Experimental Analysis and Performance Characteristic Of Heat Transfer In Shell and Twisted Tube Heat Exchanger.

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Abstract - All new heat exchanger applications in oil refining, chemical, petro-chemical, and power generation are accommodated through the use of conventional shell and tube type heat exchangers. The fundamental basis for this statistic is shell and tube technology is a cost effective, proven solution for a wide variety of heat transfer requirements. However, there are limitations associated with the technology which include inefficient usage of shell side pressure drop, dead or low flow zones around the baffles where fouling and corrosion can occur, and flow induced tube vibration, which can ultimately result in equipment failure. This paper presents a recent innovation and development of a new technology, known as Twisted Tube technology, which has been able to overcome the limitations of the conventional technology, and in addition, provide superior overall heat transfer coefficients through tube side enhancement. This paper compares the construction, performance, and economics of Twisted Tube exchangers against conventional designs for copper materials of construction including reactive metals.

Key Words: Heat exchanger, twisted tube technology, heat transfer, corrosion resistance, Increase efficiency.

1. INTRODUCTION

Heat Exchanger is a device used for efficient heat transfer from one fluid to other fluid a typical heat exchanger is shell and tube heat exchanger. They consist of series of finned tubes in which one of the fluid runs in the tube and the other fluid run over the tube to be heated or cooled during the heat exchanger operation high Pressure high temperature water or steam are flowing at high velocity inside the tube or plate system. A heat exchanger utilizes the fact that, where ever there is a temperature difference, flow of energy occurs. So, That heat will flow from higher temperature heat reservoir to the lower temperature heat reservoir. The flowing fluids provide the necessary temperature difference and thus force the energy to flow between them. The energy flowing in a heat exchanger may be either sensible energy or latent heat of flowing fluids. The fluid which gives its energy is known as hot fluid. The fluid which receives energy is known as cold fluid. It is but obvious that, Temperature of hot fluid will decrease while the temperature of cold fluid will increase in heat exchanger. The purpose of heat exchanger is either to heat or cool the desired fluid.

"Xiang-hui Tan et.al [3]", stated the effects of geometrical parameters on the performance of the twisted tube. The result reveals that the heat transfer coefficient and friction factor both increase with the increase of axis ratio a/b, while both decrease with the increase of twist pitch length P. They also stated that the emergence of twist in the twisted oval tube results in secondary flow. It exists in the form of spiral flow when a/b is big, but in the form of up and down when a/b is small. It is this secondary flow that changes the total velocity and temperature distributions of the twisted tube when compared with a plain tube with the same sectional geometric parameters. Then the synergy angle between velocity vector and temperature gradient is reduced and the heat transfer process is enhanced.

"Guo et.al. [1] ", stated the importance of synergy angle, which is the angle between velocity and temperature profile. They stated that better the synergy of velocity and temperature gradient/heat flow fields, higher will be the convective heat transfer rates under the same other conditions. A larger tube aspect ratio and a smaller twist pitch will result in a higher synergy level and thereby lead to the improvement of heat transfer, which can well explain the effects of tube structural parameters on the heat transfer performance of the Twisted elliptical tubes (TETs).

"Sheng Yang et.al [4]", discovered that the experimental Nusselt numbers/friction factors can be expressed with one unified equation for entire Reynolds number range, which confirms the early flow transition from laminar to turbulent in Twisted Elliptical Tubes. The longitudinal vortex Induced by The twisted tube wall improves the synergy between the Velocity vector and temperature Gradient, which in turn results in a better heat transfer performance.

"Xiang-hui Tan et.al [3]", stated that the heat transfer coefficient Of the twisted oval tube heat exchanger is higher and the pressure drop is lower than the rod baffle heat exchanger. They Also stated that analyze of the overall performance of the twisted oval tube shows that the twisted oval tube heat exchangers works more effectively at low tube side flow rate and high shell side flow rate.

