Experimental Study and Analysis of Heat Transfer Enhancement of Tube in Tube Heat Exchanger using Delta Winglet and Triethylene Glycol

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Abstract— The heat transfer characteristics of water based Triethylene glycol in a Tube and Tube Heat exchanger with the aid of delta winglet and inserts will being study. Investigations will be on the effects of Reynolds's number and Nusselt number with the effect of the water based Conductive fluid concentration on the heat transfer. An increase in the volume concentration of the conductive particles in the base fluid caused a significant enhancement in the overall heat transfer characteristics compared to that of water. When a delta winglet and inserts will use, further increment in overall heat transfer coefficient will find for a particular Reynolds's number and Nusselt number. The superior thermal characteristics of Conductive fluid obtained with the aid of delta winglet may be attributed to the thermal dispersion effect. This study is a comparison for Laminar flow and Turbulent flow of water based Conductive fluid for heat transfer enhancement depending on Reynolds's Number and Nusselt Number. Study also involves analysis of Heat transfer enhancement of tube in tube Heat exchanger using delta winglet, inserts and by water based Triethylene glycol.
Key words: Delta winglet, Inserts, Triethylene glycol, Tube in tube heat exchanger

I. INTRODUCTION

Heat transfer enhancements in heat exchangers is gaining industrial importance because it gives one the opportunity to reduce the heat transfer surface area required for a given application and thus reduce the heat exchanger size and cost, increase the heat duty of the exchanger for fixed surface area, reduce logarithmic mean temperature difference (LMTD) for fixed heat duty and surface area, and reduce pumping power for fixed heat duty and surface area. The automotive and refrigeration industries routinely use enhanced surfaces in their heat exchangers. Also, the process industry is aggressively working to incorporate enhanced heat transfer surfaces in their heat exchangers. Heat transfer enhancement in heat exchangers has been the subject of many experimental and analytical investigations. These techniques can be categorized as `active' or `passive'. The active techniques require external power, such as surface vibration, fluid vibration, injection, suction, and electric or acoustic fields. Passive techniques employ special surface geometries for enhancement, such as extended surfaces, rough surfaces, displacement enhancement devices, swirl flow devices, obstruction devices, and treated surfaces.

Different methods used to transfer the heat either through increasing the heat input, by increasing the velocity and by using the winglet in the flow path of the fluid. The last method used i.e. the passive way to increase the heat transfer by using the delta winglet is found to be most effective method to increase the heat transfer without any external input.

In parallel flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter flow heat exchangers the fluids enter the exchanger from opposite ends.

II. EXPERIMENT SETUP

The schematic diagram of the experimental setup used is as shown in Fig.2 As the motivation of the experiments was to study the effect of turbulant creator as well as the effect of Reynolds number on the heat transfer of heat exchanger, the tube in tube heat exchanger was selected to avoid the complexity of the problem. Moreover, various apparatus, as shown in Fig.2 such as, Rotameter, Pump, Hot water tank, Cold water tank, Thermocouples, and the Control valve were implemented in the experimental setup as per the requirement of experiments. The suspended nanoparticles can increase the surface area and heat capacity of the fluid.

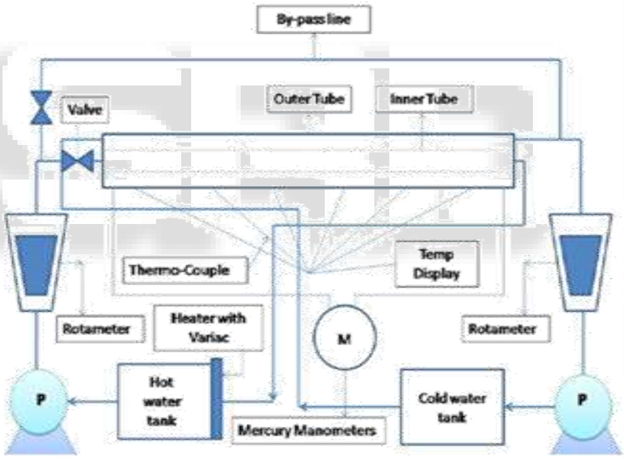

Fig. 1: Line Diagram of Tube in Tube heat exchanger

Fig.2. shows hot (insulated) water tank and cold water tank filled with water. The left side of the tank is attached with the heater with variac and the entire tank is insulated. Water in the insulated tank is heated up to 85◦ C temperature with the help of heater.

