HEAT TRANSFER ENHANCEMENT IN DOUBLE PIPE HEAT EXCHANGER USING WASHERS AS AN INSERTS

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ABSTRACT

Researchers are used different heat transfer enhancement techniques in double pipe heat exchanger by inserting various types of twisted tapes in last few years. These techniques are more applicable in various industrial areas such as cryogenics, process industries, HVAC systems etc. There is need to improve the outside heat transfer coefficient, effectiveness and thermal performance of heat exchanger, thereby reducing the cost and size of heat exchanger. In present paper washers with octagonal slot used as a insert to improve heat transfer and to reduce the weight and size of heat exchanger. Heat transfer performance of heat exchanger with washers is higher than normal heat exchanger but pressure drop, pumping power is also higher. When only heat transfer and annulus heat transfer coefficient performance is considered no consideration of pressure drop, pumping power heat exchanger with washers is superior than normal heat exchanger.

Keyword: - *Double Pipe Heat Exchanger1, Inserts2, Washers with Octagonal Slot3, Heat Transfer Rate & Heat Transfer Coefficient4.*

1. INTRODUCTION

A heat exchanger may be defined as equipment, which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running cost. The rate of transfer of heat depends on the conductivity of the dividing wall and convective heat transfer coefficient between the wall and fluids. The heat transfer rate also varies depending on the boundary conditions such as adiabatic or insulated wall conditions. The technique of improving the performance of heat transfer system is referred to as heat transfer enhancement. This leads to reduced size and cost of heat exchanger. Twisted tapes have been used extensively as a swirl generator to enhance convection heat transfer rate in finding the way to reduce the weight, size and cost of heat exchanger systems in several industrial applications such as chemical engineering process, heat recovery process, air conditioning and refrigeration systems, chemical reactors, power plant and nuclear reactor etc. Tubes with twisted tape insert are also an important group of the continuous swirling flow device that generates twin swirling flow motion over the whole tube length of flow at constant heat transfer coefficient and friction factor. There are many devices used for producing swirl flow in the tube such as helical vanes, helical grooved tubes, helical screw tape, axial-radial guide vanes and snail entry while the twisted tape is one of the most popular group because of low cost, low maintenance, low pressure loss and ease of construction. All of the swirling flow devices have been used to generate the tangential velocity, thin the boundary layer, enhance the tangential and radial turbulent fluctuation and therefore cause the increase in heat transfer rate and friction loss inside tubes. As a heat exchanger older, the resistance to heat transfer rate increases due to the fouling and scaling. This is particularly true in heat exchangers used in marine as well as chemical industries. Also in some industries there is a need to increase the heat transfer in the existing heat exchanger.

2. LITERATURE REVIEW

2.1 Heat transfer Augmentation with twisted tapes

With a view to obtain higher heat transfer, many researchers have been trying to develop an efficient design for many years. The research on heat transfer enhancement using twisted tape can be broadly divided into three group i.e. plain twisted tape, modified twisted tape and modified twisted tape geometry. With reference to a review paper on twisted tape heat transfer enhancement prepared by Kumar et al. the following summery on all the researches on twisted tape heat transfer enhancement is presented.

Behabadi et al. experimentally investigated the heat transfer coefficients and pressure drop during condensation of HFC-134a in a horizontal tube fitted with twisted tape. The refrigerant flows in the inner copper and the cooling water flows in annulus. Also empirical correlations were developed to predict smooth tube and swirl flow pressure drop. [1]

Syam Sundar and Sharma investigated the thermo physical properties like thermal conductivity and viscosity of Al2O3 nanofluid is determined through experiments at different volume concentrations and temperatures. From the result it is observed that, heat transfer coefficients and friction factor is higher when compared to water in a plain tube. Also, a generalized regression equation is developed with the experimental data for the estimation of friction factor and Nusselt number. [2]

Promvonge et al. experimentally investigated the heat transfer rate, friction factor and thermo hydraulic efficiency of the combined devices of twisted tape and wire coil. The experiment is carried out by arranging in two different forms: (1) Decreasing coil and (2) Decreasing and increasing coil while the twisted tape was prepared with two different twist ratios. [3]

