Heat transfer enhancement in concentric tube heat exchanger with tangential injection and twisted tape inserts

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Abstract.Heat exchanger has many engineering applications such as air conditioning, chemical reactor and refrigeration systems, etc. The performance of this industries mainly depends on the performance of heat exchanger. So, to increase the performance of heat exchanger many techniques have been investigated on enhancement of heat transfer rate and decrease the size and cost of the heat exchangers. In most of applications and key areas like power plants, process & chemical industries uses surface enhancement methods. Present work mainly emphasis on the both passive and active methods of heat transfer enhancement. In this work, to enhance the heat transfer rate with the help of twisted tape insert in passive method in which aluminium twisted tapes are used. In the active method fluid is injected in annulus space to generate turbulence through tangential injectors. There are six injectors are used to generate turbulence. Water is used as a working fluid in both types of heat exchanger. From the experiment it shows that, as Reynolds number increases heat transfer coefficient also increases

1. Introduction

Heat exchanger is a used for transferring heat from one source to another source having temperature difference. It follows the principle, wherever there is difference in temperature between two source there is flow of energy. So, the heat energy flows from high temperature to low temperature. The main application of heat exchanger are refrigeration and air conditioning, power production, chemical reaction control, Solar reactors, gas processing plants, and sewage treatment plant. The everyday example of heat exchanger is automobile radiator in cars which takes heat from engine and liberate it to environment through the radiator fins. A pipe in pipe heat exchanger, is one of the simplest type of heat exchanger with two pipe concentric to each other. One fluid flows through the inner pipe while the other fluid flows through the annulus space between the pipes, the inner surface of pipe gives the area for heat exchange as it is in contact with both the fluid have difference in temperature. It can be used as parallel flow and counter flow. Heat transfer rate is the main concern as laminar flow gives lesser heat transfer rate. Heat transfer rate can be advanced by introducing an obstacle or providing disturbance in fluid flow, which can be done by introducing the twisted tape/turbulator insert in a tube. Heat transfer rate improvement techniques can be classified as follows[5]:

1. Active Technique
2. Passive Technique
3. Compound Technique.

Passive technique uses surface or geometrical modifications in the flow geometry by introducing inserts or additional devices. It provide higher heat transfer coefficients by disturbing the flow behavior which leads to increase in pressure drop. Inserts, treated surface, rough surface, extended surface, additive to fluid acts as a passive technique of heat enhancement.[5]

Active technique are more complex compared to passive technique as additional component is added which needs proper design and this method also require external power source to provide desire flow modification and improvement in the rate of heat transfer. It has very limited application as it require external power in many practical applications. The active technique includes mechanical aid, surface vibration, jet impingement, injection, electrostatic field.[5]

Compound technique is one which has the merger of both active and passive method with the intention of improving the performance of the system.

Various work have been done by many researchers on heat exchanger from which **Akpinar et al.** [1] Experimentally studied that the heat transfer rate increases in the swirl generator insert into a pipe in a pipe heat exchanger in which the highest heat transfer rate was reported when operated in counterflow and with a swirl insert component having 5 holes of 3 mm diameter each. It was noted that there was 130% more heat transfer rate in swirl insert compared with pipe without insert, the hole diameter provides turbulence in the flow. Counter flow gives 5-10 % more heat transfer than parallel flow. They concluded that the rate of heat transfer increases with increase in number of holes with smaller diameters, even more enhancement was noticed when arranged in zigzag pattern. **Baig et al.** [2] experimentally studied the passive technique in pipe in pipe heat exchanger. They used plain twisted tape, tape with holes and baffles to design the heat enhancement. The outer pipe is insulated to avoid heat transfer to environment geyser is used to heat the water to specific temperature. Writer used three variation of twisted tape simple, tape with holes and tape with baffles. The following can be concluded from the experiment that, there was increase in heat transfer by 8.9% by using twisted tape insert. While the tape with holes and baffles had less heat transfer compared to full twisted tape. **Abdullah et al.** [3] examined the heat transfer enhancement in a double tube he used the convergent and divergent profile and also used the twisted tape insert to increase the heat transfer. He used stainless steel for the tubes and aluminum for the twisted tape he used three tapes with different twist ratio, the working fluid used was hot and cold water. He concluded from his experiment that the heat transfer rate is dependent on the Nusselt number, the Nusselt number for convergent and divergent tube was about 15% to 45% greater than plain tube and the Nusselt number for the combination of concentric convergent and divergent profile and twisted tape was 52% to 280% greater than the plain heat exchanger. It was also found that there was increase in Nusselt number with increase in Reynolds number for twisted ration 3, as well as increase in Nusselt number with decrease in twist ratio as fluid contact time and turbulence is more for lower twist ratio. With decreased twisted ratio, the friction factor with twisted insert increases. For those of twisted ratio 6 and 9, the friction for twist ration 3 is 28% and 50% respectively. **Chang et al.** [4] experimentally tested the effect of heat transfer by tangential injection, taking outer diameter pipe of 88.9mm and 2.5m long made of acrylic with six nozzles of diameter 22.23 are used on the tangential site. It can be concluded that the wall's axial velocity creates maximum heat flux, middle section turbulence gives high heat transfer rate. With the increase in turbulence at entrance its turbulence decreases with the axial distance.

