PERFORMANCE ANALYSIS OF PARALLEL AND COUNTER FLOW HEAT EXCHANGER WITH SQUARE TWISTED PIPE

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ABSTRACT:

Heat exchanger is a device that used to transfer thermal energy(enthalpy) between two(or)more fluids .The transient heat transfer in double tube counter flow & parallel flow heat exchanger was carried out with corrugations on inner tube by twisting the pipe from one end, which give the more swirling motion to fluid flowing through it.

The design of twisted pipe is done by using CATIA V5 software. The mass flow rate is regulated by using rotameters. Thermocouples are placed at inlet and outlet of both cold and hot fluids for measuring the required temperatures. The experimental calculations obtained from the twisted pipe heat exchanger are compared with the normal pipe heat exchanger

Keywords: - Heat exchanger, Twisted pipe, CATIA V5.

1. Introduction:

A heat exchanger may be defined as an equipment which transfers the energy from a hot fluid to a cold fluid, with maximum rate and minimum investment and running costs. In heat exchangers the temperature of each fluid changes as it passes through the exchangers, and hence the temperature of the diving wall between the fluids also changes along the length of exchanger. Examples of heat exchangers intercoolers and preheaters, regenerators, automobile radiators etc.

(i) In a parallel flow heat exchanger, as name suggests, the two fluid streams (hot and cold) travels in the same direction. The two streams enter at one end leaves at the other end. The flow arrangements and variation of temperature of fluid streams in case of parallel flow heat exchanger, are shown in figure. The temperature difference between the hot and cold fluid goes on decreasing from inlet to outlet. Since this type of heat exchanger needs a large area of heat transfer, therefore it is rarely used in practice.

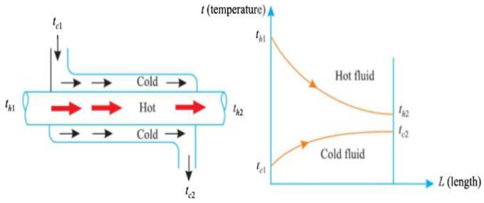

Fig: Parallel flow heat exchanger

(ii) In a counter flow heat exchanger, the two fluids flow in opposite direction. The hot and cold fluids enters at the opposite ends. The flow arrangement and temperature distribution for such a heat exchanger are in shown figure. The temperature difference between the two fluids remains more or less nearly constant. This type of heat exchanger, due to counter flow, gives maximum rate of heat transfer for a given surface area. Hence such heat exchanger are most favored for heating and cooling of fluids.

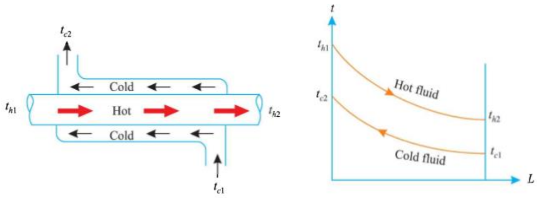

Fig: counter flow heat exchanger

In this experiment we are using square twisted pipe is made up stainless-steel material. That square twisted pipe was inserted in hallow circular pipe. Hot water supplied through the square twisted pipe and cold water supplied through circular pipe. We are using square twisted pipe to increase more heat transfer rate and effectiveness.

Fig: Square twisted pipe

2. Literature Review:

A W Date et.al. [1], experimentally determined pressure drop and heat transfer characteristics of flow of water in a spirally grooved tube with twisted tape insert. Laminar to fully turbulent ranges of Reynolds numbers was considered. The grooves are clockwise with respect to the direction of flow. Compared to smooth tube, the heat transfer enhancement due to spiral grooves is further augmented by inserting twisted pipe having twist ratios 10.15, 7.95 and 3.4. It is found that the direction of twist (clockwise and anticlockwise) influences the thermo-hydraulic characteristics. Constant pumping power comparisons with smooth tube characteristics show that in spirally grooved tube with and without twisted tape, heat transfer increases considerably in laminar and moderately in turbulent range of Reynolds numbers. Constant pumping power comparison with smooth tube shows that the spirally grooved tube without twisted tape yields maximum heat transfer enhancement of 400% in the laminar range and 140% in the turbulent range. Similar comparison for spirally grooved tube with twisted tape shows maximum enhancement of 600% in the laminar range and 140% in the turbulent range.