"Ozden Agra et. al.[5]", showed the variation of pressure drop penalty (h/ΔP) with Reynolds numbers for number of enhanced tubes. They stated that Even though enhanced tubes have higher heat transfer coefficient values, their h/Δp values are lower than those of the plain tube due to their higher pressure drops. From the above we can find that most of the researchers focused on the heat transfer and pressure drop performance of the twisted oval tube heat exchanger with traditional shell-tube heat exchanger design. Therefore in present study the performance evaluation of the twisted tube is carried out for multi pass type of heat exchangers aiming to obtain the performance, the twisted tube heat exchanger and plain tube heat exchanger is experimentally studied in the present work and compared with each other. In present study, the twisted tube made of major and minor diameters of 10 mm and 9 mm respectively and pitch, as in fig.1, is studied. The tubes are made of copper and are enclosed in the shell of inner dia.150 mm & outer dia. 162 mm Tube is made in multiple tube pass (10 pass) of each pass 360 mm length. This arrangement style is similar to the most common configuration for feed water heater used in thermal power plant. The performance parameters are then studied in the plain tube of 9mm ID, 10mm OD and length of 380 meter for comparison in the same environment.

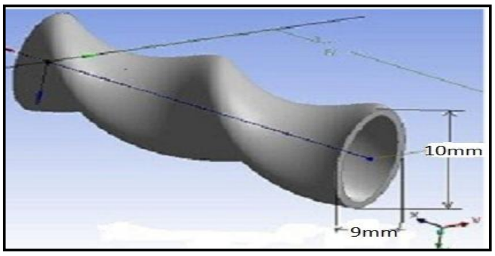

Fig:1. Dimensions of twisted tube for one turn

There are Eight flow rates used in this experiment 10 lpm,12 lpm, 14 lpm, 16 lpm,18lmp, 20lpm,22lpm and 24 lpm are employed resulting in Reynolds number of fully developed flow range of Re 2500 to 1.25 x 10^6 covering turbulent flow. The temperature and pressure are calculated across the heat exchanger at various mass flow rate of hot and cold water. The various features like overall heat transfer coefficient, friction factor, Nussle number are calculated by using temperature, mass flow rate, and pressure drop across heat exchanger.

It is reported by "Guo et.al [2]", that in twisted tubes, heat transfer increases because of turbulence and secondary flow.

2. HEAT TRANSFER ENHANCEMAENT TECHNIQUES

- Heat transfer enhancement is one of the fastest growing areas of heat transfer technology.
- The technologies are classified into active and passive techniques depending on how the heat transfer performance is improved.
- A twisted tube is a typical passive technique that uses a specific geometry to induce swirl on the tube side flow.
- The twisted tube heat exchanger consists of a bundle of uniquely formed tubes assembled in a bundle without the use of baffles.
- Twisted tube technology provide highest heat transfer coefficient possible in tubular heat exchanger.
- In uniform shell side flow the complex interrupted swirl flow on shell side maximizes turbulence while minimizing pressure drop.
- The tube ends are round to allow conventional tube to tube sheet joints.
- Swirl flow in tube create turbulence to improve heat transfer.
- By keeping the flow turbulent one secures a high heat transfer performance.

3. Technical Detail for Plain Tube bundle & Twisted Tube bundle.

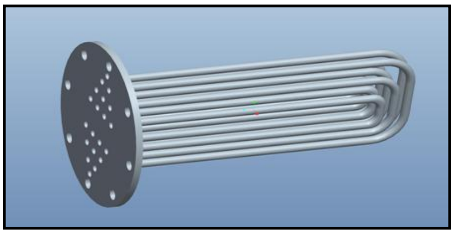

Fig:2. Plain Tube bundle

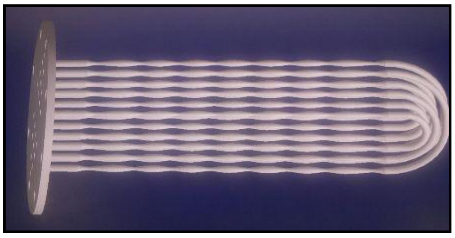

Fig:3. Twisted Tube bundle.