From the above literature it is observed that whenever vortex flow is generated the maximum heat transfer enhancement will be achieved. The two methods were studied one with twisted tape insert and another tangential injection. The twisted tapes gives higher heat transfer rate but with this method the pressure drop also increases which is a passive heat transfer technique. The working fluid used in above literature is limited to air as working fluid in tangential injection method, in some cases the water is used. The heat transfer rate is strongly dependent on Reynolds number and Nusselt number. Also depends on the number of tangential entries, twist ratio etc.

2. Problem Statement

Heat transfer enhancement in double pipe heat exchanger by using multiple tangential entry along length and twisted tape insert with water as working fluid.

3. Objective

a) To develop experimental setup.
b) To make the equipment compact and using minimum pumping power.
c) To analyze and study the data collected.
d) Investigation of heat transfer coefficient.

e) To study the effect of tangential entry on heat transfer enhancement.
f) To study the effect of twisted tape on heat transfer enhancement.

4. Experimental Setup

In this experiment there are three setups used to calculate heat transfer rate at different conditions. Simple concentric pipes are used to calculate the heat transfer rate. In second setup concentric pipe with tangential injectors are used and in the third set twisted tape insert is used in the inner pipe to form the turbulent flow and to calculate the heat transfer rate.

The following parameters are used in the experimental setup.

Inner pipe (hot water)	Inner diameter-16.5 mm Material-aluminum	Outer diameter-21.5 mm
Outer pipe (cold water)	Inner diameter-42 mm Material- UPVC	Outer diameter-48.5 mm
No. of nozzles-6	Diameter of nozzle-4.5 mm	
Twisted tape	Width- 12 mm Pitch- 80 mm Length-1000 mm Material- Aluminium Length of heat exchanger-1000 mm	Twist ratio: 6.66

Flow rate- 300 LPH to 600 LPH

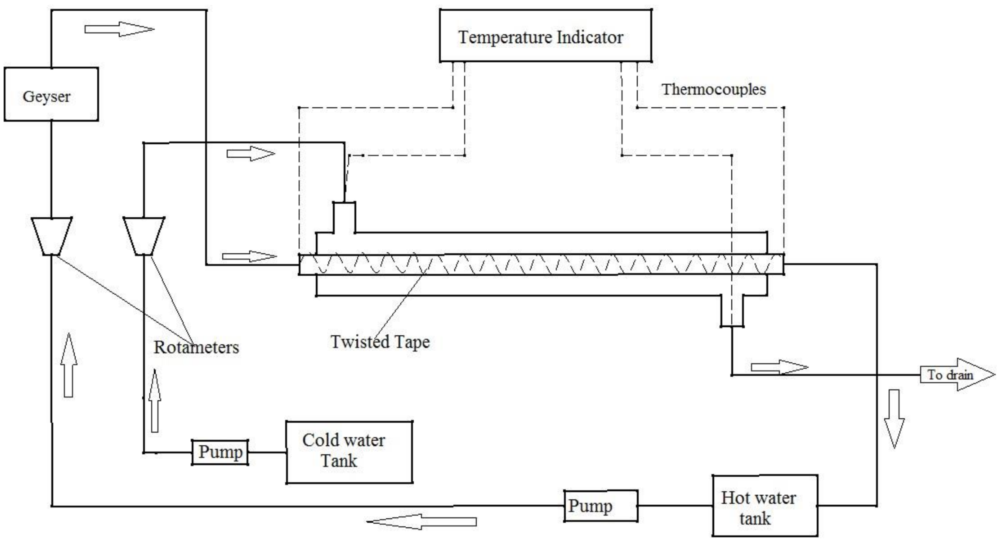

Figure 1:Schematic Layout of heat exchanger with twisted tape insert.

