overall size can be reduced.

Twisted tape inserts are of great use in present day power plants because it enhances the heat flux by swirling.

1.1 TWISTED TAPE INSERTS

The twisted tape inserts are being widely used in heat transfer applications due to their easy manufacturing, very high performance, low cost and effectiveness. If the thermal energy is conserved more economical handling of heat transfer will be possible. The improved ways in heat exchanger has enabled compact heat exchangers and the same heat flux at even low velocities. This also results in a reduced pressure drop.

1.2 CIRCULAR FINS

In line circular fins in circular cross section is the most used fin configuration used for cooling purpose in turbine blades. These fin increases the heat transfer by two ways one by fin wetted area and second and the passage of the flowing fluid downstream the flow. The main cause behind its vast use is its ease of manufacturing yet it is not clear by any study is this the most effective fin type.

1.3 LITERATURE SURVEY

S.K Saha, S. Dhal, and A.Dutta, [1] done an experimental investigation on a circular tube in which evenly spaced twisted-tape inserts was fitted, and they studied the Heat transfer performance and pressure drop characteristics. They kept the flow laminar and flowed it swirling. A highly viscous fluid with average prandtl number was taken. The twisted tapes used in the experimental study was evenly spaced and had a single twist and was connected by a thin circular rod. During the study they varied the twisted tape width and tube rod diameter one by one. In the heating test section they used an electrical heater for this purpose and kept the constant heat flux condition in two types namely the axial constant heat flux and circumferential constant heat flux. By studying the results they found that punching the tapes on their place rather than connecting them through a circular rod improves the heat transfer performance greatly. They studied the effect of twist ratio, Reynolds number, prandtl number and space width and studied by varying them accordingly. If the tape width is shortened that results in diminished heat transfer performance. There is no effect of phase angle more than zero but it results in the manufacturing complexity and higher cost. They found that the straight flow through plain tube shows a greater difference in heated friction factor and isothermal friction factor for the periodic swirl flow than found in this experimental investigation.

P.G. Vicente et al [2] done an experimental study on the Corrugated tubes in which water and ethylene glycol has been used as test fluids within the range 2000 to ninety thousands of Re and Prandtl number from 2.5 to 100 so that we can obtain their heat transfer and isothermal friction. The real advantage which are made by corrugated tubes have been evaluated by the calculation of one of the performance evaluation criteria commonly used in the enhanced heat transfer literature.

Alberto Garcı, Pedro G. Vicente, Antonio Viedma [3] done an experimental investigation on Helical-wire-coils which was fitted inside a round tube for characterizing thermal and hydraulic behavior in laminar flow, transition flow and turbulent flow in which water and water–propylene glycol mixtures was used as test fluids within the range 80 to 90,000 of Reynolds number and Prandtl number from 2.8 to 150. That results, heat transfer rate has been increased up to 200% if smooth tube heat exchanger fitted with wire coils have been taken under the transition state and pumping power kept constant.

Smith Eiamsa-ard, Chinaruk Thianpong, Pongjet Promvonge [4] done an experimental study on Double pipe heat exchanger which was fitted with regularly spaced twisted tape elements, cold and hot water was used as test fluid in shell side and tube side to obtain heat transfer and friction factor characteristic. The result shows if there will increase in the free space ratio(S) there was improvement in heat transfer coefficient as well as friction factor.

Chang et al [5] done an experimental study on a Tube in which broken twisted tape(BTT) having twist ratio one, one and half, two, two and half or infinite have been inserted for the measurement of the longitudinal heat transfer distribution and pressure drop coefficients in which Re having range of 1000–40,000. By use of the correlation between empirical heat transfer and pressure drop they calculated the local Nusselt number and mean Faning friction factor for the tube having BTT insert are made to help the industrial applications.

P. Promvonge, S. Eiamsa-ard, [6] done an experimental investigation on a circular tube using wire in the form of a coil as a turbulator and the cross section of wire was square. In uniform heat flux, turbulent flow characteristic kept Re in the range of 5000 to 25,000 that results there was increase in heat transfer and loss in friction over smooth wall tube. There was increase in Nusselt number when they increased the value of Re and the decrements of pitch for both the cases circular coils as well as square wire coils.