Pongjet Promvonge [2], studied influences of insertion of wire coils in conjunction with twisted tapes on heat transfer and turbulent flow friction characteristics in a uniform heat-flux, circular tube using air as the working medium. The wire coil used as a turbulator is placed inside the test tube while the twisted tape is inserted into the wire coil to create a continuous swirl flow along the tube wall. The effects of insertion of the two turbulators with different coil pitch and twist ratios on heat transfer and friction loss in the tube are examined for Reynolds number ranging from 3000 to 18,000. The experimental results are compared with those obtained from using wire coil and twisted tape alone, apart from the smooth tube. The results indicate that the presence of wire coils together with twisted tapes leads to a double increase in heat transfer over the use of wire coil and twisted tape alone. The combined twisted tape and wire coil with smaller twist and coil pitch ratios provides higher heat transfer rate than those with larger twist and coil pitch ratios under the same conditions. Therefore, the combined wire coil and twisted tape should be applied instead of using a single one, leading to more compact heat exchanger.

P. Promvonge and S. Eiamsa-ard. [3], they have experimentally investigated the heat transfer, friction factor and enhancement efficiency of circular tube fitted with conical ring tabulator and a twisted tape swirl generator. Air is used as a testing fluid for a Reynolds number range from 6000 to 26000 maximum heat transfer rate of 367% is obtained by using the conical ring tabulators. They have also observed that the maximum heat transfer rate is obtained at lower twist ratio for all the given range of Reynolds number value, The average increase in heat transfer rate obtained by using the conical ring tabulator and twisted tape at twist ratio of 3.75 and 7.5 are 367% and 350% over the plain tube.

3. Design and fabrication of experimental setup:

Design of the geometry was constructed CATIA V5 software. As the twisting for the pipe was available to construct in it, by the command tool twist and was twisted by taking the reference points as axis of the pipe and required number of twists in the pipe with twisted ratio of 6. It was important value to designing of twisted pipe heat exchanger.

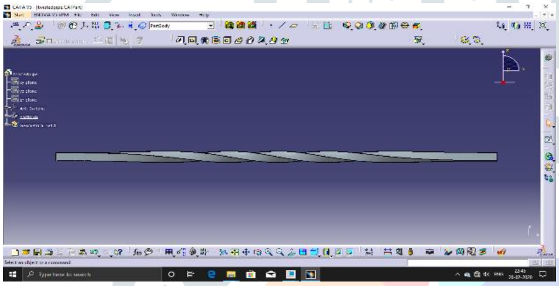

Fig: Geometry of twisted pipe

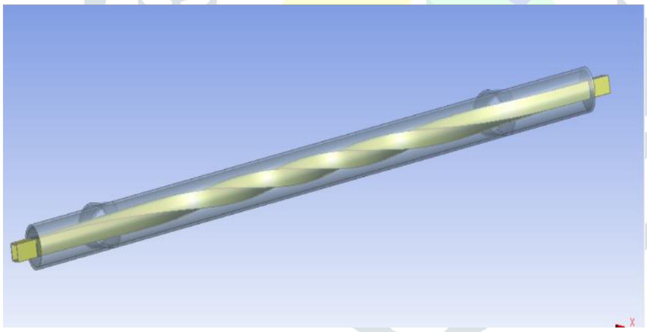

Fig: Square twisted pipe heat exchanger

In this experimental setup, the stainless steel and galvanized iron are used as the pipe materials. Manufactured circular and square geometry as twisted pipe heat exchanger. The circular pipe with 38.1mm diameter of 70cm length. The square twisted pipe with 15mm side of 75cm length. The rotameter are connected to cold water inlet and hot water inlet of the supply. For giving required mass flow rate of water. The thermocouples (k type) are connected to cold water inlet, outlet and hot water inlet, outlet.

