RESEARCH ARTICLE OPEN ACCESS

Experimental Investigation of Heat Transfer Using "Twisted Aluminium Tape"

Mr.B.Meganathan M.E, (Assistant Professor), Yuvanarajan.R, Vishal.P.V, Saravanan.A, Yuvaraj.R
Department of Mechanical Engineering, Velammal Institute of Technology, Chennai, India.

ABSTRACT
Heat exchanger has a wide industrial and engineering applications. Increasing the efficiency of heat exchanger will increase the overall performance of the unit. This paper is about increasing the heat transfer coefficient of heat exchanger by causing a turbulence in the liquid flow through the pipe. For causing the turbulence, liquid flow is subjected to a Twisted Aluminium Tape (TAT) which will increase the Reynolds number of flow. This will ensure heat transfer through the length of flow and thus there will be an increased heat transfer rate. The increased turbulence and higher shear caused by Twisted Aluminium Tape (TAT) will offer resistance to fouling also.
KEY WORDS: Twisted Aluminium Tape in path of liquid flow, Turbulent flow created, Over all heat transfer increased.

I. INTRODUCTION

Heat exchanger is a device in which heat is transferred form one medium to another across a solid surface. Efficiency of heat exchanger depends on the type of flow. If the flow is laminar, heat transfer in the boundary of liquid flow will be maximum and heat in the center of flow will not be transmitted efficiently. But due to the surface roughness factor of the pipes used for flow, the flow of all liquids will be a transitional flow. This factor increases the heat transfer coefficient to some extent. If the flow is fully turbulent the heat concentrated in the center of liquid flow will spread equally and the temperature of fluid will be even throughout the flow. This will ensure constant heat transfer throughout the length of flow.

In this paper we aimed to increase the efficiency of heat exchanger by causing a turbulence in the liquid flow. For causing the turbulence in the liquid flow, a twisted Aluminium tape is used. As aluminium is cheap and can be twisted easily and can withstand hightemperature, the twisted tape is made in aluminium material.

Twisted Aluminium Tape (TAT) when placed in the path of liquid flow, creates a high degree of turbulence i.e. Reynolds number of flow increases. This will increase the Heat transfer coefficient of the liquid and there will be a pressure drop in the liquid flow due to the resistance caused by Twisted Aluminium Tape (TAT). This factor will increase the load on pump which will increase the pump cost. To increase the pressure, a taper clip is placed at the outlet of heat exchanger. This taper clip will increase the pressure of outlet fluid.

Fouling is one the major factor which will reduce the heat transfer coefficient of a heat exchanger. Fouling is a dirt layer that gradually build up on heat transfer surfaces, increases thermal resistance. If the flow is laminar or transitional, fouling on the inner surface of heat exchanger will be high. This factor requires the heat exchanger to be cleaned periodically. But when the flow is turbulent, due to high shear caused by the flow there will be a resistance to fouling also

II. EXPERIMENTAL SETUP

For proving the above theory, we took a counter flow heat exchanger and inserted a Twisted Aluminium Tape in the inner pipe. The inner pipe is subjected to a hot water flow (60 to 70°C) and the outer pipe is subjected to flow of water in ambient temperature. Inlet and outlet temperatures of both the pipes are measured with the help of Resistance Temperature Detector (RTD). To handle the pressure drop in the flow, taper clips and provided at the outlet of inner pipe. The experimental setup is shown below.