Pongjet Promvonge, [7] done an experimental study on a circular tube in which wire coil and twisted tape both were inserted and air was used as test fluid and uniform laminar flow was takes place. When both of these twisted tape as well as wire coil were used in combined ways having smaller ratio of twist and coil pitch gives higher heat transfer rate as compared to those with larger ratio of twist and coil pitch having same conditions.

P. Bharadwaj, A.D. Khondge, et al [8] done an experimental study on Spirally grooved(keeping clockwise with respect to direction of flow) tube with twisted tape insert in order to obtain "pressure drop and heat transfer characteristics of flow of water" in a 75-start ranging Re in laminar to fully turbulent flow. That results the thermal and hydraulic characteristics depends on the direction of twist that is either clockwise direction as well as counter clockwise direction.

2. EXPERIMENTAL SET-UP

Fig -1: SET-UP

2.1 PIPE

The cylindrical pipe has been made of copper. Then it is fabricated with circular fins on its periphery.

Fig -2: Pipe with fins

2.1.1 PIPE SPECIFICATINOS-

The pipe specification is given has follows

Table -1: The pipe specification

Diameter of pipe	1.5"
Length of pipe	35"
Conductivity of copper	5.96×10^{07} w/mk
Pipe material	Copper

2.1.2 FIN SPECIFICATION-

Fig -3: Fin

The fin specifications is as follows

Table -2: the fin specifications

Fin material	Aluminium
Fin internal dia	1.5”
Fin external dia	2.5”
Conductivity	5.96×10^{07} w/mk

2.2 TWISTED TAPE-

A twisted tape has been used. It is used by varying the twist ratio, less value of twist ratio causes more swirl in flow and more hear transfer. The tape length is kept less below the internal diameter of the tube.

Fig -4: **Twisted tape**

2.2.1 TWISTED TAPE SPECIFICATION-

Table -3: Twisted tape specification

Length of twisted tape	35”
Material	Tin
Twist ratio	2, 3, 5
Dia of tape	1.4”

2.3 ACCESSORIES

2.3.1 DIGITAL THERMOMETER-

The digital thermometer used in this experiment had a temperature limit between -50˚ c to 110˚ c. the digital thermometer is non toxic unlike the mercury thermometer. It was able to measure the dry bulb temperature, wet bulb temperature and dew point temperature. The digital thermometer used is very reliable and robust. The error limit of the thermometer was +.1˚ c to - .15˚ c.

Fig -5: Digital thermometer

2.3.2 ROTAMETER-

A rotameter has been used in my experiment for the measurement of flow rate. The range of the rotameter was from .5 l/s to 20 l/s. the error value of the rotameter is +- .1%. so it gives nearly accurate readings.

Fig -6: **Rotameter**

3. CALCULATION

3.1 Formulae used in calculation

For laminar without twisted tape: Hausen’s equation

$$\mathrm{Nu} = 3.66 + \frac{[0.06668\mathrm{RePr}(d/L)]}{[1 + .04[\mathrm{RePr}(d/L)]^{\left(\frac{2}{3}\right)}}$$

With twisted tape: Manglic and bergele’s equation

$$\mathrm{Nu} = 0.106(\mathrm{Sw})^{.767}(\mathrm{Pr})^{1/3}$$

Where,

$$\mathrm{Sw} = \frac{\mathrm{Re}}{Y^{0.5}}$$

Y =twist ratio

The following correlations has been used in calculating friction factor.

f = 16/Re (without twisted tape)

For twisted plate

$f = (15.76/Re)[(\pi-\delta/d)/(\pi- 4\delta/d)(1+10^{-6}S_w^{2.55})^{(1/6)}]$

δ =thikness of twisted tape =1 mm

3.2 Heat transfer rate, Reynolds number, Nusselt number and friction factor without twisted tape

The following reading has been taken without inserting the twisted tape into the pipe. The flow is varied from .5 to 2.5 l/s at difference of each 0.5. Accordingly the heat transfer rate, Reynolds number, Nusselt number and friction factor have been calculated. Following are values of the water inlet and outlet when the tube is fabricated with fins but twisted tape has not been inserted and has been inserted in the tube.

