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Comparison of Heat Transfer Characteristics of Shell and Tube Heat Exchanger by using Twisted Tapes and Wire Wound Wire Matrix as tube Inserts

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Abstract:
In present day it is necessary to optimize the heat transfer characteristic of heat exchangers, as heat exchangers are universal equipments which are used in day to day life, in industry, home appliances, transportations and power production units. Thermal characteristics are studied for the tube in the shell and tube heat exchanger working with water as working fluid for two different configurations of twisted tape.1)Twisted tapes and 2)Soldered wire wound inserts(wire wound wire matrix). Experiment was carried out by using these two types of inserts on the tube side. This project work deals with laminar flow in the tube side; Re varies from 200 to 600. Experiment carried out by maintaining the constant tube wall temperature with tube flow rate and shell flow constant. Twisted tapes used in this experiment have 2.2 twist ratio, and. The heat transfer and pressure drop in case of twisted tape and Soldered wire wound inserts with baffles are found to increase by 110 to 120% and 130 to 140% respectively compared to that of plain tube.

I. Introduction:

Heat exchangers are the devices, provides the flow of thermal energy between two or more fluids at different temperature. Fundamental of heat exchanger principle is to facilitate an efficient heat flow from hot fluid to cold fluid. Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & homemade applications figure 1 shows the basic structure of shell and tube heat exchanger.

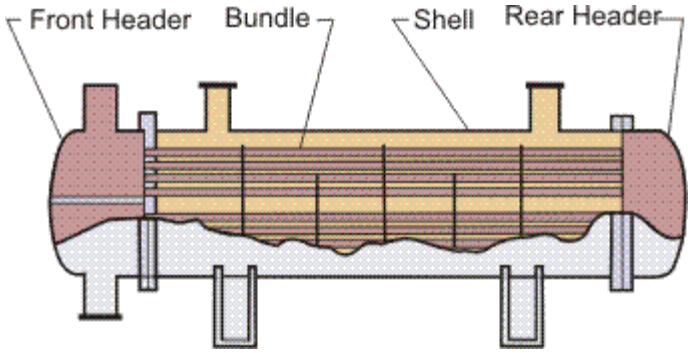

Fig-1 Shell and Tube Heat Exchanger

Increase in heat exchanger's thermal performance which can result in fabricating more dense and economical heat exchangers. There are three methods to increase the thermal performance of heat exchangers, those are.

Active Method

This method requires some external power input for the improvement of thermal performance of heat exchanger; examples are mechanical aids, surface vibration, fluid vibration, electrostatic fields, suction and jet impingement

Passive Method

This method generally uses amendments to the flow in the tube of heat exchangers by fitting inserts into the tube. Such method does not need any type of external power. Due to these inserts the flow get disturbed and turbulence is created which results in increase in pressure drop, decreasing the tube wall temperature and thereby increase in heat transfer coefficient.

Compound Method

When two or more methods incorporated simultaneously to obtain improvement in thermal performance of heat exchanger is termed as compound method. Hence obtained thermal performance of heat exchanger is greater than that produced by any one method of them when used individually.

II. Literature Survey

The literature survey shows different passive techniques for enhancing thermal performance of heat exchanger. Manglik and Bergles [1] gave experimental data for three different twisted tapes under uniform wall temperature boundary conditions. The experiments were conducted with water and ethylene glycol as working medium. From the experimental results the authors resulted that improvement in thermal performance takes place due to developed swirl flow due to the tape twist. Due to decrease in the area of flow there is increase in flow velocity and turbulence mixing, which results in increase in heat transfer coefficient and pressure drop.

S.Selvam et al [2] performed Experimental investigations of heat transfer and friction factor characteristics of a circular tube fitted with full-length twisted tape with pins of different twist ratios have been studied in tube in tube heat exchangers for the turbulent flow of Re ranging between 10000 to 23 000. Author suggested that use of bonded twisted tape with pins in the tube in tube heat exchanger enhances the heat transfer with significant pressure drop.

S. Eiamsa-ard et al [3] reported result of experiment conducted using delta-winglet twisted tape and typical twisted tape, the values of Nusselt's number and friction factor in the tube fitted with delta-winglet twisted tape are evidently higher than those in the plain tube and also tube with typical twisted tape, author gives that the Nu and friction factor increases as twist ratio decreases. Also oblique delta-winglet twisted tape gives better thermal characteristics than straight delta-winglet twisted tape. M Ahmed et al [4] conducted experiment on the tube fitted with three twist ratios (y=23, 11.5, 8) and air is used as working media, author gives that as the Reynolds number increases average heat transfer coefficient increases. That is average heat transfer coefficient with twisted tapes 1.3 to 3 times higher than that of the smooth tube.

Saha et al [5] experimentally studied the friction factor and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape.