Klaczak investigated experimentally the heat transfer for laminar flow of water in an air cooled vertical copper pipe with twisted tape inserts of various pitch value. The tests were executed for laminar flow within a range of Reynolds number ($110 \leq Re \leq 1500$), Graetz number ($8.1 \leq Gz \leq 82.0$) and twist ratio ($1.62 \leq y \leq 5.29$). Result shows that the heat transfer increases with increase in twisted tape pitch value. [4]

Fetroni et al. experimentally analyzed, the isothermal pressure drop tests, were performed on horizontal round tube with equally spaced and short-length twisted tape. Various test are made with a range of twist ratio ($1.5 \leq y \leq 6$) and various spacing between two twisted tapes ($30 \leq S \leq 50$). The Darcy friction factor associated with the tested twist ratios and spacing between two twisted tapes combinations was calculated, and a relation correlating this factor to Reynolds number, twist ratio and spacing between two twisted tapes was developed. [5]

Changhong Chen et al. analyzed the computational fluid dynamics (CFD) modeling for the optimization of regularly spaced short-length twisted tape in a circular tube. The configuration parameters are given by the spacing between two twisted tapes, twist ratio and twist angle. The result is made such that the mean heat transfer and flow resistance increase with an increase in twist angle. [6]

Yadav experimentally investigated on the half-length twisted tape insertion on heat transfer & pressure drop characteristics in a U-bend double pipe heat exchanger. The experimental results revealed that the increase in heat transfer rate of the twisted tape inserts is found to be strongly influenced by tape-induced swirl. [7]

2.2 Heat transfer Augmentation with wire coils

Inaba and Ozaki showed that the turbulent flow induced by a wire coil enhances heat transfer even in the downstream of the wire coil. They developed empirical relations for Nusselt number as a function of Pr and p/e (where P denotes pitch of the coil and e denotes diameter of the coil). Pressure drop is found to be proportional to the length of the wire coil. Both high heat transfer characteristics and small pressure loss can be obtained by utilizing the leading edge effect near the tube and the turbulent flow in the downstream of the wire coil. Among all the tested configurations p/e=10 is found to be optimum for heat transfer enhancement with smaller pressure drop. [8]

2.3 Major Findings from Literature Survey

From above literature survey we will find that an experimental study was conducted to investigate the air flow friction and heat transfer characteristics in a circular tube fitted with twisted tape inserts of different twist ratios for turbulent flow regime.

The double counter twisted tape offered a significant enhancement of heat transfer, friction factor as well as thermal enhancement efficiency compared with the plain tube values.

In general observations, it was found that the heat transfer, friction factor and thermal enhancement efficiency increased with decreasing twist ratio. Furthermore, the Nusselt number increased with the increasing Reynolds number while the opposite trends were found for the case of friction factor and thermal enhancement efficiency.

The thermal performance factor in case of single twisted tape is higher followed by triple twisted tape and twisted tape with circular ring .For the better thermal performance factor in a heat exchanger core disturbance and surface disturbance of fluid flow both play a significant role.

3. EXPERIMENTAL SETUP

Fig 1.shows the experimental setup of the concentric tube double pipe heat exchanger. It consists of calming section, test section, overhead water tank for supplying cold water & a constant temperature reservoir (35 litre capacity) for supplying hot water within-built heater, pump, temperature sensors, thermostat and the control system. The hot water is flows through the inner pipe and cold water is flows in the annulus which can be admitted at any one of the ends enabling the heat exchanger to run as a counter flow exchanger. The outer pipe is well insulated using 20 mm diameter asbestos rope to decrease heat losses to the surrounding. Two calibrated rotameters, with the flow ranges 0.02 to 0.1 kg/sec, are used to measure the flow of cold water. The water, at room temperature is drawn from an overhead tank using gravity flow. Similarly a rotameter of same capacity is provided to control the flow rate of hot water from the inlet hot water reservoir. The inlet temperature of hot water is maintained at 333 K and the cold water at 303 K. Experiments were conducted counter flow arrangement at various mass flow rates of hot water ($\dot{m}_h$) ranging from 0.02 to 0.1 kg/sec with an increment of 0.02 kg/sec at each time keeping the mass flow rate of cold water ($\dot{m}_c$) through annulus is kept constant at 0.02 kg/sec. Range of the Reynold's number in the present study was 3000 to 24000.The outlet temperature of cold water and hot water were noted at each time. Similarly the experiments were repeated by changing the cold water flow rates keeping the hot water flow rate constant at 0.02 kg/sec. changing the cold water flow rates keeping the hot water flow rate constant at 0.02 kg/sec.