Fig: Experimental setup

4. EXPERMENTATION PROCEDURE

. First switch ON the unit panel.

. Start the flow of cold water through the annulus and run the exchanger as counter flow or parallel flow.

. Switch ON the heater provided on the panel & allow to flow through the inner tube by regulating the valve.

. Adjust the flow rate of hot water and cold water by using rotameters & valves.

. Keep the flow rate same till steady state conditions are reached.

. Note down the temperatures on hot and cold water sides. Also note the flow rate.

. Repeat the experiment for different flow rates and for different temperatures. The same method is followed for parallel flow also.

5 . DATA COLLECTION AND ANALYSIS

The data was collected for square twisted pipe heat exchanger. The different flow rates for cold water and hot water are taken for parallel and counter flow heat exchanger. The heat transfer rate for cold water in test section. Q_c, can be expressed as,

$$Q_c = m_c * cp_c *(Tc_o - Tc_i)$$

Where, m_c is the flow rate of cold water, cp_c is the specific heat of water, Tc_o and Tc_i are outlet and inlet cold water temperatures respectively. The heat transfer rate for hot water, can be expressed as,

$$Q_h = m_h * cp_h * (Th_i - Tho)$$

Where, m_c is the flow rate of hot water, Cp_h is the specific heat of water, Th_i and Th_o are outlet and inlet hot water temperature respectively. All the thermophysical properties are calculated at the averages of inlet and outlet hot fluid temperatures.

$$Q_{avg} = \frac{Q_h + Q_c}{2} \text{ watts}$$

LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD): This is defined as that temperature difference which, if constant, would give the same rate of heat transfer as usually occurs under variable conditions of temperature difference.

$$\text{LMTD} = \frac{(T_{ho} - T_{co}) - (T_{hi} - T_{ci})}{\ln\left(\dfrac{T_{ho} - T_{co}}{T_{hi} - T_{ci}}\right)} = \frac{\theta_2 - \theta_1}{\ln\left(\dfrac{\theta_2}{\theta_1}\right)}$$

OVERALL HEAT TRANSFER COEFFICINET:

The rate of heat transfer between hot and cold fluid is given by

$$Q = U_o A_o / LMTD$$

Where, U_o is overall heat transfer coefficient based on outer surface area of tubes, W/m²-K

A_o is the total outer surface area of tubes, m²

EFFECTIVENESS: Effectiveness of a heat exchanger is defined as the ratio of actual heat transfer rate to the theoretical maximum possible heat transfer rate.

Effectiveness: $$\varepsilon = \frac{Q}{Q_{\max}}$$

It can be shown that $$\varepsilon = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}} \quad \text{if } m_h c_h < m_c c_c$$

$$\varepsilon = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} \quad \text{if } m_c c_c < m_h c_h$$

\Where,

m_h and m_c are the mass flow rate of hot and cold fluids respectively in kg/s;

c_h and c_c are the specific heat of hot and cold fluids respectively in J/kg–K.