M.M.K. Bhuiya et al. [6] experimentally studied influence of triple helical tapes inserted for turbulent flow through a tube on heat transfer enhancement. Triple helical tapes with different helix (α=90 130 170) are used for experiment, author observed that, the helical tape with helix angle 90 gives maximum heat flux compared to other helical tapes.

Anil S Yadav [7] studied influence of the half length twisted tape on thermal characteristics in a U-bend double pipe heat exchanger, author used oil as working media, result obtained as 40% heat transfer coefficient increased in tube fitted with half length twisted tapes than that of plain tube.

V Zimparov and P Penchev [8] experimentally suggested the different tube inserts for a shell and tube heat exchanger between twisted tapes, springs.

C. Yildiz et al. [9] were studied twisted narrow tapes and thin metallic strips placed in the inner pipe of a concentric double-pipe heat exchanger using air as hot and water as cold fluid and gives their effect on heat transfer and pressure drop for parallel and counter current flow. The experiments were performed with Re number between 3400 and 6900. The effect of the turbulators on the heat transfer is more evident for high Re.

A W Date [10] developed experimental numerical model for predictions of heat transfer for twisted tape insert in fully developed laminar flow at constant temperature. Bodius Salam [11] gives an experimental study heat transfer coefficient turbulent flow of water in the tube fitted with the twisted tape, author observed that by using twisted tape 13% increase in the Nu and 70% increase in the heat flux than those obtained from plain tube.

N. B. Dhamane et al [12] experimentally investigated heat transfer and pressure drop in tube fitted with the typical twisted tape as well as wavy twisted tape, taken air as working media, author found that het transfer rate increased by17 to 40% in the tube fitted wavy twisted tapes of twist ratio 8.33, and as twist ratio increases heat transfer rate also increases along with pressure drop. F T. Kanizawa et al [13] gives new correlation for the heat transfer and pressure drop in tube fitted with twisted tape for both single phase and two phase flow in tube.

S. Ray, A.W. Date [14] gives the numerical prediction of laminar flow as well as turbulent flow and thermal properties in duct fitted with the twisted tape. Author proposed the correlation for heat transfer coefficient and pressure drop. S W Chang [15] used single, double and triple twisted in the tube for experiment, author gives the heat transfer characteristics enhances with number of twisted tapes in the tube for the Re ranging from 1500 to 14000.

S V. Patil and P. V. Vijay Babu [16] performed experimental study on the concentric double pipe heat exchanger with twisted tapes fitted into the inner duct and Ethylene glycol as working fluid, author found that for twisted tape with low twist ratio gives better heat transfer rate and pressure drop.

A. V. N. Kapatkar et al [17] experimentally studied the thermal performance of the heat exchanger fitted with different twist ratio as well as made up of different materials, author suggested that the aluminum twisted

tape with twist ratio 5.2 and 4.2 are performed better that Stainless Steel twisted tapes. S. Eiamsa-ard and P. Promvonge [18] performed experiment to find heat transfer rate and friction factor on wavy tube fitted with helical tape, author gives that the combination of both wavy surfaced tube and helical tape gives higher heat transfer rate compared with friction factor. S.D.Patil et al [19] experimentally studied the straight delta winglet and typical twisted tapes fitted in the tube of double pipe heat exchanger, water is used as working fluid. Author found that for same twist ratio and Re the straight delta winglet preformed better than typical twisted tape. Al Amin et al [20] studied experimentally the heat transfer performance by placing a rotating twisted tape inside the tube; author gives that heat transfer performance is better when the flow rate is high and RPM of twisted is more.

Sarada et al [21] did experimental and numerical analysis of turbulent flow of air flowing through tube built in with mesh inserts, they studied 16 different mesh inserts with varying mesh density, author concluded there result that experiment result for higher density mesh is not possible that can be optimized by CFD analysis.

Mehmet Sozen and T M Kuzay [22] numerically studied the improved heat transfer in circular tubes filled with rolled copper mesh and Reynolds number ranging from 5000-19,000. With water as the working fluid, the tube is applied with uniform heat flux, they resulted up to ten times increase in heat transfer coefficient with brazed porous inserts compared to plain tube at the rate of increased pressure drop.

Hsieh et al [23] Experimentally tested the heat transfer performance in tubes with square, rectangular and crossed longitudinal strip inserts with Aspect ratio AR=1 and 4.

Ehsan Rezaei et al [24] studied the enhancement of heat transfer coefficient and pressure drop of fluid flow through pipe fitted with butterfly inserts of different inclination angle by imperialist competitive algorithm (ICA), author found that the maximum performance heat exchanger is for butterfly insert with 950 inclinations.

