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Experimental Analysis of Heat Transfer Augmentation By Passive Methods

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***Abstract* –** The method of improving the performance of a heat exchanger is called as Heat Transfer Augmentation or enhancement. These techniques are widely used in areas like refrigeration and air-conditioning equipment (evaporator and condenser for heating and cooling), thermal power plants, space vehicle and electronic component cooling, radiators in automobiles, solar air heater etc. There are mainly two types of augmentation techniques namely Active and Passive. Active methods are those in which external power input is required for heat transfer enhancement, whereas in case of Passive methods, surface or geometrical modifications are done to the flow channel by incorporating inserts or additional devices. When any two or more methods are employed simultaneously, they are known as Compound methods. This paper is the summary of the experimental work carried out by passive heat transfer augmentation in a concentric tube counter flow heat exchanger using different types of twisted tapes.

***Keywords* -** *Heat Transfer Augmentation, Passive Methods, Twisted Tapes, Effectiveness.*

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I. INTRODUCTION

The heat exchanger is a device which is used to transfer the heat from a hot fluid to a cold fluid with maximum rate and minimum running cost. The applications of heat exchangers are primarily involved in OTEC (Ocean Thermal Energy Conversion) systems, Sugar Factories, Dairy Plants, Chemical Industries etc. Now a days, due to energy scarcity problem there is a need to design an energy efficient heat exchanger so as to minimize energy losses with low operational cost. In order to improve the performance of a heat exchanger, one of the way is to increase the heat transfer coefficient.

The techniques for enhancing heat transfer coefficient are mainly classified into two types. One is active method, which requires additional power input, for example fluid vibration, jet impingement, pulsation by cams and reciprocating plungers, using magnetic or electrostatic fields to disturb the seeded particles in a flowing stream etc. The other method is passive method such as using coils or twisted tapes, rough surfaces, helical screw tape inserts, baffles, extended surface additives etc. The third technique which is called as compound method includes combined application of both active and passive methods to obtain heat transfer enhancement which is greater than that produced by either of them when used individually. This technique has limited applications as it involves complicated design. Twisted tapes and inserts are the most economical and easiest ways to augment heat transfer.

In industries, passive methods are employed because of the following advantages:

1. Passive techniques do not need any external power source and hence more economical.
2. They can be used in the design of compact heat exchangers.
3. The manufacturing of inserts is simple and they can be easily employed in existing heat exchangers.
4. It is also applicable to solar air heaters and in the cooling of electronic equipment.
5. Passive insert configuration can be selected according to the heat exchanger working condition.

II. OBJECTIVES OF THE WORK

- To study the basic working of heat exchangers.
- To design and fabricate a concentric tube counter flow heat exchanger.
- To design four types of inserts for heat exchanger.
    - Simple Twisted Type
    - Perforated Twisted Type.
    - Baffles Type
    - Jagged Twisted Type
- To obtain the best design on the basis of maximum heat transfer coefficient/heat transfer rate.
- To do thermal analysis to find quantities like,
  1. Effectiveness of heat exchanger
  2. The amount of heat lost or gained
  3. Heat Transfer Coefficient.

III. DESIGN OF HEAT EXCHANGER

In this work, a concentric tube counter flow heat exchanger is designed and fabricated. The tubes of heat exchanger are having diameters of the range 16 mm to 50 mm. The smaller diameters of 16 to 25 mm are preferred for compact design, whereas larger diameter tubes are selected for heavily fouling fluids, because they are easier to clean by mechanical methods. The copper tube is used and thickness (gauge) is selected, so that it withstands the internal fluid pressure and provide inadequate corrosion allowance. Also, the optimum length of the exchanger is selected, so as to reduce the tube diameter in order to reduce the cost. The designs finalised are:

External Tube Dimensions:- D_i = 25.40mm, D_o = 28.60mm, Thickness = 18BWG & Length = Lo = 1000 mm.

Internal Tube Dimensions:- D_i =16.65mm, D_o =19.05 mm, Thickness = 18BWG & Length = Li = 1000 mm.

Standard diameters and wall thicknesses for copper tubes are given in Table I.

