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Experimental study of passive heat transfer enhancement technique with the help of various factor by using twisted tape insert inside a tube in tube heat exchanger

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Abstract— Enhancing heat transfer surface are used in many engineering function such as refrigeration , air conditioning, chemical reactor and heat exchanger systems, hence many techniques has been investigated on improvement of heat transfer rate and reduce the size and cost of the concerning equipment particularly in heat exchangers. These techniques are categorized as active and passive technique .The active technique compulsory external power while the passive technique does not require any external power. The passive technique are expensive compared with the active technique since the swirl flow add manufacturing method is simple and can be simply engaged in an offered heat exchanger .One of the most significant technique used are passive heat transfer technique. These techniques when adopted in heat exchanger provide that the usually thermal performance enhanced notably.

Heat transfer is very attractive field for functional, economic and environmental basis; it is nearly associated to each part of human lives. In this project study about the types of heat transfer enhancement technique and how it works accurately. In these report largely focused on the passive technique. This technique usually uses surface or geometrical modifications to the flow channel by insert, incorporating or additional devices. For example, inserts extra part, swirl flow devices, rough surfaces, extended surfaces, additives for fluids and coiled tubes.

The probable conclusion of my work is to find the effects of the Typical Twisted tapes (TT) on the heat transfer improvement and friction factor behaviors in turbulent flow regimes ($5000 \le Re \le 17{,}100$) are described. The Typical twisted tape, twisted tapes with dissimilar twist ratio (y/w=2.5, 3 and 3.5) are tested using the water as the working fluid.

***Keywords— Thermal performance,* Twisted tapes, Twist ratio, swirl flow, Tabulators**

I. INTRODUCTION

This enhancement technique used to make the improvisation in the heat transfer mode. To achieve this there are few modifications in the working area is made. Due to this enhancement of heat transfer rate the system able to sustain the large load of generating heat. Also the difference between the temperatures is also kept within range. The task of improvement in the Heat transfer can be also attained by influencing surface of fluid, electrostatic fields or mechanical stirrers. These latter methods are often considered as energetic or active methods since they consume the external power during its working. Though these energetic methods have received attention in the research literature their practical applications have been very limited. In this section therefore I focus on some specific example of passive techniques. i.e those based on modification of the heat transfer surface a more complete and extended discussion of the full spectrum of enhancement techniques can be found in reference manglik. Increasing the

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turbulence of fluid flow results in the more surface area and better mixing of it and hence it leads to increase in heat transfer. These modified results generally result in an increase in pressure drop along with the increase in heat transfer. However, with suitable performance assessment and accompanying optimization, results towards significant heat transfer improvement relative to a smooth (untreated) heat transfer surface of the same nominal (base) heat transfer area can be achieved for a variety of applications. The increasing attractiveness of diff. Heat transfer enhancement techniques is very much important in industry because of heat exchanger offer the opportunity
1) To reduce the heat transfer surface area required for a given application and thus reduces the heat exchanger size and cost.
2) Increase the heat duty of the exchanger and
3) Permit closer approach temperature.

Classification of Augmentation Techniques:
They are broadly classified into three different categories:
1. Passive Techniques
2. Active Techniques
3. Compound Techniques.

Passive Techniques: The Passive technique does not need any straight forward input of external power supply; instead of it they utilize power from the working system. Due to this it cause for a growth in the fluid pressure drop. They generally use surface or geometrical modifications to the flow channel by inherent inserts. By agitating the fluid flow, system raises the heat transfer rate. But this phenomenon is exceptional for extended surfaces. The augmentation of Heat transfer by these methods can be achieved by using;

(i) **Treated Surfaces**: Treated surfaces having a fine scale alteration to their coating which may be continuous or discontinuous. This type of surfaces is primarily used for boiling and condensing duties.

(ii) **Rough surfaces**: The roughness of surface disturbs the equally or evenly distributed surface. In particular applications this roughness proves helpful feature. In this project this factor improves the disturbances in the stream field adjutant to boundary wall. But surface area for heat transfer is not improved.

(iii) **Extended surfaces**: Extended surfaces like fins are the effective for the transmission of the heat. In recent trends the developed extended areas are to be apt for the enhancing the heat transmission. The principle behind this is nothing but the disturbance created by this fins.