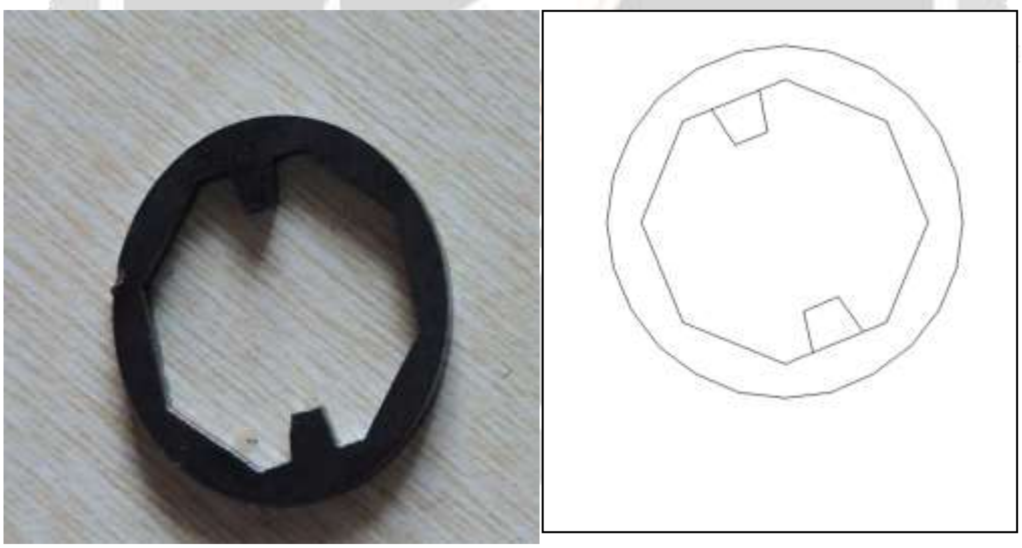

Fig 3.1 Washer with slot of Octagonal shape

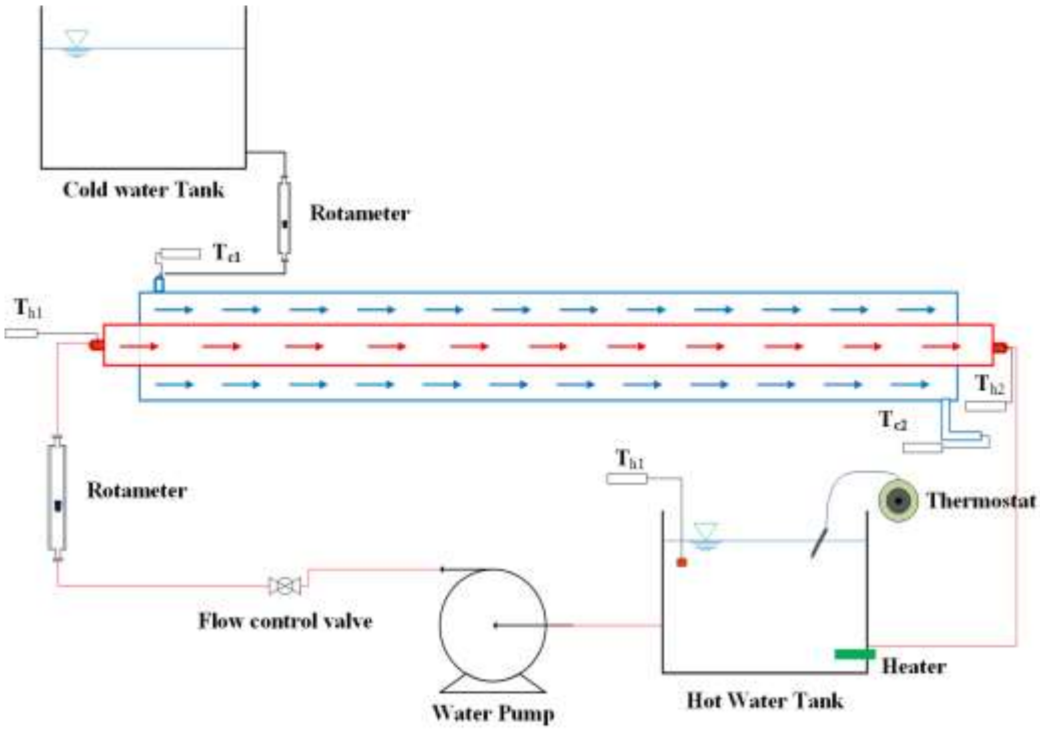

Fig 3.2 Schematic Diagram of Experimental Setup

3.1 Specifications of heat exchanger used

The experimental study is done in double pipe heat exchanger having the specifications as listed below (All parts are made up of Mild Steel)

Table 3.1 Specification of Setup

S.No	Component	Specifications
1.	Outer pipe	ID = 30 mm , OD = 32 mm
2.	Inner pipe	ID = 11 mm , OD = 12 mm
3.	Washers with slots	ID = 13 mm , OD = 26 mm
4.	Thermostat	30-110 °C
5.	Heater	Heating Capacity upto 90°C

Fig 3.3 Actual Experimental Setup

3.2 Observation Tables

Table 3.2: Experimental trials for bare pipe

Hot Mass Flow Rate (Kg/Sec)	Cold Mass Flow Rate (Kg/Sec)	60 Sec	120 Sec	180 Sec	Average
0.02	0.02	307.8	308	308.5	308.1
0.04	0.02	308.2	308.7	308.9	308.6
0.06	0.02	308.6	309.6	310.3	309.5
0.08	0.02	309.7	309.9	310.7	310.1
0.1	0.02	309.2	309.8	311	310
0.02	0.02	307.8	308	308.5	308.1
0.02	0.04	305.9	306.4	307.2	306.5
0.02	0.06	304.1	305.2	306.3	305.2
0.02	0.08	303.6	304.5	305.1	304.4
0.02	0.1	303	303.4	304.1	303.5