Fig. 2: Experimental Setup

As the water in the insulated tank is reached to 80 C both the pump are operated in order to supply the hot and cold fluid through the test rig. During the experiment the hot fluid is passed through the tube side and the cold fluid is passed through the shell side. The mass flow rate at which the water is passing through the respective channel i.e. tube side and shell side can be varied with the help of Rotameter. Mass flow rate on both the side of test rig i.e. Tube side and shell side is kept fixed with the help of the Rotameter as shown in the Fig.2

Mass flow rate of hot fluid (LPM)	Mass flow rate of cold fluid (LPM)	Temperature variation of Tube side fluid
2	4,6 & 8	50 to 85
4	2,6 & 8	50 to 85
6	2,4 & 8	50 to 85
8	2,4 & 6	50 to 85

Table 1: Matrix Of Experiments Performed

Total twelve thermocouples are provided in the experimental setup as shown in the Fig.2. Out of this twelve thermocouple one is fixed in the hot water insulated tank located in the left side below the test rig i.e abbreviated as T1. At the inlet of the tube side one thermocouple is provided abbreviated as T2. Similarly one thermocouple is also provided at the output of the tube side flow T3. Rest thermo-couples are kept in the test rig. Starting from the right side of the test rig each thermo- couple is fixed as constant distance on the shell side. they are abbreviated from T4 to T12 res. Number of experiments are performed by varying the mass flow rate in both the channels and by varying the inlet temperature of the water at the tube side. The matrix of the experiments performed is shown below in the Tab.1 As shown in the above Tab.1 flow both the rotameter is set to the specific value. Also we can see that the value for the hot fluid rotameter does not match with the value as that in cold fluid rotameter. i.e. the value for both the rotameter is never kept same. This is due to the fact that specific heat at constant pressure at a specific temperature remains constant. After measuring the readings from the various thermocouple the results are calibrated to and the various parameters of the flow inside the tube and the shell side.

1) Inner Tube:

As the hot fluid water is made to pass from the tube side and the cold water is made to passed from annulus side, the heat transfer takes place between the hot water and the cold water. There are mainly three resistance which obstruct the heat transfer between hot and cold fluid, which are

- Convective resistance between hot fluid and inner surface of tube
- Conduction resistance offered by the tube wall
- Convection resistance between cold fluid and outer surface of tube

To insure maximum heat transfer from tube wall (i.e less conduction resistance), copper as tube material was selected which is shown in Fig4.

2) Outer Tube:

The outer tube was insulated in order to keep the heat loss from the shell side as low as possible. In order to provide sufficient strength and rigidity the outer tube was made of the stainless steel.

3) Delta winglet:

Delta winglet is made of aluminum foil. Purpose of the delta winglet is to obstruct the flow of triethylene glycol (TEG) flowing from the shell side. As a result flow path of TEG is disturbed and hence turbulence is created. For preparing delta winglet long strip of aluminum is cut from aluminum sheet. Size of aluminum sheet is kept 65 cm long and 4 cm in width. After the strip is cut, triangles of 2.5 cm base and 1.5 cm height are marked over the entire length of strip keeping distance of 2 cm between two triangles. After marking the strip is fold from the center line of the strip along its entire length. Cut is made on the two side of the triangle as per the marking and then long strip is unfolded in order to erect the triangles from the base. Thus at every 2 cm distance triangles are erect. The same strip with delta winglets is wound around the inner tube of tube in tube heat exchanger.