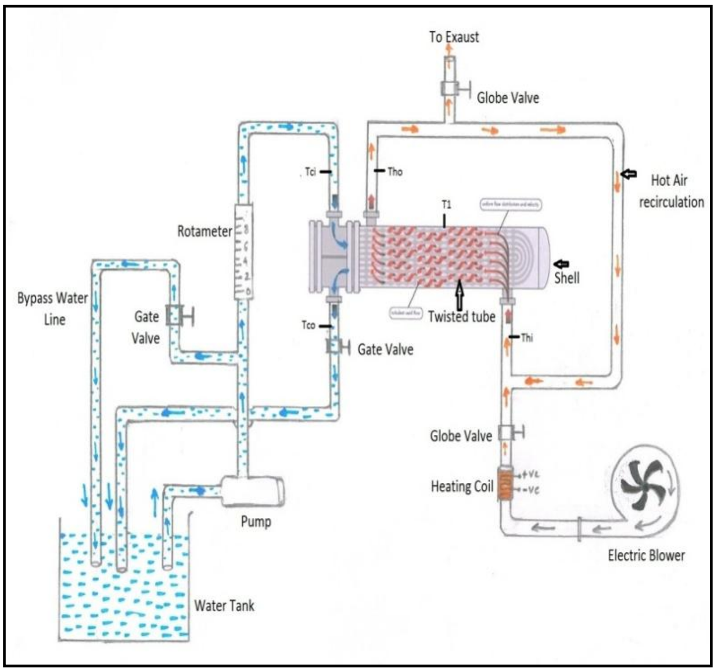

Fig:4. Experimental setup with Twisted Tube Inserted in the Shell.

4. EXPERIMENTAL SET-UP

The setup consist of Shell in which tubes bundle are fitted at the center of shell. Shell front head divided into two part one part for inlet of cold water & other part for outlet of hot water. Water tank is use for supplying and collecting of water, A blower is used to force the air over the tube inside a shell, Heating coil is used for heating the air to heat the tubes inside a shell, centrifugal type of water pump is to pump the cold water at the inlet of shell front head & then water is pass to tubes & it is heated inside the tube we get hot water at the outlet & then water is back to the water tank, the capacity of water tank is 45 liters, the tube length including the circular end is 360 mm, inner diameter of tube is 9 mm, outer diameter of tube is 10 mm, & shell length is 400 mm, inner diameter is 150 mm, Outer diameter is 162 mm. The tube material is copper and shell dia is mild steel, Anemometer is used to measure the velocity of air, outer surface of shell & mild steel piping are insulated by glass wool insulation in order to reduced heat loss, for measuring the flow rates Rotameter is used range of 0-100 lpm with the help of valve flow rate of water is controlled, Thermocouple of T type is used with a digital temperature indicator, Tubes are assembled into a bundle on a triangular pitch one row at a time with each tube being turned to align the twists at every plane along the bundle length. Experimental setup shown in fig:4 as given below.

5. EXPERIMENTAL PROCEDURE

By using the tap water fill the water tank and then start the pump also switch on Ammeter, Voltmeter, Temperature indicator, Heating coil & Blower, then Ammeter & Voltmeter set the current & voltage range with the help of thermostat which gives the uniform heat flux to the heating coil. Initially only first inlet valve is opened but exit valve is closed, this ensure that the tubes are completely fill with water. First of all take the reading of plain tube, setup would be run for about half an hour for steady state, set the rotameter reading with the help of valve at 10 LPM take the water temperature reading at inlet, outlet i.e (Tc_i, Tc_o) & hot air reading at inlet, outlet i.e (Th_i, Th_o). also note down ammeter & voltmeter reading. After obtaining steady state take second reading at 12 LPM & note down all reading, repeat the same procedure at different flow rate i.e from 10 LPM to 24 LPM after each 10 minute time interval. Similarly air side velocity varies from 2.8 m/s to 4.7 m/s. Tubes are heated with the help of hot air & hence conduction heat transfer takes place & inside water get heated, the hot air is recirculate continuously, then the procedure is repeated. Replacing the plain tube bundle with twisted tube & compare the plain tube & twisted tube parameter.