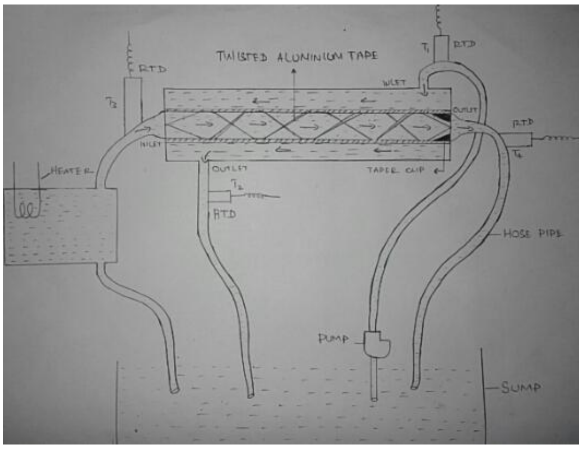

FIGURE2.1. Experimental setup

2.2 TWISTED ALUMINIUM TAPE

An aluminum tape of 2 mm thick is selected. We used Lathe to give the tapes the desired twist. One end of the tape was kept fixed on the tool part of the lathe while the other end was given a slow rotatory motion by holding it on the chuck side, The tape was kept under tension by applying a mild pressure on the tool part side, to avoid the distortion, thus creating the required twist in the tapes. As the aluminium is light weight, corrosion resistance, ductile and good in thermal conductivity, aluminium material is selected.

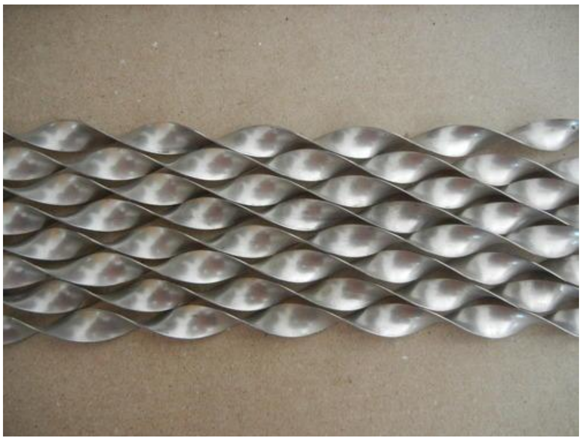

FIGURE 2.2 Twisted aluminium tape

2.3 RESISTANCE TEMPERATURE DETECTOR (RTD)

Electrical resistance thermometer (RTD)operate on the principle that a metal's electrical resistance changes with temperature. RTD have typical uncertainties/errors of 0.1 °C although special ones can give plus or minus 0.01 °C and can be used to calibrate other instruments such as thermocouples**.**RTD is used to find the inlet and outlet temperatures of inner and outer pipes in this setup. We selected RTD because of its high accuracy repeatability and low drift.

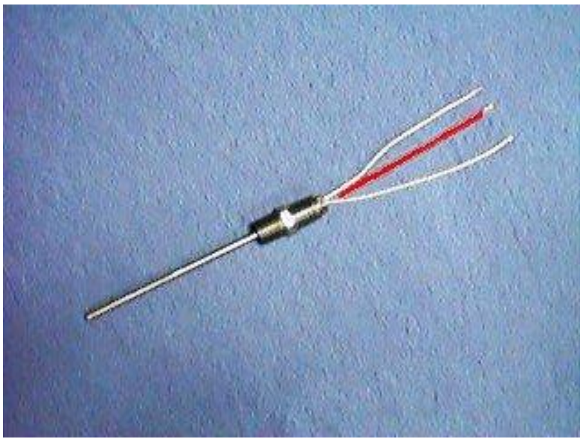

FIGURE 2.3. Resistance thermometer (RTD)

2.4 TAPER CLIPS

Taper clips are fixed in the outlet of inner pipe. Due to the resistance in the flow caused by the twisted aluminium tape, there will be a pressure drop in the flow. This pressure drop will increase the priming cost of the pump. So, to compensate the pressure drop, two taper clips are provided at the outlet of inner pipe. This taper clips will reduce the outlet voulme of pipe. As we know, volume is inversly proportional to pressure $V\alpha$ (1/P), when the volume decreases, pressure of flow will be increased.

FIGURE 2.4. Taper clips

2.5 OUTER PIPE

Outer pipe is made in mild steel.We selected mild steel because it is much cheaper to purchase and requires less time to machine. This can significantly cut down the amount of turning or boring needed to prepare the mild steel pipe.Thermal conductivity of mild steel is around 14 to 20(W/(m•K)) this results in convection of heat which will reduce the accuracy of heat transfer coefficient calculated. To avoid this problem the outer pipe is insulated with insulation tape on the outer surface.