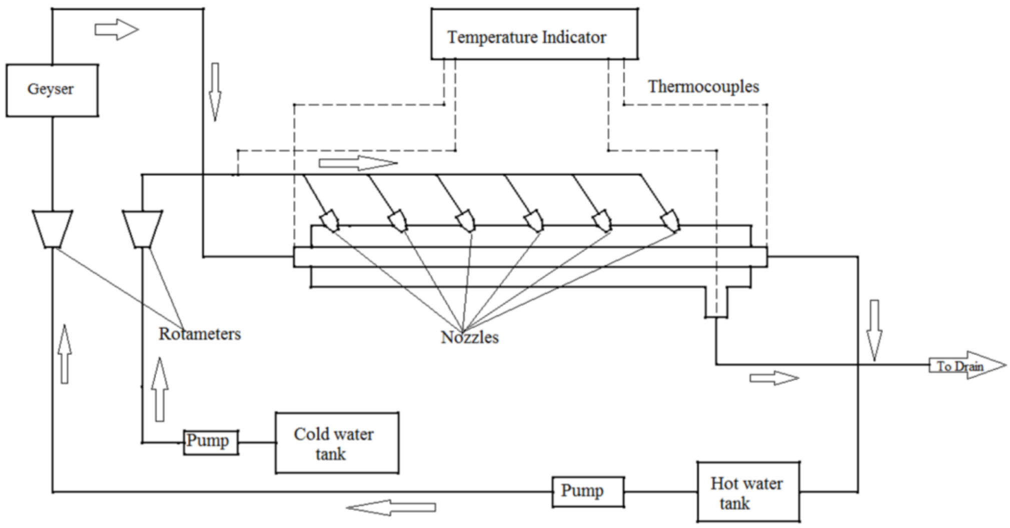

Figure 2: Schematic layout of heat exchanger with tangential entry.

Figure 3:Working setup of concentric pipe heat exchanger with twisted tape insert.

Figure 4:Working setup of concentric pipe heat exchanger with tangential injectors.

The Twisted tape is inserted at the inner pipe of the heat exchanger and the flow rate for hot fluid is kept constant while the cold fluid flow rate is varied. Later the flow rate of cold fluid is kept constant and hot fluid flow rate is varied. The setup is changed to twisted entry and the above process continues.

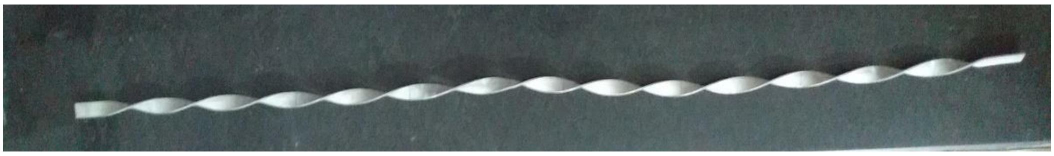

Figure 5: Aluminum twisted tape.

5. Mathematical Equations

Heat Transfer Rate

$$Q_h = m_h \times C_{ph} \times (T_{hi} - T_{ho}) \quad (1)$$

$$Q_c = m_c \times C_{pc} \times (T_{co} - T_{ci}) \quad (2)$$

The average heat transfer rate for hot and cold fluid

$$Q_{avg} = \frac{Q_h - Q_c}{2} \quad (3)$$

Log mean temperature difference

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \quad (4)$$

Where,

$\Delta T_1 = T_{hi} - T_{ci}$ $\quad \Delta T_2 = T_{ho} - T_{co}$

Overall Heat Transfer Coefficient

$$U_O = \frac{Q_{avg}}{A \times \Delta T_m} \quad (5)$$

Reynold Number

$$Re = \frac{\rho \times V \times D_h}{\mu} \quad (6)$$

Nusselt Number

$$Nu = 0 \cdot 012[Re^{0.87} - 280] \times Pr^{0.4}\left[1 + \left(\frac{D}{L}\right)^{\frac{2}{3}}\right] \quad (7)$$