6. RESULT AND DISCUSSION

The fouling resistance of the heat exchanger is assumed to be zero. First the analytical calculation is done and then it is compared with the experimental readings and calculations.

Heat transfer from hot and cold fluids as given by:

$$Q = m_h . Cp_h .(Th_i - Th_o) = m_c . Cp_c .(Tc_o - Tc_i) \quad (1)$$

For calculating the Number of transfer units:

$$NTU = \frac{U_0 A}{Cmin} \quad (2)$$

U_0 can be determined by the following formula:

$$\frac{1}{U_0} = \frac{1}{ho} + \frac{ro}{hi.ri} + \frac{ro.\ln\left(\frac{ro}{ri}\right)}{K} \quad (3)$$

In "(3)", hi and ho can be calculated by employing the relation for Nusselt number as follows:

$$Nu_i = 0.023.Re^{0.8}.Pr^{0.3} \quad (4)$$

$$h_i = \frac{Nui.k}{di} \quad (5)$$

$$Nu_o = 0.26.\ Re^{0.6}.Pr^{0.37}\left(\frac{Pra}{prw}\right)^{0.25} \quad (6)$$

$$h_o = \frac{Nuo.k}{di} \quad (7)$$

Heat Exchanger effectiveness given by formulae:

$$\varepsilon = \left\{ \frac{1-e^{[-NTU\ (1-C)]}}{1-c\ e^{[-NTU\ (1-C)]}} \right\} \quad (8)$$

In this way outlet temperature of water can be found. Experimental values are found as:

$$m.\ Cp.\ (Thi - Tho) = U.\ A.\ F.\Delta T_{LMTD} \quad (9)$$

Friction factor for the plain tube is determined by:

Turbulent range: $$f = \frac{0.316}{Re^{0.25}} \quad (10)$$

Friction Factor for twisted tube is given in the form of unified equation by"Sheng Yang et.al.[4]", as :

$$f = 1.529.\ (Re)^{-0.350}.\ \left[\frac{A_i}{B_i}\right]^{1.686}.\left[\frac{s}{d_i}\right]^{-0.366} \quad (11)$$

The pressure drop for both the tubes was calculated by the equation given by "Ozden Agra et.al.[5] ...

$$\Delta P = f.\ \left[\frac{L}{d}\right].\ \left[\frac{\rho.U^2}{2}\right] \quad (12)$$

Reynolds No. is given by:

$$Re = \frac{\rho v D}{\mu} \quad (13)$$

Experimental, analytical and numerical studies are done to determine the behavior of twisted tube and compared with the plain tube in order to analyze twisted tube's applicability in multipass applications.

The experiment is dividing in two cases.

Cases I: Experiment on test tube with plain Tube bundle.
Cases II: Experiment on test tube with Twisted Tube bundle.

Based on observation table & calculations following are plotted for interpretation of performance:-