Fig. 3: Delta winglet

SR No.	PART NAME	SPECIFICATIONS	No
1	Inner Tube	ID : 25 mm, OD : 28 mm,	1
2	Material of inner tube	Copper	
3	Outer Tube	ID : 62.5 mm, OD : 65 mm,	1
4	Material of outer tube	SS STEEL	
5	Thermocouple	TYPE : K AND TEMPERATURE RANGE: -5◦C T0 550 ◦C (chromel - alumel)	12
6	Mercury Manometers	LEAST COUNT 1cm	1
7	Heater Variac With Thermostatic Switch	CAPACITY: 3 Kw	1
8	PUMP	20 LPM	2

Table 2: Specification of Experimental Setup

4) Short Inserts:

Short inserts are also made from the aluminum foil. The size of this insert is 20 cm long, 1cm in diameter and 1cm pitch between the consecutive wound. Here, the length of insert is kept 20 cm. This inserts also were fitted on the inner tube as shown in fig-4.

Fig. 4: Short inserts wounded on inner copper tube

III. EXPERIMENTAL PROCEDURES

Cross section area of inner tube is given by:

$$A1 = \frac{\pi}{4} \text{ x } di^2$$

Similarly cross section area of shell side is given by:

$$A2 = \frac{\pi}{4} \text{ x } (d02^2 - d01^2)$$

Where, d02: Inner side of the Shell
d01: Outer diameter of tube
Equivalent diameter of shell:
De = (d02 - d01)

Rotameter gives the reading in Liter per minute (LPM) which is converted first into Liter per second by dividing the readings of Rotameter by 60 and then converted into m3/s by dividing Liter per second by 1000 as shown below:

$$m = \frac{LPM}{60 \times 1000} \quad \frac{m^3}{S}$$

When the mass flow rate is divided by the cross sectional area of the channel which the flow is passing it gives velocity of flow:

$$V_{(h)} = \frac{m}{A_1} \quad \frac{m^3}{S \times m^2} \quad = \frac{m}{s}$$

For finding whether the flow is laminar flow or turbulent flow, Reynolds number for the hot fluid is calculated as shown below:

$$Reh = \rho\upsilon D/\mu$$

Similarly; Reynolds number for the shell side fluid is calculated as shown below:

$$Rec = \rho VD/\mu$$

Friction factor for the tube flow is given by:

$$F_1 = \{(1.58 \text{ LN } (R_e) - 3.28\}^{-2}$$

Similarly, the Prandtl number is given by:

$$P_r = \frac{Cp\mu}{K}$$

Nusselt number for the flow of the fluid is also given by:

$$Nu = \frac{\left(\frac{f}{2} \times P_r \times R_e\right)}{(1.07) + \left(12.7 \times \left(\frac{f}{2}\right)^2\right) \times (P_r^{2/3} - 1)}$$

Internal heat transfer co – efficient,

$$h_i = \frac{Nu.K}{A_2}$$

Using Colburn Co – relation,

$$Nu = \left(0.023 \times R_e^{0.8}\right) \times P_r^{0.33}$$

Tavg is the mean temperature of the different temperature reading obtained by the thermo couple fitted at equal distance over the entire length of the shell:

$$\text{Total average } T_{avg} = \frac{T5 + T6 + \ldots\ldots\ldots\ldots + T12}{8}$$

For heat transfer in flow systems, most notably in heat exchangers. The LMTD is a logarithmic average of the temperature difference between the hot and cold streams at each end of the exchanger. The larger the LMTD, the more heat is transferred. The use of the LMTD arises straight forwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties.

$$LMTD = \frac{\{(T_2 - T_{12}) - (T_3 - T_4)\}}{ln\frac{(T_2 - T_{12})}{(T_3 - T_4)}} \qquad (^\circ C)\ (K)$$