6. RESULTS AND DISCUSSION

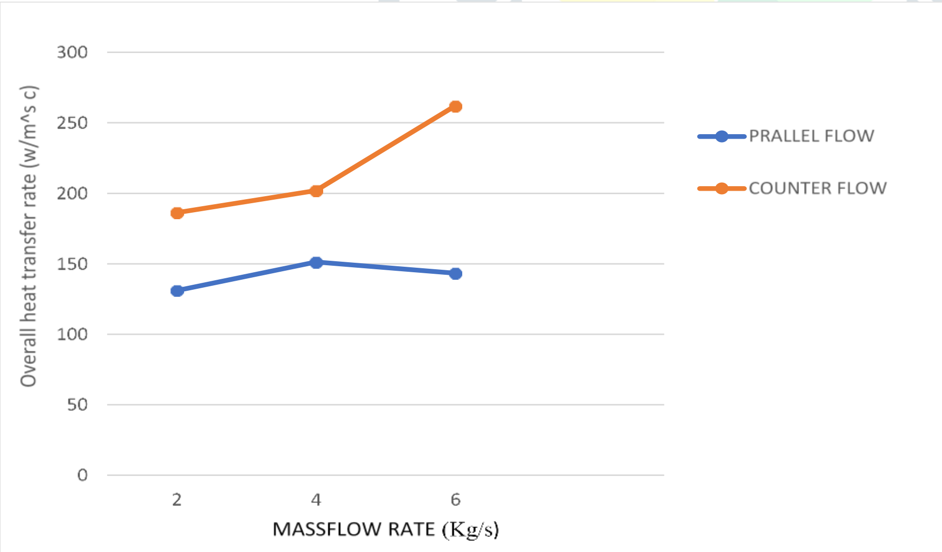

Fig: 6.1 overall heat transfer rate Vs mass flow rate at cold water fixed.

From the fig. 6.1 it is observed that there is increased in overall heat transfer rate with mass flow rate. As overall heat transfer rate increases the water flow will causes more turbulence due to which heat transfer rate will increases. It was conducted where the cold water mass flow is fixed at maximum level and hot water mass flow is varies from minimum to maximum level.

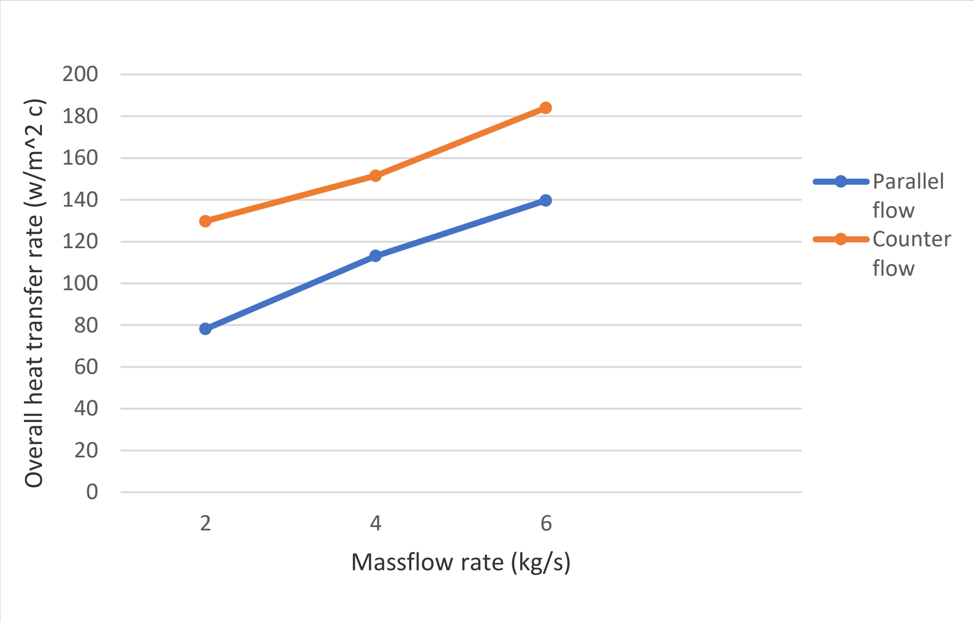

Fig 6.2 Overall heat transfer rate Vs mass flow rate at hot water fixed.

it is observed that there is increased in overall heat transfer rate with mass flow rate. As overall heat transfer rate increases the water flow will causes more turbulence due to which heat transfer rate will increases. It was conducted where the hot water mass flow is fixed at maximum level and cold water mass flow is varies from minimum to maximum level.