Table 3.3: Experimental trials for Octagonal washer inserted pipe

Hot mass flow rate (kg/sec)	Cold mass flow rate (kg/sec)	60 Sec	120 Sec	180 Sec	Avarage
0.02	0.02	312	312.6	313.5	312.7
0.04	0.02	313.8	314.1	316.5	314.8
0.06	0.02	314.6	315.8	318.2	316.2
0.08	0.02	315	317.3	318.4	316.9
0.1	0.02	315.6	317.4	318.6	317.2
0.02	0.02	312	312.6	313.5	312.7
0.02	0.04	307.2	307.5	309.6	308.1
0.02	0.06	305.6	306.4	308.7	306.9
0.02	0.08	304.3	305.9	306.9	305.7
0.02	0.1	303.9	305.2	306.2	305.1

4. RESULTS AND DISCUSSION

Tab.5.1 indicates the heat transfer rate for different simulated conditions for the washer inserted and normal tubes. It can be revealed that heat transfer rate increases with the increase in mass flow rate and washer inserted tubes show higher value than the bare condition. For a constant value of $\dot{m}_c$ = 0.02 kg/s and varying $\dot{m}_h$, Octagonal washer inserted tubes showed an average improvement of 52.84 % over the normal geometry . Similarly For a constant value of $\dot{m}_h$ = 0.02kg/s and varying $\dot{m}_c$, it showed an improvement by 40% over the normal geometry.