Table -4: Heat transfer rate and friction factor without twisted tape

T_i (°C)	T_o (°C)	$\dot{V}$ (L/s)	$\dot{m}$ (kg/s)	Q (watt)	Re	Nu	f
40	37.4	0.5	0.0083	90.2204	297.52	7.235	0.053
	37.8	1.0	0.0166	152.653	595.05	9.297	0.027
	38.2	1.5	0.025	187.397	892.59	10.53	0.0179
	38.5	2.0	0.0333	208.164	1190.11	12.08	0.0134
	38.7	2.5	0.0416	225.51	1487.64	13.13	0.0107

3.3 Heat transfer rate, Reynolds number, Nusselt number and friction factor with twisted tape (TR 5)

Table -5: Heat transfer rate and friction factor with twisted tape (TR 5)

T_i (°C)	T_o (°C)	$\dot{V}$ (L/s)	$\dot{m}$ (kg/s)	Q (watt)	Re	Nu	f
40	37.2	0.5	0.0083	97.143	297.52	9.166	0.0352
	37.7	1.0	0.0156	159.592	595.05	15.598	0.0198
	38.0	1.5	0.0250	208.164	892.59	21.288	0.01491
	38.3	2.0	0.0333	235.920	1190.11	26.540	0.01242
	38.6	2.5	0.0416	242.858	1487.64	31.486	0.01084

3.4 Heat transfer rate, Reynolds number, Nusselt number and friction factor with twisted tape (TR 3)

Table -6: Heat transfer rate and friction factor with twisted tape

T_i (°C)	T_o (°C)	$\dot{V}$ (L/s)	$\dot{m}$ (kg/s)	Q (watt)	Re	Nu	f
40	37.1	0.5	0.0083	100.612	297.52	11.83	0.0362
	37.6	1.0	0.0166	166.53	595.05	20.12	0.0213
	37.9	1.5	0.025	218.572	892.59	27.48	0.0163
	38.2	2.0	0.0333	249.797	1190.11	34.26	0.01373
	38.5	2.5	0.0416	260.200	1487.64	40.64	0.01203

(TR 3)

3.5 Heat transfer rate, Reynolds number, Nusselt number and friction factor with twisted tape (TR 2)

Table -7: Heat transfer rate and friction factor with twisted tape (TR 3)

T_i (°C)	T_o (°C)	$\dot{V}$ (L/s)	$\dot{m}$ (kg/s)	Q (watt)	Re	Nu	f
40	37.4	0.5	0.0083	104.082	297.52	14.5	0.0375
	37.8	1.0	0.0166	173.47	595.05	24.65	0.0228
	38.2	1.5	0.025	228.98	892.59	33.65	0.0177
	38.5	2.0	0.0333	263.674	1190.11	41.96	0.0149
	38.7	2.5	0.0416	294.899	1487.64	49.77	0.0131

4. RESULT

4.1 GRAPH OF REYNOLDS NUMBER VS NUSSELT NUMBER

It is obvious from the graph that as the mass flow rate or Reynolds number is increasing the value of Nusselt number is also increasing. The Nusselt number represents the heat flux. So with increasing value of Nusselt number, heat flux is increasing.

When keeping the twist ratio 5, the nusselt number values are not much increased. Because not much swirl is produced. The variation of Reynolds number with nusselt number keeping the twist ratio 3 are much higher if compared to the values of nusselt number without twisted tape and a little bit high with use of twisted tape used with a twist ratio of 5. For twist ratio 2 though the nusselt number is increasing with increasing Reynolds number, yet the values of the nusselt number is very high if compared with tube without twisted tape and little high than the values keeping the twist ratio 5 and 3.