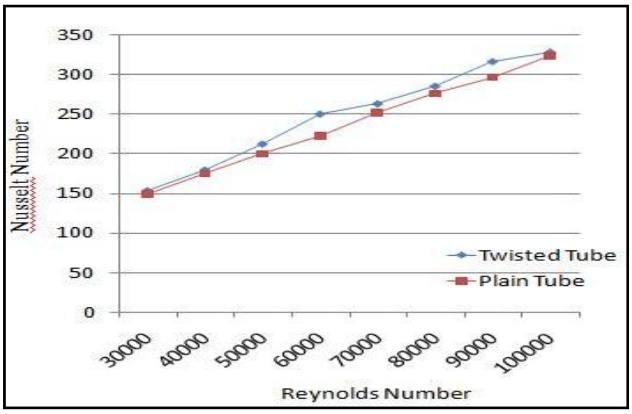

Fig: 1. Reynold Number Vs Nusselt Number

From above graph it is observed that when Reynolds number is increased the nusselt number is also increasd. and when Reynolds number increased water flow more turbulence and due to which heat transfer rate will be increased. Heat transfer coefficient is directly proportional to the nusselt number i.e increased with nusselt number heat transfer coefficient also increased. minimum nusselt number is obtained in plain tube and maximum nusselt number is obtained with twisted tube.

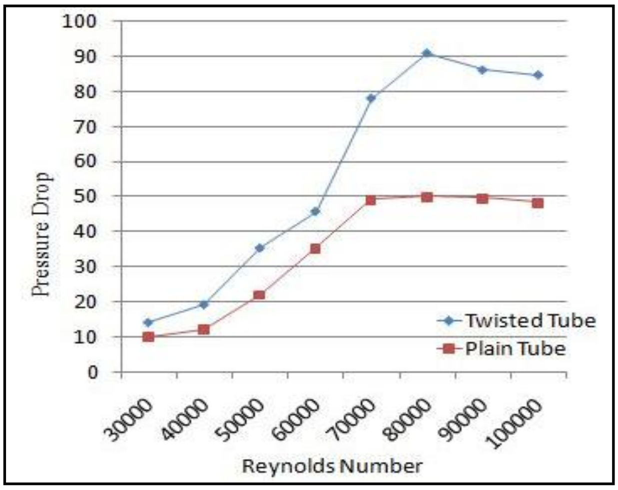

Fig: 2. Reynold Number Vs Pressure Drop.

From above graph it is observed that pressure drop increases with increased in Reynold number. In twisted tube pressure drop is more and in plain tube pressure drop is less with increase of Reynold number as shown in above graph hence it is clear that the performance of Twisted tube is better than plain tube as shown in above graph.

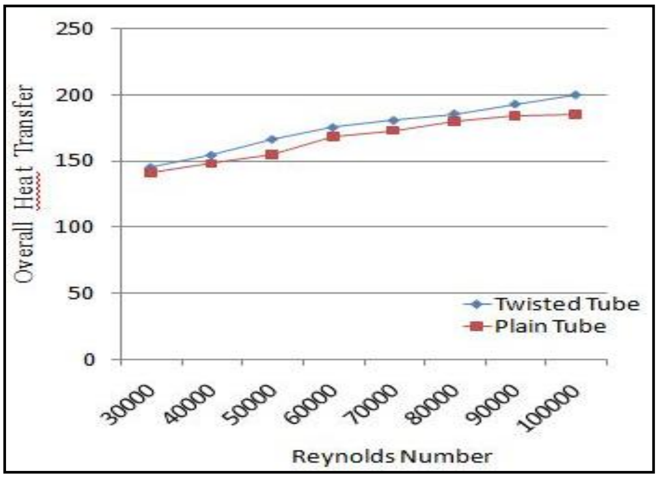

Fig: 3. Reynold Number Vs. Overall Heat Transfer

From above graph it is observed that Reynold number is increased with increased the overall Heat transfer coefficient. the water flows more turbulence hence Reynolds number increased. From graph it is observed Twisted tube create more turbulence than plain tube which gives more Reynold number twisted tube gives maximum heat transfer coefficient than plain tube.