Fig.5.1 shows the variation of annulus heat transfer coefficient for different varied $\dot{m}_c$ keeping $\dot{m}_h$ constant at 0.02 kg/s. It is observed that annular heat transfer coefficient is increases for washer inserted tubes than bare tube .

Table 4.1: Heat transfer calculations for normal and washers inserted heat exchanger

Sr No	Condition	Mass Flow rate (kg/s)	Normal geometry (Watt)	Octagonal washer geometry (Watt)
1	$\dot{m}_c$ constant at 0.02 kg/s and $\dot{m}_h$ varying	0.02	497.52	886.311
2		0.04	593.706	1220.846
3		0.06	648.04	1417.377
4		0.08	698.206	1618.126
5		0.1	752.59	1785.431
6	$\dot{m}_h$ constant at 0.02 kg/s and $\dot{m}_c$ varying	0.02	497.52	886.311
7		0.04	677.296	1099.619
8		0.06	723.329	1179.021
9		0.08	727.562	1191.615
10		0.1	736.083	1200.021

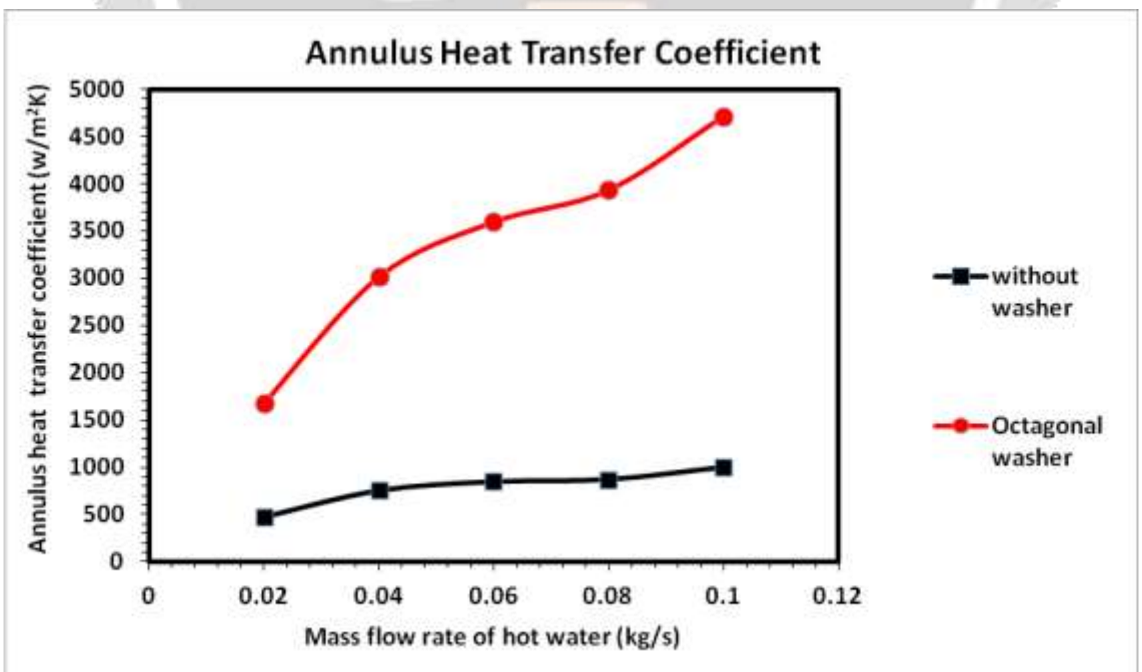

Fig. 4.1: Variation of annulus heat transfer coefficient with varying mass flow rates of cold water in counter flow

Fig.5.2 represents fin effectiveness for various types of washers inserted tubes under different conditions. Effectiveness was calculated by the simple relation ,i.e.