TABLE I: Tube Dimensions

OD (mm)	Wall Thickness (mm)				
16	1.2	1.6	2.0	-	-
20	-	1.6	2.0	2.6	-
25	-	1.6	2.0	2.6	3.2
30	-	1.6	2.0	2.6	3.2
38	-	-	2.0	2.6	3.2
50	-	-	2.0	2.6	3.2

(Where OD = Outer Diameter)

IV. FABRICATION PROCEDURE FOR INSERTS

1. Take aluminium or copper sheet of thickness 1mm.
2. Cut them on hydraulic press in desired width & length (12mm x 1000 mm) keeping 2 mm allowance for compensating the length after twisting.
3. The cut tapes are then given corrugations on die for required wave-widths on both sides.
4. After corrugations drill two holes each on one end on tapes.
5. Hold the tape between headstock & tail stock on lathe machine using drilled holes.
6. Rotate the headstock (chuck) end & at the same time move tailstock by required amount towards the headstock till we get desired shape &pitch.

The actual photographs of twisted tape for varying wave widths but same twist ratio are shown in below figures.

Figure 1. Simple Twisted Insert

Figure 2. Perforated Twisted Insert

Figure 3. Jagged Twisted Insert

Figure 4. Baffle Type Insert

Figure 5. Experimental Test-Rig

Figure 6. Copper Tubes for Exchanger

V. EXPERIMENTATION

1. Firstly assemble whole set up, check whether the connections are correct.
2. Put sufficient water in hot water tank to heat it up to certain temperature using heater.
3. Wait for the water to get heated up to desired temperature.

4. Maintain the temperature of the two inlet tanks i.e. hot water and cold water tank.
5. Check the flow rate of water through inner tube and outer tube at required temperature.
6. Now put insert into inner tube through which hot fluid is to pass, remember to pack the both ends of the inner tube to reduce losses.
7. Check whether the two inlets of hot and cold fluid are in proper end.
8. Now take note of reading of hot and cold water temperature by using digital thermometer. Note down the reading.
9. Firmly deep the two motors into respective tanks, ensure that the temperature should not fall or rise in this process.
10. Start the process by switching 'ON' button of motors.
11. Observe the flow of fluid at different temperature and take readings on putting digital thermometer into two outlet tanks.
12. Note down the reading after the temperature becomes stable.
13. Take this readings at different temperature and inserts
14. Find effectiveness, overall heat transfer and heat transfer coefficient by using formulae.

VI. ANALYSIS AND CALCULATIONS

The general equation for the rate of heat transfer across a surface in terms of overall HT coefficient is:

$$Q = U.A.\Delta Tm$$

Where Q = Heat transferred per unit time in W,
U = Overall heat transfer coefficient in $W/m^{2}\,{}^{0}C$,
A = Area of heat-transfer in m^2,
ΔTm= Mean temperature difference in ${}^{0}C$.

The main aim in design of the heat exchanger is to determine heat transfer rate using the temperature differences available. The overall heat transfer coefficient can be defined as the reciprocal of overall thermal resistance to heat transfer, which is the sum of several individual thermal resistances. For heat exchange across a typical concentric tube counter flow heat exchanger, the equation is,

$$Uo = \frac{1}{ho} + \frac{1}{hod} + \frac{do}{di} \times \frac{1}{hid} + \frac{do}{di} \times \frac{1}{hi} + \frac{do\ln\left(\frac{do}{di}\right)}{2kw}$$

Where Uo = the overall coefficient based on the outside area of the tube in $W/m^{2}\,{}^{0}C$,
ho = Outside fluid film coefficient in $W/m^{2}\,{}^{0}C$
hi = Inside fluid film coefficient in $W/m^{2}\,{}^{0}C$,
hod = Outside dirt coefficient (fouling factor) in $W/m^{2}\,{}^{0}C$,
hid = Inside dirt coefficient in $W/m^{2}\,{}^{0}C$,

kw = Thermal conductivity of tube wall material in $W/m^{o}C$,
di = tube inside diameter in m &
do = tube outside diameter in m.