2.6 INNER PIPE

Inner pipe is made in copper. We selected copper because of its excellent thermalconductivity, ductility,strength, ability to hold close tolerance,corrosion resistance, cost reduction. It also offers resistance to fouling. Thermal conductivity of copper is around 399(W/(m•K)), so, there will be good convection of heat from flowing liquid.

III. SPECIFICATIONS

Outer pipe material	= Mild steel
Inner pipe material	= Copper
Hose pipe	= vinyl
Taper clip	= stainless steel
Outer pipe outer diameter	= 62mm
Outer pipe inner diameter	= 60mm
Inner pipe outer diameter	= 32mm
Inner pipe inner diameter	= 30mm
Heat transfer length	= 1.5m
Twist ratio of (TAT)	= 1:3
Width of (TAT)	= 20mm

Water at room temperature (20 to 25°C) is allowed to flow through outer pipe and hot water at 60-70ºC temperature is flowed through inner pipe**.**

3.1FORMULA USED FOR CALCULATION

1.Overall heat transfer coefficient, U

Performance of heat exchanger is evaluated normally by the overall heat transfer coefficient "U" that is defined by the equation

$Q = U \times A \times LMTD$

Where,

Q = Heat exchanged, KW

A= Heat transfer surface area, m²

LMTD= Log mean temperature difference in °C

1.U = Overall heat transfer coefficient, W/m²K

2.Heat transferred in hot fluid,$Q_h = WxC_{ph}$ x $(T_i\text{-}T_o)$

3.Heat transferred in cold fluid Q_c= W x C_{pc} x ($t_o – t_i$)

4.Heat transfer coefficient, $h_i = q/\Delta T(KW/(m^2K))$

5. Heat flux (q) = Q/A (KW/m^2)

6.Temperature range of hot fluid $\Delta T = T_i - T_o$ (K)

7.Temperature range of cold fluid$\Delta t = t_i - t_o$ (K)

8. Effectivness, $\epsilon = (t_o – t_i) / (T_i\text{-}T_o)$

9.LMTD = $((T_i – t_o) / (T_o - t_i))/ \ln((T_i – t_o) / (T_o – t_i))$

10.Reynolds number (Re) = ρVD / µ

Where,ρ= Density of the fluid (kg/m^3)

µ= Dynamic viscosity (kg/(m-s))

V = Mean velocity of fluid (m/s)

D = Diameter of pipe (m)

11.Nusselt number (Nu) = $0.023 \Pr^n Re^{(4/5)}$

Where, Pr = Prandtl number

12. Entrance length L_e= $1.359D(Re)^{1/4} \approx 10D$= 0.3m

IV. RESULT AND DISCUSSIONS

1.Reynolds Number vs Heat transfer coefficient

In this study, first we took the performance test of counterflow heat exchanger without twisted tape(TAT) and then with twisted tape(TAT). Both the results are compared and shown in the graph (fig4.1). The graph clearly shows that, when the flow is subjected to the twisted tape, the heat transfer coefficient (h_i) increases. This is because, the twisted tape will increase the reynolds number(Re) of flow, when the reynolds number(Re) increases, heat transfer coefficient also increases simultaneously.

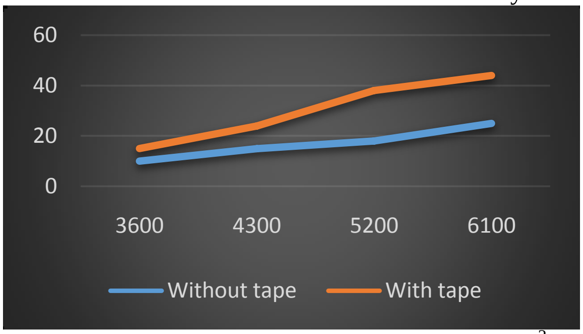

FIGURE 4.1. Reynolds Number(Re) vs hi (KW/m^2K)

2. Heat transfer (Q) vs Temperature of fluids

The temperature of fluid at inlet and outlet of both the pipes are compared with the heat transfer rate at both conditions (with & without TAT) and the results are shown in graphical form in fig.4.2& 4.3. The graph clearly shows that the outlet temperature of hot fluid reduces when the flow is subjected to TAT.