Heat transfer coefficient (theoretical)

$$h = \frac{Nu \times k}{D} \quad (8)$$

Heat transfer coefficient(Experimental).It can be calculated from Wilson Plot

$$\frac{1}{h_{expt}} = \frac{1}{U_o} \pm b \quad (9)$$

6. Results and Discussion

For the range of Reynolds number from 2300 to 4700, heat transfer coefficient results are obtained for simple pipe, tangential injection tube and tube with twisted tape for parallel and counter flow .The results of the test are plotted for simple pipe, tangential injection tube and tube with twisted tape for both the flow models.

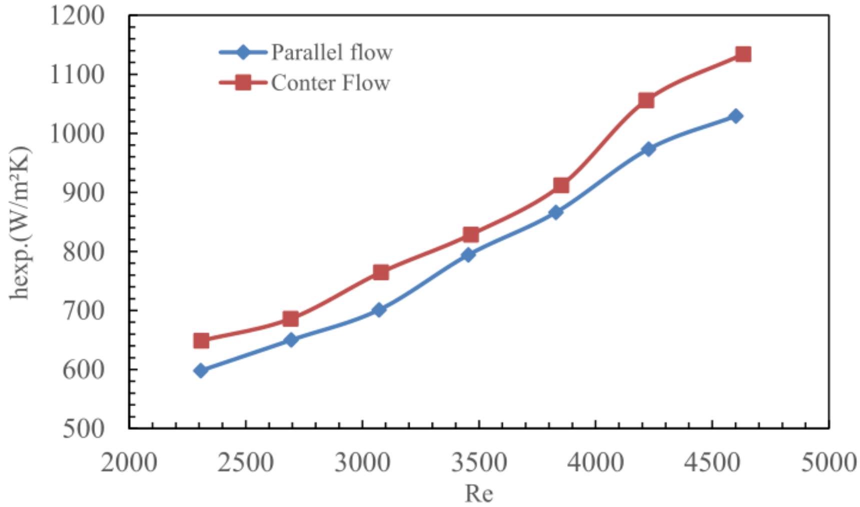

Figure 6: Comparison of heat transfer coefficient in parallel and counter flow configuration for different Reynolds number for simple pipe in pipe tube.

Above graph shows the comparison of heat transfer coefficient for different Reynolds number in simple pipe for parallel and counter flow configuration. It is observed that, heat transfer coefficient increases as the Reynolds number increases. For plain tube counter flow dominates over the parallel flow configuration by 7.333 %.

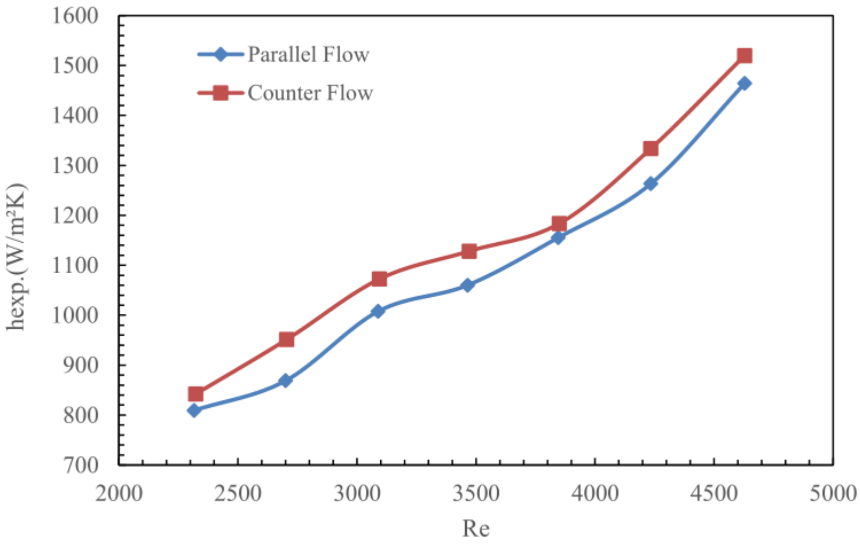

Figure 7: Comparison of heat transfer coefficient for different Reynolds number for tangential injection in parallel and counter flow configuration.