(iv)**Displaced enhancement devices**: Displaced enhancement devices are the supporting features and these are used to enhance the carried heat transport. The principle behind this is the displaced and vibrating stream of fluid from both hot and cold surfaces of the channel tube.

(v) **Swirl flow devices**: These devices create and intersect the whirling fluid stream. This whirling stream is of secondary types cycling fluid in a duct channel. There are mainly three devices namely cored screws or helical strips and twisting tapes.

(vi) **Coiled tubes**: The coils or tubes consisting coils are improve the conciseness of the exchangers. The heat transfer is enhancing by using it and the cause for it is the generation of vortices and the secondary type's fluid.

(vii) **Surface tension devices**: Surface Tension devices are nothing but the surfaces having elongated hollow slots. The result of these slots is to enhance the flowing speed of fluid.

(viii) **Additives for liquids**: Additives are the particles generally miscible in the working fluids. It may be also solid state particles or gaseous fluids. These additives push down or dissipate the surface tension of the fluid in boiling system.

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(ix) **Additives for gases**: Also in the gaseous fluid the additives proves effective. The solid or liquid particles are the additives for this gaseous fluid.

Important Definitions:

In this section a few important terms commonly used in heat transfer augmentation work are defined.

- **Thermo-hydraulic performance: -** When significant increment in heat transfer coefficient along with the less friction factor is achieved for specific Reynolds number then the performance of insert is considered as good. This performance can be utilized to express the comparisons of various inserts like twisted tape, wire coil, etc., under a particular fluid flow condition.
- **Nusselt number:-**The Nusselt number is a technique to quantify the convective heat transfer mode eventually occurred at the surface. Nusselt number is defined as h di /k, where h is the convective heat transfer coefficient, d is the diameter of the tube and the thermal conductivity is ‘K’.
- **Prandtl Number:-** The ratio of the molecular momentum diffusivity (υ) to the heat molecular diffusivity (α) is known as the Prandtl number.
- **Pitch:-** The distance between the two points appeared in the unique plane and measured along the parallel direction of the twisting tape is known as the Pitch of that Tape.
- **Twist ratio, y/w:-**The twist ratio is defined as the ratio of pitch to inside diameter of the tubey/w = H/di, where H is the twist pitch length and d is the inside diameter of the tube.

Figure 1 Typical Twisted Tube

II Experimental setup

Convective heat transfer through pipe is studied by inserting surfaces roughness parameter such as twisted tapes, internal fins etc. it is seen from literature review that twisted tape is of prime importance which affects the heat transfer through wall of pipe for carrying out the experimental work on the twisted tapes, test section, expt. Setup used is as shown in below.

Figure 2- Actual Experimental Setup

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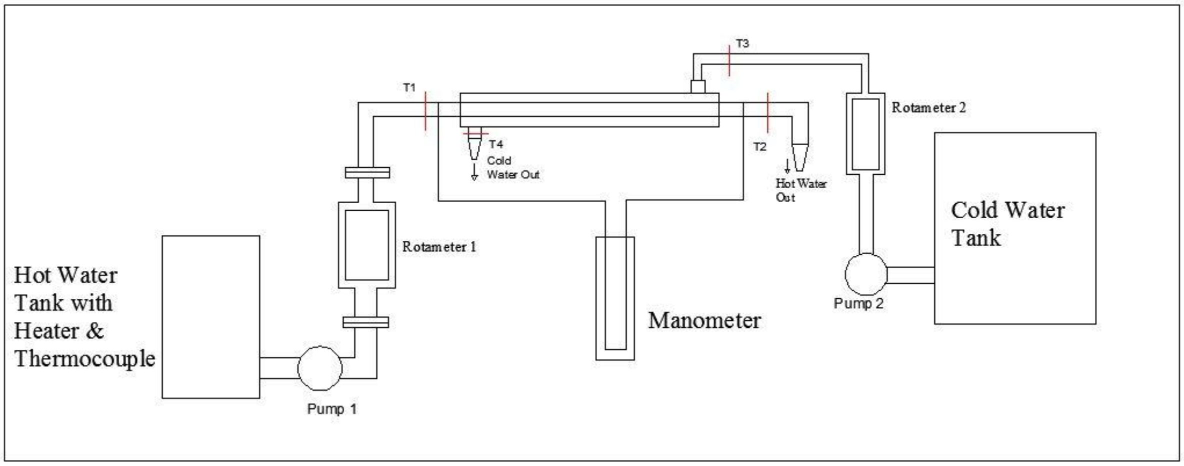

Figure 3 -Schematic Diagram of Experimental Setup

1. Tube in Tube Heat Exchanger:-

Development of the test section is the main task of dissertation work. Here Copper tube is used at the inner side of test section having 1500 mm length and 25.4mm inside dia. At the outer side G.I pipe is used having 1500mm length and 52 mm inner dia. & at the one end of outer pipe opening for cold water and at the opposite end outlet of cold water is provided.