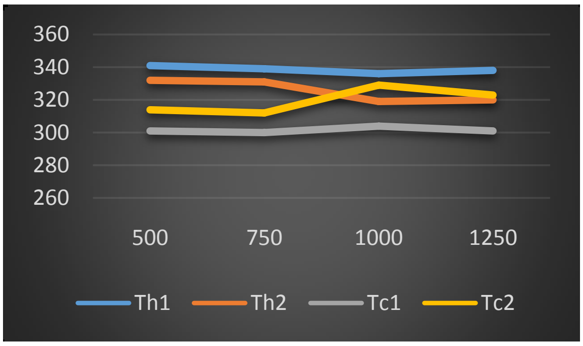

FIGURE 4.2. Heat transfer (Q), vs Temperature of fluids in (k) (without tape)

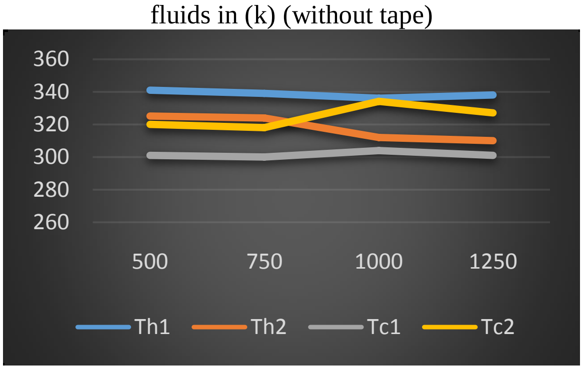

FIGURE 4.3. Heat transfer (Q) vs Temperature of fluids in (K) (With tape)

3. Length of pipe (L) vs Heat transfer rate (Q)

As said before, If the heat transfer length increases it will simultaneously increase the performance of heat exchanger. As we know, the length of pipe is directly proportional to heat transfer (Q), when the length of fluid flow increases, heat transfer rate also increases. The fig 4.4. clearly shows the heat transfer rate for different length of pipes we calculated.

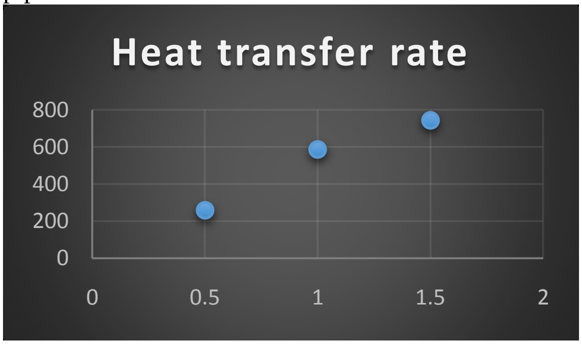

FIGURE 4.4. Length of pipe in (m) vs Heat transfer rate (Q)

V. FUTURE WORK

- In future, the next step is to rectify the pressure drop due to aluminium tape.
- We are also working on reducing the loss due to fouling factor
- We also try to reduce the workoutput to the agitator.

REFERENCES

[1] Saha, S. K. and Bhunia, K. Heat transfer and pressure drop characteristics of varying pitch twisted-tape-generated laminar smooth swirl flow. In Proceedings of 4th ISHMT–ASME Heat and Mass Transfer Conference, India, 2000, 423–428 (Tata McGraw-Hill, New Delhi).

[2] Saha, S. K. and Duttia, A. Thermo-hydraulic study of laminar swirl flow through a circular tube fitted with twisted tapes.Trans. ASME, J. Heat Transfer, 2001, 123, 417–421.

[3] S.Z. Heris, M. Nasr Esfahany, S.Gh. Etemad, Experimental investigation of convective heat transfer of sio2/water nanofluid in circular tube, International Journal of Heat and Fluid Flow 28 (2)(2007) 203-210.

[4] W.Y. Lai, B. Duculesciu, P.E. Phelan, R.S. Prasher, Convective heat transfer with fluids in a single 1.32-mm tube, in: Proceedings of ASME International Mechanical Engineering Congress and Exposition.

[5] Heat and mass transfer by R.S.Khurmi and K.Battachariya 2012-2013.