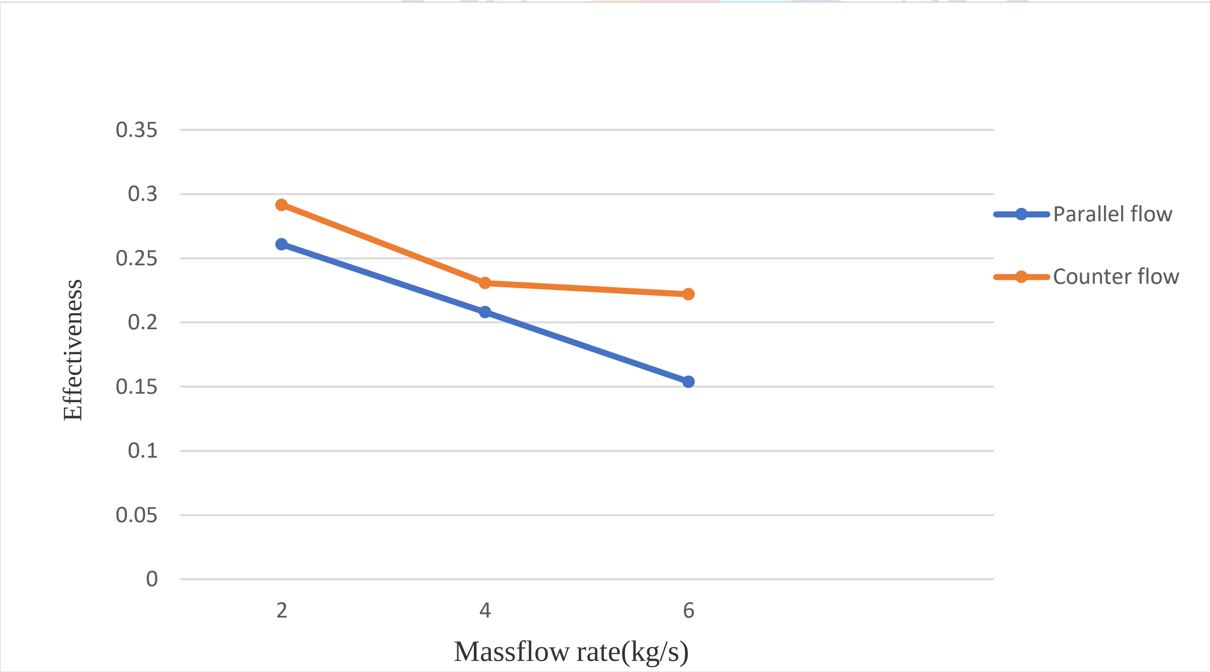

Fig 6.3 Effectiveness Vs mass flow rate at cold water fixed.

it is observed that there is decreasing in effectiveness with mass flow rate. As effectiveness decreases the water flow will causes more turbulence due to which effectiveness will decreases. was conducted where the cold water mass flow rate is fixed at maximum level and hot water mass flow rate is varies from minimum to maximum level.