Figure 4 - Tubes in Tube Heat Exchanger with Insulation

2. Pumps:-
Two centrifugal pumps are used in the experimental setup for circulating hot water from inner side of tube and other pump is used for circulating cold water at annulus side. Pumps have 0.5 HP capacities. The other specifications are as follow.

- 110 Volt, 60 Hz, 2.75 Amp
- Single Phase Motor ,1/2 HP Motor, 3400 RPM, Flow: 650 (GPH)
- Pump Inlet: 1" NPT, Pump Outlet: 1" NPT, 4-1/2" W x 5-1/2" H x 10" L
- Max Total Head: 110 Feet, Max Suction Lift: 20 Feet
- Manufactures: LAKSHMI PUMPS.

3 Rotameter:-
It is basically a Variable Area Meter, exactly reverse of Orifice Plate. The glass tube of rotameter has convex shape. Due to this the annular area between the float and surface of tube is produces. The achieved position of the float in the passage of tube is according to the flow rate of the stream flow i.e. it denotes the flow rate of the fluid. Two rotameters are taken one for to measure cold water flow rate and other for hot water flow measurement the Range of rotameters are as 150 LPH to 1500 LPH(both).The used rotameters are manufactured by CVG TECHANOCRAFTS INDIA, MUMBAI

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Figure 5 – Rotameter

4 Manometer:-

One manometer is used. It is U-tube manometer. The mercury is filled with the manometer as a manometric fluid. It is used to measure the pressure drop. Across inner tube of heat exchanger (test section).Flexible pipe is used to connect the limbs of manometer.

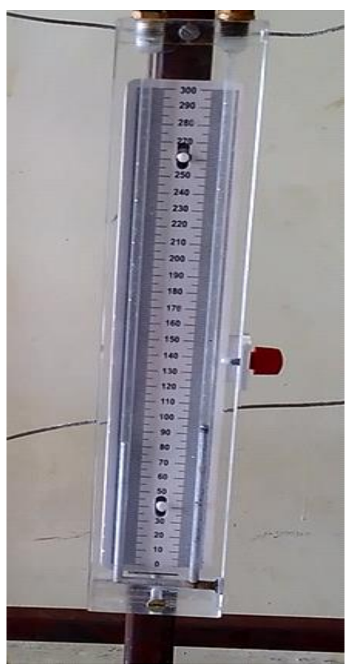

Figure 6 – Manometer

5 PT-100 RTD Sensors and Temperature Indicator:-

PT 100 RTD sensors are used to temperature measurements. Four numbers of RTD-sensors used to measure inlet and outlet hot & cold water temperature. These are supplied by Sensography Company.

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Figure 7 - Temperature Indicator

6 Control Panel:
It is used for controlling temperature of hot water by using heater and temperature indicator circuit.

III Specifications of twisted tapes

Sr. No.	Width (mm)	Pitch (mm)	Length (mm)	Material
1	10	25	1500	M.S.
2	12	36	1500	M.S.
3	14	49	1500	M.S.

IV Experimental Procedure

a) To heat the water heater is put on 48°C in a constant temperature water tank of capacity 120litres. The tank is provided with a centrifugal pump & a bypass valve for recirculation of hot water to the tank & to the experimental setup.
b) To pass hot water at 48°C through the tube side of heat exchanger at desired flow rate.
c) To pass the cold water through the annulus side of heat exchanger in counter current direction at a 1050 LPH..
d) To record the water inlet and outlet temperature for both hot water & cold water and surface temperatures only after temperature of both the fluids attains a constant value.
e) To record the manometer reading.
f) To repeat the procedure for different hot water flow rates ranging from 240LPH TO 744 LPH and at temperature (48°C)

Observation table:
Following are the observation table for Nusselt number and Reynold number for plain tube and twisted tape having twist ratio 3.5.