Comparison of heat transfer coefficient for different Reynolds number for simple pipe with tangential injection at annulus space for parallel and counter flow configuration. It is observed that, heat transfer coefficient increases with the increase in Reynolds number. In counter flow configuration heat transfer coefficient is more than that of parallel flow configuration. For plain tube with tangential injection, counter flow dominates over the parallel flow configuration by 5.47%.

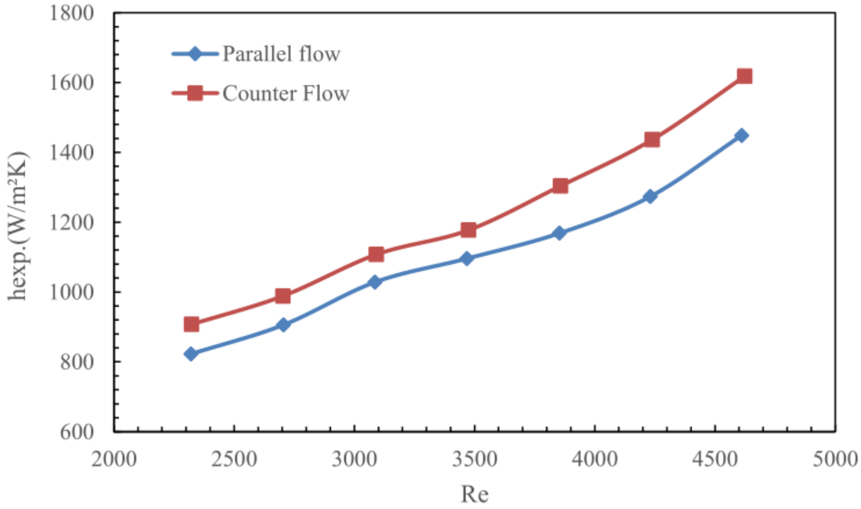

Figure 8: Comparison of heat transfer coefficient for different Reynolds number in simple pipe with twisted tape insert for parallel and counter flow configuration.

Comparison of heat transfer coefficient for different Reynolds number in simple pipe with twisted tape insert for parallel and counter flow configuration. It is observed that, heat transfer coefficient increases with increase in Reynolds number. In counter flow model the coefficient of heat transfer is more than that of parallel flow model. In simple pipe with twisted tape insert, counter flow dominates over the parallel flow configuration by 10.09 %.

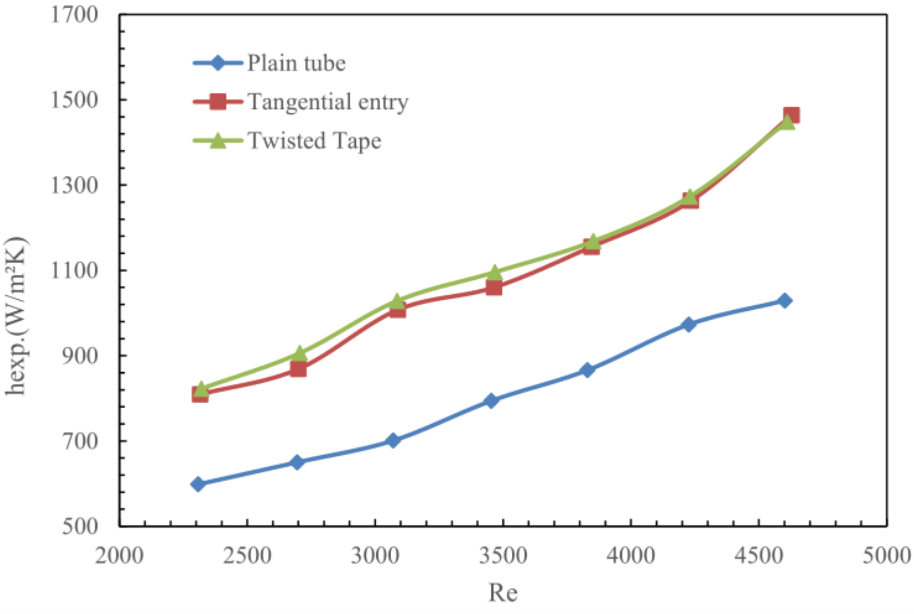

Figure 9: Comparison of heat transfer coefficient for different Reynolds number in plain tube, tangential injection and twisted tape insert for parallel flow configuration.