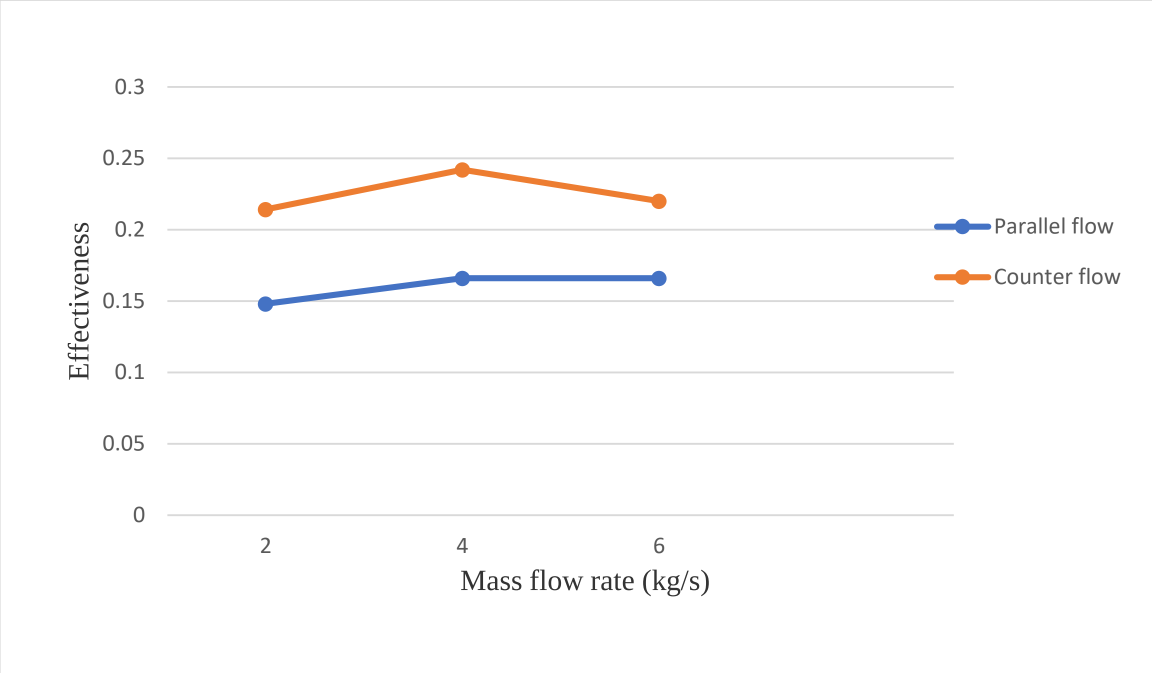

Fig 6.4 Effectiveness Vs mass flow rate at hot water fixed

it is observed that there is decreasing in effectiveness with mass flow rate. As effectiveness decreases the water flow will causes more turbulence due to which effectiveness will decreases. was conducted where the hot water mass flow rate is fixed at maximum level and cold water mass flow rate is varies from minimum to maximum level.

7. CONCLUSIONS

In this experimentation and analysis for square twisted pipe heat exchanger had completed the calculations gives overall heat transfer rate and effectiveness at cold water mass flow rate and hot water mass flow rate are fixed , from the results we states that cold water mass flow fixed condition producing more heat transfer rate and effectiveness at both parallel and counter flow conditions.

8. ACKNOWLEDGEMENT

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9.REFERENCES

1) Todd Griffith, Luai. Hadhrami, Je-Chin Han," Heat transfer in rotating rectangular channels with dimples", Journal of Turbo Machinery, 125(2003)555-565.

2) P.K. Pal and S.K. Saha,"Thermal and friction factor characteristics of laminar flow through square duct and rectangular duct with transverse ribs and twisted tapes with and without oblique teeth" Journal of enhanced heat transfer 17(2010)1-21.

3) P. Bharadwaj, A.D. Khondge, A.W. Date, "Heat transfer and pressure drop in a spirally grooved tube with twisted tape insert," International Journal of Heat and Mass Transfer 52 (2009) 1938–1944 4) Pongjet Promvonge ,"Thermal augmentation in circular tube with twisted tape and wire coil turbulators", Energy Conversion and Management 49 (2008) 2949–2955

5) P.Promvonge, S.Eiasma-ard" Heat Transfer behavior in a tube with combined conical-ring and twisted tube insert" International journal on Heat Transfer(2007)

6) Vamsi Mokkapati, Chuen-Sen Lin "Numerical study of an exhaust heat recovery system using corrugated tube heat exchanger with twisted tape inserts." International Communications in Heat and Mass Transfer 57 (2014) 53–64

7) Pranab Kumar Pal, Sujoy Kumar Saha "Experimental investigation of laminar flow of viscous oil through a circular tube having integral spiral corrugation roughness and fitted with twisted tapes with oblique teeth.", Experimental Thermal and Fluid Science 57 (2014) 301–309

8) Ventsislav Zimparov,"Enhancement of heat transfer by a combination of single start spirally corrugated tube combined with twisted tape inserts.", Experimental Thermal and Fluid Science 25 (2002)535–546

. 9) Pongjet Promvonge, S. Pethkool, M. Pimsarn, C. Thiaffong," Heat transfer augmentation in a helically ribbed tubes with double twisted tape inserts", International communication in Heat and Mass Transfer 39(2012)953-969.