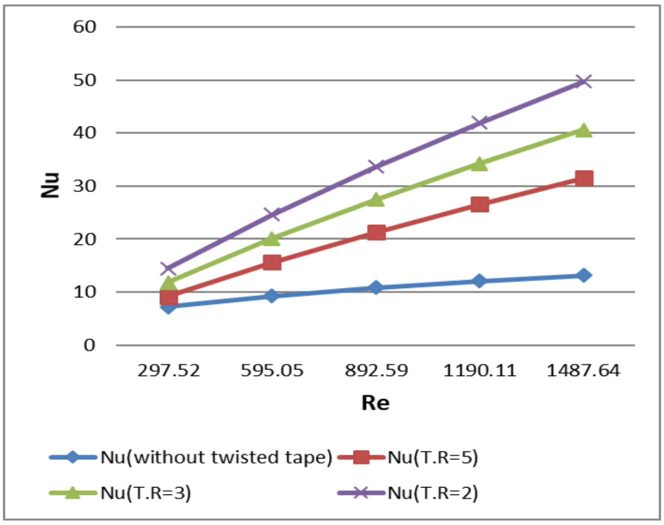

Chart -1: Graph Of Reynolds Number Vs Nusselt Number

The graphical representation between the Reynolds numbers with nusselt number is shown in the graph. The nusselt number is increased as the Reynolds number increased. When twisted tape inserted, the nusselt number increased sharply. The high value of nusselt number is achieved when the twist ratio is kept less. The highest value of nusselt number is with twist ratio of 2.

4.2 GRAPH OF REYNOLDS NUMBER VS FRICTION FACTOR

A graphical representation between Reynolds number and friction has been shown in figure. As the Reynolds number is in laminar region and its values are low, the value of friction factor is very high. As the Reynolds number increases further the value of friction factor decrease at a very high rate yet the flow is in laminar region. When the value of the Reynolds number increases more, yet the friction factor decease but the rate of decrement is less as compared to earlier one. All the flow is kept in laminar range.

When keeping the twist ratio 5, the nusselt number values are not much increased. Because not much swirl is produced. The variation of Reynolds number with nusselt number keeping the twist ratio 3 are much higher if compared to the values of nusselt number without twisted tape and a little bit high with use of twisted tape used with a twist ratio of 5. For twist ratio 2 the nusselt number is increasing with increasing Reynolds number, yet the values of the nusselt number is very high if compared with tube without twisted tape and little high than the values keeping the twist ratio 5 and 3.

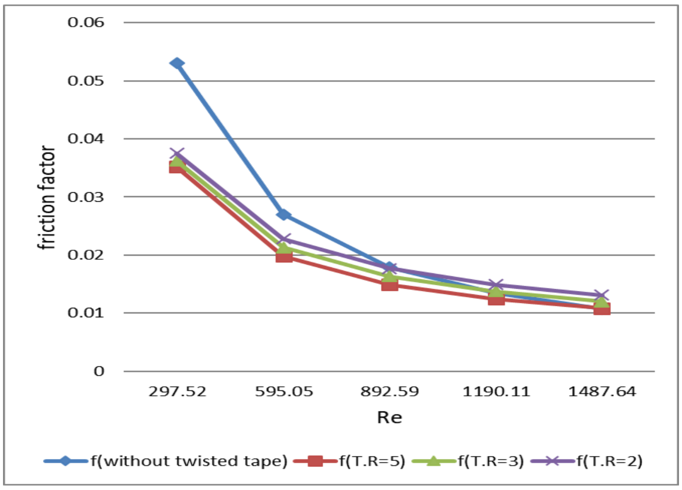

Chart -2: Graph of Reynolds Number Vs Friction Factor

The variation of friction factor with Reynolds number with has been shown in figure. The friction factor is decreased as the twisted tape is inserted in the test section. The high value of friction factor is achieved with high twist ratio and in my experiment with 2.

5. CONCLUSIONS

The results has been shown in graphs .the results clearly shows that

1. Heat transfer rate steadily increases with the increasing mass flow rate or Reynolds number.
2. As the twisted tape is inserted inside the tube, heat transfer rate increases continuously at a very high rate.
3. The lower twist ratio values results in higher heat transfer rates as the figure of heat transfer rate with twist ratio 5 is less than that of with twist ratio 2.
4. As the twisted tape is inserted the friction factor value decreases than a normal pipe values.
5. Lower twist ratio results in higher friction factor values.

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