Similarly Cp and Ch value with respect to the temperature is calculated as shown below:

$$Ch = Cp \times \rho \times mh \times 1000$$

Value of specific density, Prandtl number (Pr) and Thermal conductivity (W/mK) is taken from the table of thermo-physical properties of water:

$$Cc = Cp \times \rho \times mc \times 1000$$

The conductive heat transfer for the tube side flow (hot side) is given by:

$$Qh = \{Ch \times (T2 - T3)\}$$

The conductive heat transfer for the shell side flow (cold side) is given by:

$$Qc = \{Cc \times (T12 - T4)\}$$

Overall heat transfer coefficient Uo is determined from the known parameters as shown in the equation below

$$U_0 = \frac{Q_C}{LMTD \times 2\pi \times d_i}$$

Using the equation heat transfer h in the shell side is calculated as shown below:

$$\frac{1}{h_0} = \left[\frac{1}{U_0} - \left\{\left(\frac{r_{01}}{r_i} \times \frac{1}{h_1}\right) - \left(\frac{\frac{r_{01}}{2}}{K_C} \times LN\left(\frac{r_{01}}{r_i}\right)\right)\right\}\right]$$

IV. RESULT AND DISCUSSION

The Experimental study carried out as per above methodology can be shown by graphical representation of Reynolds's number(Re) Vs. Nusselt number (Nu) for various six cases discussed below.

SR No.	TUBE PROFILE	CONDUCTIVE FLUID
1	PLAIN TUBE	PLAIN WATER
2	PLAIN TUBE	TRIETHYLENE GLYCOL ($C_6H_{14}O_4$)
3	TUBE WITH INSERTS	PLAIN WATER
4	TUBE WITH INSERTS	TRIETHYLENE GLYCOL ($C_6H_{14}O_4$)
5	TUBE WITH DELTA WINGLET	PLAIN WATER
6	TUBE WITH DELTA WINGLET	TRIETHYLENE GLYCOL ($C_6H_{14}O_4$)

Table No: 3 Experimental Cases

Graphs (Fig: - 5.1) are graphical representation of experiment carried out at LPM Mh=4 and Mc = 8, Mh = 6 and Mc = 8 for the base line along with water and TEG by means of inserts and Delta winglet respectively. Base line results are mostly consistent for all the LPM for water and with insert, the results of Nusselt number increases by average 77% at LPM Mh=4 and Mc=8 for the same LPM along with Inserts and TEG, Nusselt number increases by 95% for the LPM Mh = 4 and Mh = 8 by the combination of

TEG fluid and delta winglet the average increases of Nusselt is 100%.

Comparison of Re vs. Pr number for all six cases at Mh= 4 and Mc= 8 LPM:

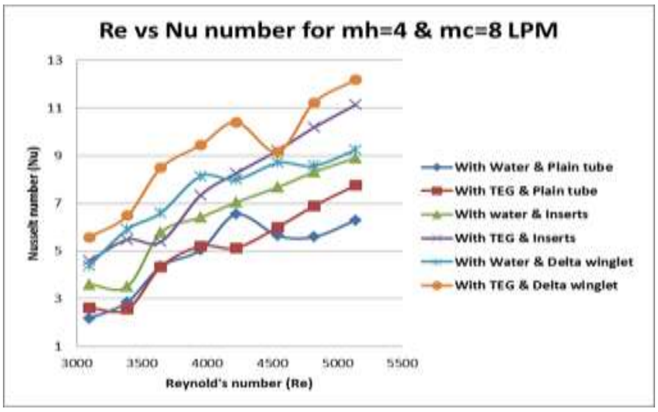

Fig. 5.1: Reynolds's (Re) number Vs. Nusselt number (Nu)

Comparison of Nu vs. Pr number for all six cases at Mh= 4 and Mc= 8 LPM:

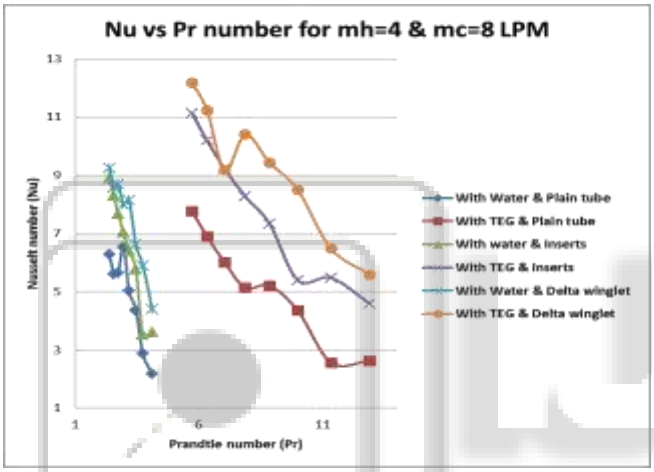

Fig. 5.2: Nu vs. Pr at LPM Mh= 4 & Mc= 8 for all cases

Above Fig:- 5.2 give the explanation of relation between Nusselt number and Prandtl number at the LPM Mh=4 Mc=6,Mh=4 Mc=8, Mh=4 Mc=10, Mh=6 Mc=4, Mh=6 Mc=8, Mh=6 Mc=10, Mh=8 Mc=4, Mh=8 Mc=6, Mh=8 Mc=10, Mh=10 Mc=4, Mh=10 Mc=6, Mh=10 Mc=8.For the above given LPM Nusselt number is increase as the inlet temperature of tube is increase, as a result Prandtl number is decrease. At LPM Mh=4 and Mc=8 as shown in Fig:- 5.2 for the water and delta winglet the Nusselt number is 9.237 and Prandtl number is 2.40 as compare to TEG and delta winglet the Nusselt number is 12.30 and prandtl number is 5.73. there are enormous difference as compare with water and delta winglet. Such circumstances are similar for all other readings.

The maximum difference of Nusselt and Prandtl number with increase in temperature is shown at the TEG and Delta winglet combination and then after TEG and Inserts, water and Delta winglet, water and Insert respectively.

V. Conclusion

Following conclusions has been made from the experimental study carried out for the heat transfer enhancement co efficient using turbulent generators and conductive fluids.

- The Experimental study shows that increase in Reynolds number increases the Nusselt number.
- Nusselt number is increasing in ascending order for plain tube and water, plain tube and TEG, Inserts and water, Delta winglet and water, Inserts and TEG, Delta winglet and TEG.
- When the flow at tube side (Mh) is 4 LPM and annulus side (Mc) flow is 8 LPM percentage increase in the Nusselt number for plain tube with TEG is 24%, for Inserts with water is 42%, for insert with TEG is 77%, for delta winglet with water is 48% and for delta winglet with TEG is 95% as compared to plain tube. For Mh = 6 LPM and Mc = 8 LPM percentage increase in the Nusselt number for plain tube and TEG is 35%, for Inserts with water is 46% , for Inserts with TEG is 89%,for delta winglet with water is 60% and for delta winglet with TEG is 90% as compared to plain tube. For Mh = 4 LPM and Mc = 8 LPM percentage increase in the Nusselt number for plain tube and TEG is 20%, for Inserts with water is 35%, for Insert with TEG is 65%, for delta winglet with water is 36% and for delta winglet with TEG is 80% as compared to plain tube. Similarly for Mh = 6 Mc = 8, Mh = 6 Mc = 4, Mh=6 Mc = 2, Mh = 4 Mc = 8, Mh = 4 Mc = 6, Mh =4 Mc = 2, Mh = 2 Mc = 8, Mh = 2 Mc = 6, Mh = 2 Mc = 4 LPM combinations percentage increase in the Nusselt number is there.

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