Calculations for Baffles Type Inserts at Temp of $80^{o}C$:

$$A_{c/s} = 4.68 \times 10^{-5}$$

As Reynolds number for given tube is given by,

$$Re = \frac{\rho V De}{\mu}$$

To find V,
We know continuity equation,

$$Q = AxV$$

As density = mass/volume (i.e. $\rho = m/V$.)
Therefore, $m = A \times \rho \times V$
For mass flow rate = m = 0.01492 kg/sec

$$0.01492 = Vx972x4.68x10^{-5}$$

$$V = \frac{0.01492}{972X4.68x10-5} = 0.328m/s$$

V= 0.328 m/s

$$\text{So, } Re = \frac{972x0.328x\ 16.65x10^{-3}}{0.670x\ 10^{-3}} = 14953.1$$

Re = 14953.1

From Reynolds number, flow is turbulent.(Re>2000)
Correlation used for turbulent flow is;

$$Nu = \frac{hLc}{k}$$

$$= CRe^{a}Pr^{b}\left(\frac{\mu}{\mu m}\right)^{-m}$$

$$= 0.023xRe^{0.8}Pr^{(1/3)}\ x1$$

$$= 0.023x\ (14953.1)^{0.8}x\ (Pr)^{(1/3)}$$

$$\text{Equation 2c, } \rightarrow \frac{hde}{k} = 0.023\ x\ (14953.1)^{0.8}x\ (2.23)^{(1/3)}$$

$$h = \frac{0.670\ X\ 0.023\ X\ 14953.1^{0.8}\ X\ 2.23^{1/3}}{16.65\ X10-3}$$

$$h = 2910.83\ w/m^{2\,0}K$$

Also LMTD is given by,

$$\Theta m = \frac{\theta 1 - \theta 2}{\ln(\theta 1/\theta 2)}$$

$$= \frac{35.3 - 29.4}{\ln(35.3/29.4)} = 32.287^{0}C$$

Heat transfer rate in kW is given by,

$$Q = 2910.83x\ \pi\ x\ 19.05\ x\ 10^{-3}x1x32.287$$

$$= 5.62kw$$

For Effectiveness (ϵ),

$$Q_{actual} = m_{h}C_{ph}\,(T_{Hin} - T_{Hout})$$

$$= 0.01492\ x\ 4.198\ x\ 10^{3}x\ (80\text{-}59.4)$$

$$= 1291.5 \text{ watts}$$

$$Q_{maximum} = m_{c}C_{pc}\ (T_{Hin} - T_{Cin})$$

$$= 0.011\ x\ 4.178\ x\ 10^{3}x\ (80\text{-}30)$$

$$= 2297.9 \text{watts}$$

$$\text{Therefore, } \epsilon = \frac{Qactual}{Qmaximum}$$

$$\epsilon = \frac{1291.5}{2297.9}$$

$$\epsilon = 0.562$$

VII. GRAPHS AND CONCLUSION

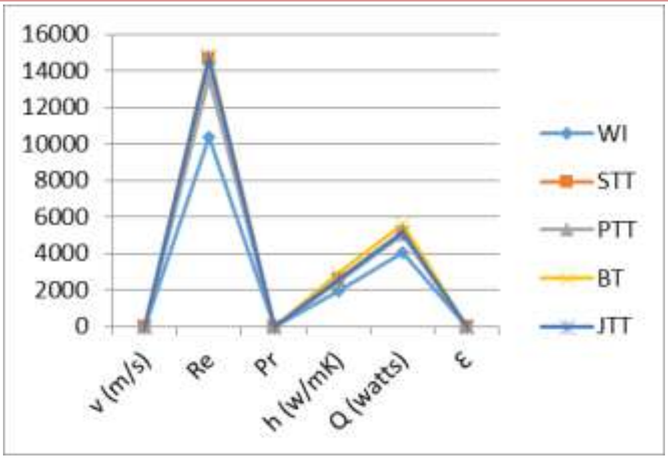

Figure 5. Graph for various performance parameters

The heat transfer enhancement, thermal performance and effectiveness of different twisted inserts have been investigated experimentally. The experiments performed for the tube fitted with different twisted inserts with different design, and also for different area of contact. Based on the experimental results, following will be parameters which could be summarized as follows:

1) The increase or decrease of Nusselt number obtained for the tube with inserts in comparison to those of the without insert values.

2) The highest heat transfer coefficient among the inserts tested and amount by which it is higher than the value of without insert tube.

3) The overall heat transfer for the tube equipped with twisted inserts will be compared with those of the without insert values.

4) The maximum effectiveness possible with the baffles type inserts inserted tube with a particular configuration among the tested ones.

5) The maximum deviations between the predicted results and experimental results for each factor will be checked.

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