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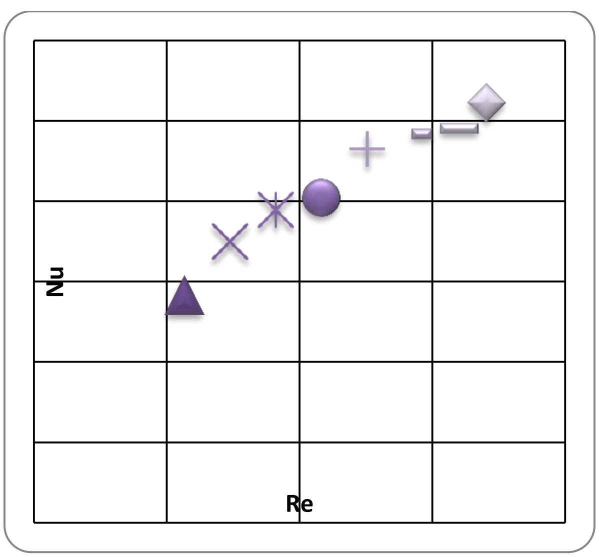
Sr.No	Qc LPH	Qh LPH	mh (kg/sec)	Vh (kg/sec)	q c watt	q h watt	Q average watt	h inner w m2/k	Nu	Re
1	1050	240	0.066	0.13157	970.299	1019.265	994.782	711.229	28.2887	5655.95
2	1050	312	0.086	0.17104	1091.21	1219.465	1155.338	996.553	31.672	7343.31
3	1050	384	0.106	0.21051	1333.7	1411.262	1372.482	979.7	38.9487	9087.13
4	1050	456	0.125	0.2499	1453.45	1578.999	1517.224	1074.91	42.719	10817.6
5	1050	528	0.145	0.2895	1576.73	1698.384	1637.558	1159.88	46.0904	12537.6
6	1050	600	0.165	0.3289	1698.02	1803.142	1750.582	1235.36	49.0743	14267.4
7	1050	672	0.185	0.3684	1576.19	1774.901	1675.547	1166.44	46.3219	16020.7
8	1050	744	0.196	0.39142	1455.45	1640.381	1547.915	1063.26	42.2111	17064

Table 1 for Plain Tube

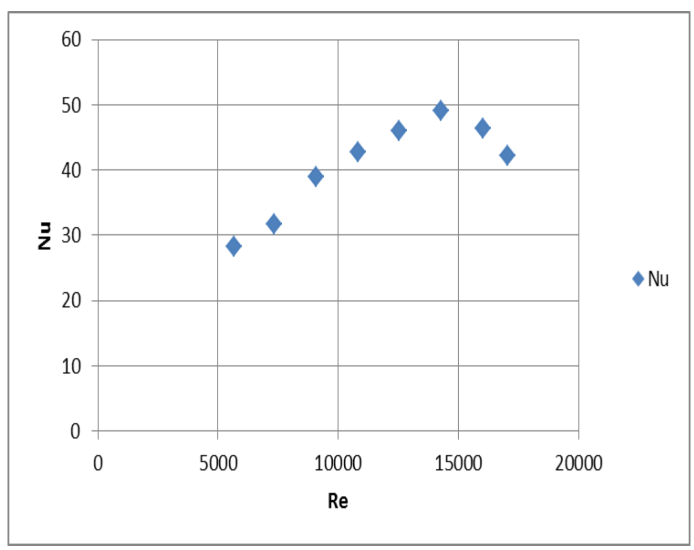
Sr.No	Qc LPH	Qh LPH	mh (kg/sec)	Vh (kg/sec)	q c watt	q h watt	Q average watt	h inner w m2/k	Nu	Re
1	1050	240	0.0659	0.1315	970.298	1019.265	994.7815	711.229	28.2887	5653.03
2	1050	312	0.0857	0.171	1212.87	1253.866	1233.37	881.206	35.044	7363.13
3	1050	384	0.1055	0.2105	1334.16	1411.263	1382.712	980.524	38.9815	9086.3
4	1050	456	0.1253	0.2499	1455.15	1623.75	1539.599	1091.04	40.5063	10795.9
5	1050	528	0.1451	0.2895	1576.04	1759.03	1653.533	1167.02	46.5928	12527.2
6	1050	600	0.1649	0.3289	1698.02	1792.279	1745.151	1219.32	48.437	14267.4
7	1050	672	0.1847	0.3684	1698.02	1853.07	1775.546	1336.42	49.1086	16007.3
8	1050	744	0.2045	0.3914	1819.31	1966.237	1892.774	1317.17	52.3078	17020.8