Comparison of heat transfer coefficient for different Reynolds number in simple pipe in pipe, tangential injection and twisted tape insert for parallel flow configuration. It is observed that, heat transfer rate increases with increase in Reynolds number. For parallel flow configuration, tangential injection gives 35.95% higher coefficient of heat transfer over a simple tube heat exchanger and twisted tape gives38.30%higher coefficient of heat transfer over a simple tube heat exchanger. Also it is observed that, tube with twisted tape insert dominates over tangential injection in parallel flow configuration with 1.75 %.

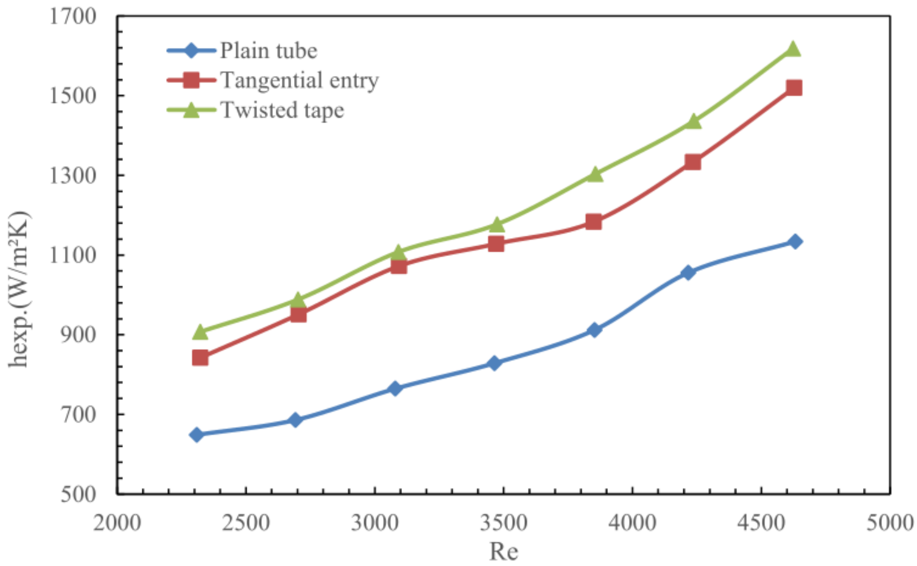

Figure 10: Comparison of heat transfer coefficient for different Reynolds number in plain tube, tangential injection and twisted tape insert for counter flow configuration.

Comparison of heat transfer coefficient for different Reynolds number in plain tube, tangential injection and twisted tape insert for counter flow configuration. It is observed that, coefficient of heat transfer increases with increase in Reynolds number. For counter flow configuration, tangential injection gives 33.58 % and twisted tape insert gives 41.80 % higher heat transfer coefficient over simple pipe in pipe heat exchanger. Also twisted tape insert dominates over the tangential injection in counter flow configuration by 6.22%.

7. Conclusion

The heat transfer levels are produced in this work by placing tangential injectors along the length and inserting twisted tape into the inner pipe of pipe in pipe heat exchanger. Experiment shows that, the coefficient of heat transfer with increase in Reynolds number. Twisted tape insert in counter flow configuration gives highest heat transfer coefficient i.e. 52.20% more than simple pipe in pipe heat exchanger in parallel flow configuration and 41.80 % more than plain tube heat exchanger in counter flow configuration. Also, simple pipe with twisted tape insert dominates over simple pipe with tangential injection by 1.75% in parallel flow configuration and 6.22 % in counter flow configuration. For parallel flow configuration, tangential injection gives 35.95 % and for counter flow configuration, it gives 33.58 % higher heat transfer coefficient over plain tube heat exchanger.

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