$$\varepsilon = \frac{C_C(T_{c2} - T_{C1})}{C_{min}(T_{h1} - T_{c1})}$$

For a constant value of $\dot{m}_c$ of 0.02 kg/s, as $\dot{m}_h$ was increased the effectiveness of the octagonal washer inserted heat exchanger is maximum than bare one. Similarly for a constant $\dot{m}_h$ and as $\dot{m}_c$ are varied, the effectiveness decreases as seen in the graph. The rise in temperature for varying $\dot{m}_c$ decreases for a washer inserted tube compared with the bare one. At higher mass flow rates the flow field is being disturbed severely when compared to the bare tube. Hence heat transfer capability of the washers inserted tube decreases causing reduction in effectiveness. Hence in order to have a better performance by the washers for heating a liquid flowing in the annulus region, mass flow rate of liquid in the annulus should be minimum and mass flow rate of hot liquid flowing inside the inner tube should be maximum.

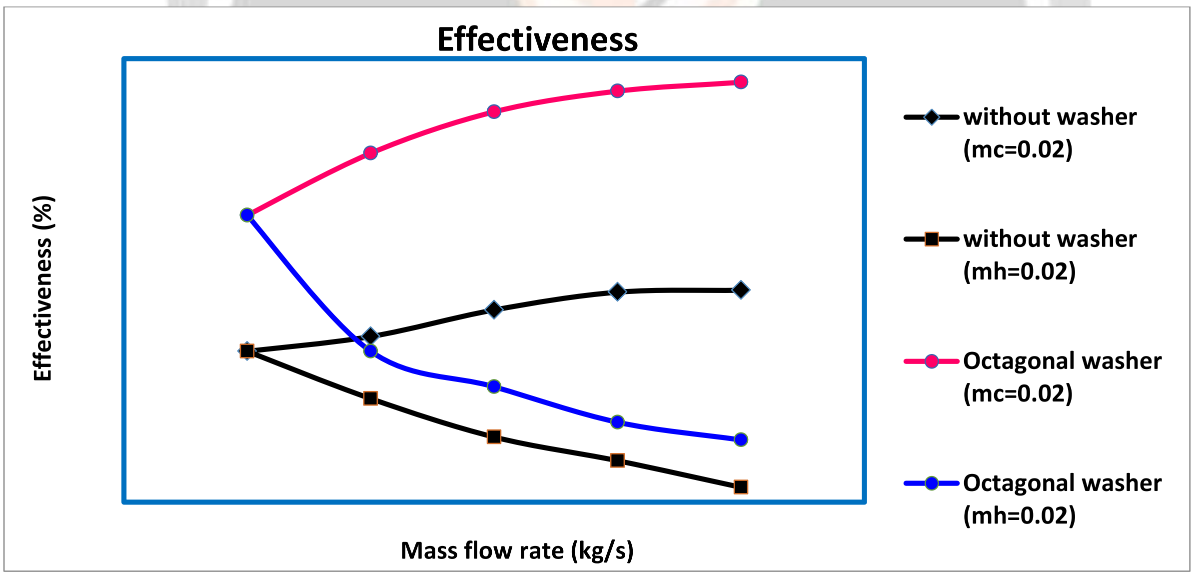

Fig. 4.2: Variation of fin effectiveness with varying mass flow rates of cold water and hot water

5. CONCLUSION

In the present work experimental study of washer inserted double pipe heat exchanger is done with hot fluid flowing in the inner tube and cold fluid in the annulus.. Results indicated octagonal washer configurations shows an overall improvement in the thermal characteristics compared with bare one. For better Performance the mass flow rate of the cold fluid should be kept low where as that of the hot liquid should be high. Octagonal washer slot configuration show a marginal improvement over the other in terms of temperature rise, heat transfer rate and heat transfer coefficient. For a constant value of $\dot{m_c}$ of 0.02 kg/s, as $\dot{m_h}$ was increased, the effectiveness of the Octagonal washer showed 50 % higher than normal geometry. In addition to this even they provide the advantage of lesser material and hence reduced weight. Hence it can be concluded that Octagonal configuration can be a better alternative compared to the normal geometry and reduced weight of the heat exchanger assembly.

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