Table 2 for Typical Twisted Tape having (y/w=3.5)

Following graph are for Nu vs Re for plain tube and twisted tape with twist ratio 3.5 respectively



Graph 1



Graph 2

Observation table:

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For pressure drop and friction factor- following table shows observation table for pressure drop and friction factor for plain tube and twisted tape of 3.5 twist ratio similarly graph

Sr.No	Qh LPH	mh (kg/sec)	Δh (m)	ΔP(N/m2)	F	Re
1	240	0.0659	0.009	53.41	0.0264	5653.0305
2	312	0.0857	0.014	82.06	0.024	7363.1325
3	384	0.1055	0.02	122.21	0.0236	9086.3047
4	456	0.1253	0.028	169.32	0.0232	10795.8861
5	528	0.1451	0.037	223.31	0.0228	12527.2348
6	600	0.1649	0.047	285.69	0.0226	14267.3974
7	672	0.1847	0.058	348.9	0.022	16007.3048
8	744	0.2045	0.065	390.262	0.0218	17020.7517

Table 3 for Plain tube

Sr.No	Qh LPH	mh (kg/sec)	Δh (m)	ΔP(N/m2)	f	Re
1	240	0.06598	0.008	59.898	0.0296	5633.392
2	312	0.0857	0.014	100.536	0.0294	7340.803
3	384	0.1055	0.02	150.19	0.029	9056.552
4	456	0.1253	0.029	210.21	0.0288	10760.545
5	528	0.1451	0.038	276.18	0.0282	12579.03
6	600	0.1649	0.045	353.93	0.028	14302.82
7	672	0.1846	0.06	442.46	0.0279	17523.39
8	744	0.1962	0.068	490.47	0.0274	17039.84

Table 4. For Typical Twisted Tape having (y/w=3.5)

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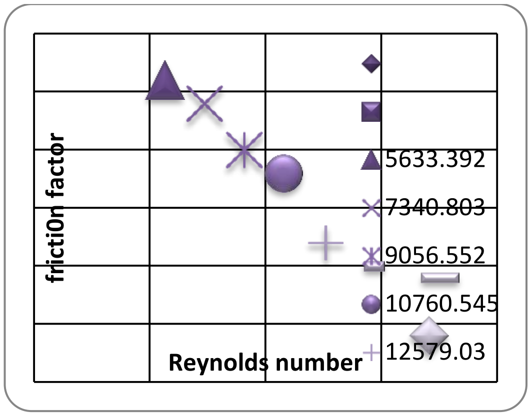
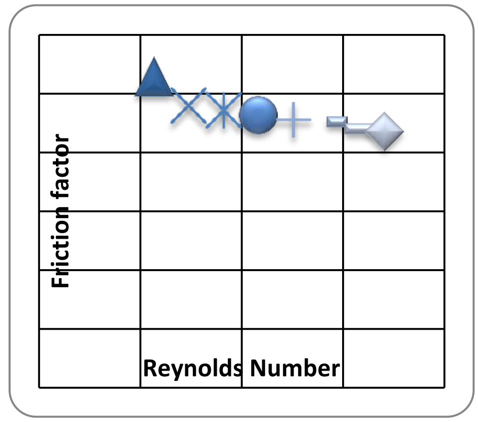


Graph 3 Plain tube



Gaph 4 twist ratio 3.5

V. Conclusion

The effects of the Typical Twisted tapes (TT) on the heat transfer enhancement and friction factor behaviors in turbulent flow regimes (5000 ≤ Re ≤ 17,100) are described. The Typical twisted tape, twisted tapes with different twist ratio (y/w=2.5, 3 and 3.5) are tested using the water as the working fluid. The conclusions are drawn as follows:

1. With decrease in twist ratio, Nusselt Number increases but at the same time pressure drop also increases.

2. For higher twist ratio, show greater Nusselt Number, heat transfer coefficient and friction factor than the lower twist ratio, because of higher degree of turbulence generated.

3. The use of the inserts in the tubes are not only improve the heat transfer rate but they also raises the pressure drop. As the pressure drop and the pumping power is directly proportional hence this results in the increment of the pumping cost. Hence according to the need the above stated insertions may be utilized for augmentation of heat transfer.

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