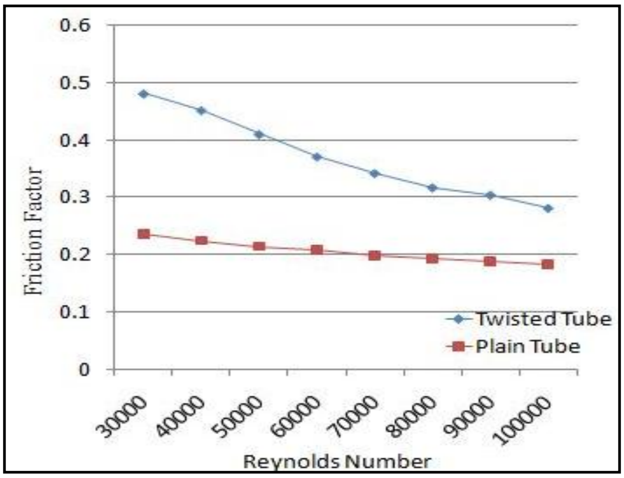

Fig: 4. Reynold Number Vs Friction Factor

From above graph it is observed that friction factor is decreased when the Reynolds number is increased because friction factor is inversely proportional to the velocity. hence velocity is increased i.e Reynold number is also increased and friction factor will decreased. In twisted tube friction factor is more and due to these pressure drop is maximum in tube. From graph it is observed that less friction factor is obtained in plain tube.

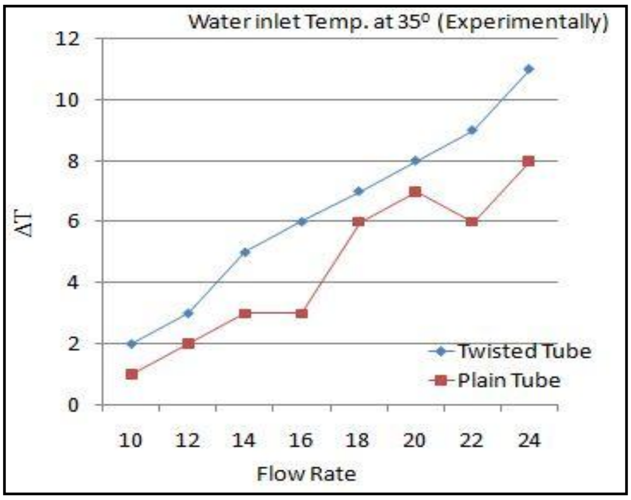

Fig: 5. Flow Rate Vs Temperature difference

From above graph it is observe that water inlet temperature at 35^0 experimentally, the flow rate increases with increase in temperature difference It is found that performance of Twisted tube is more as compare to plain tube because in twisted tube flow rate is more and temperature difference is also more.

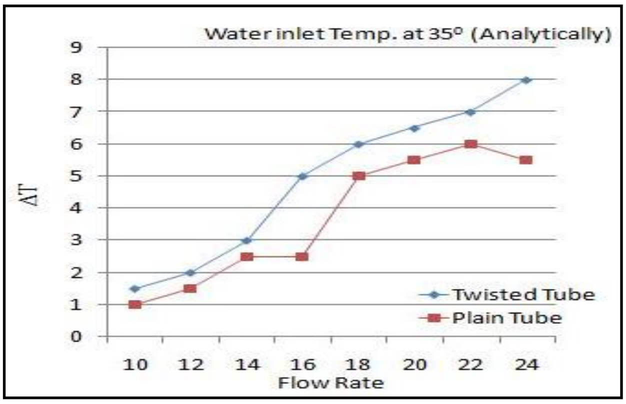

Fig: 6. Flow Rate Vs Temperature difference

Analytical calculation are used to verify the experimental setup, comparisons of the performance of both tube as shown above: The performance of twisted tube is better than plain tube analytically due to increase of flow rate in twisted tube turbulence is also increases, temperature difference is vary with increase of flow rate.

7. CONCLUSIONS

Analytical study has been done to get the experimental and Numerical values verified. By using twisted tube we get highly turbulent flow compare to plain tube. Tube and shell type of cross flow heat exchanger was employed. Reynolds number range for fully develop flow is from Re 2500 to 1.26×10^6 covering turbulent range. overall heat transfer coefficient of twisted tube heat exchanger increases compare to plain tube.

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