Details of twisted tapes and soldered wire wound inserts:

Initially stainless steel twisted tapes of width 12mm, thickness 3mm and length 825mm having twist ratio 2.2 are fabricated. Strip of same material of height 5.5mm, length 12mm were made, then at equal distances those strips are fixed on the hence fabricated twisted tapes as baffles at an angle of 450 with normal axis of twisted tape by the aid of gas welding using copper as the filling material. Figure -2

Soldered wire wound Tabulators are used in present experiments as second inserts, these inserts has high wire loop density on rigidly fixed central rod where the loops of wires soldered to central wire rod. These inserts for present work fabricated with pitch 9.5mm; pitch indicates the distance between the two conjugative wire loops. As shown in figure-3.

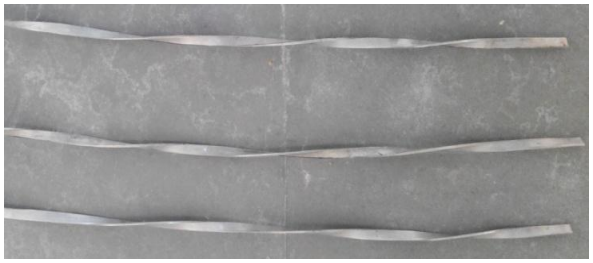

Fig-2 Twisted tapes.

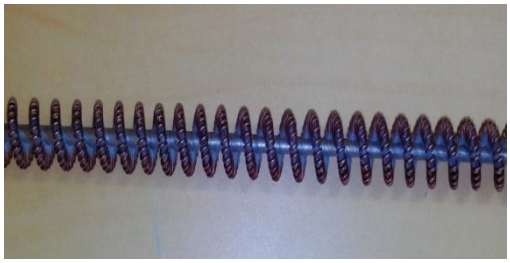

Fig-3 Soldered wire wound inserts.

Experimental setup

The experiment set up of 1-2 pass shell and tube heat exchanger that has been used in this experiment. Experimental shell and tube heat exchanger that used has 18 numbers of tubes of internal diameter of 16mm and length 825mm. The set up includes two digital flow meter; four thermocouples to measure the inlet and out let temperature of shell as well as tube side. LAB VIEW software is incorporated to draw the readings from the heat exchanger to the computer system. Set up further includes the hot water tank and cold water tank of same capacity of 30 litters, the external power source is used for heating the water in the hot water tank. In this experiment hot water is allowed to flow though the tubes of heat exchanger and cold water is made to flow in the shell of heat exchanger.

Experiment procedure

All the rotameters & Thermocouples are calibrated first.The set up is cleaned and both the tanks are filled with the water, up to a certain limit. By using the external water heater which is fixed to the hot water tank the water is heated to required temperature. Both pumps are turned on by turning on the switch of motors connected to the pumps. By turning on the pump required amount of water is allowed to flow into shell (Cold Water), and also into the tube (Hot Water) by operating the control valve. Temperature of inlet water at the tube and the shell are noted given by the thermocouple. After flow gets stabilized, the temperature of out lets of shell and tube are noted. All the readings are obtained on the digital display and the readings are sent to the

computer system and obtained the tabular column directly by using the LAB VIEW software. Lab view software is prepared to calculate the heat transfer coefficient and pressure drop of heat exchanger using the BELL DELAWARE method. Same procedure is followed by inserting the soldered wire wound Turbulators and twisted tapes.

III. Results and discussions

i) Variation in Reynolds Number

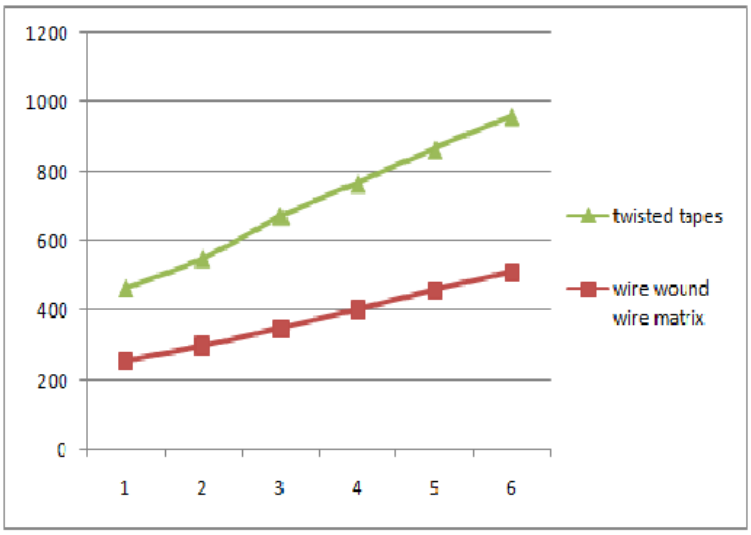

Fig-4 variation in Reynolds number

The above plot shows the variation of Re with respect to both the inserts. By observing above graph we can conclude that the Reynolds number for twisted is more than that of in case of wire wound wire matrix inserts. Hence turbulence nature of fluid in case of twisted tape as inserts in more that leads in increasing in the heat transfer rate.

ii) Variation in Pressure Drop

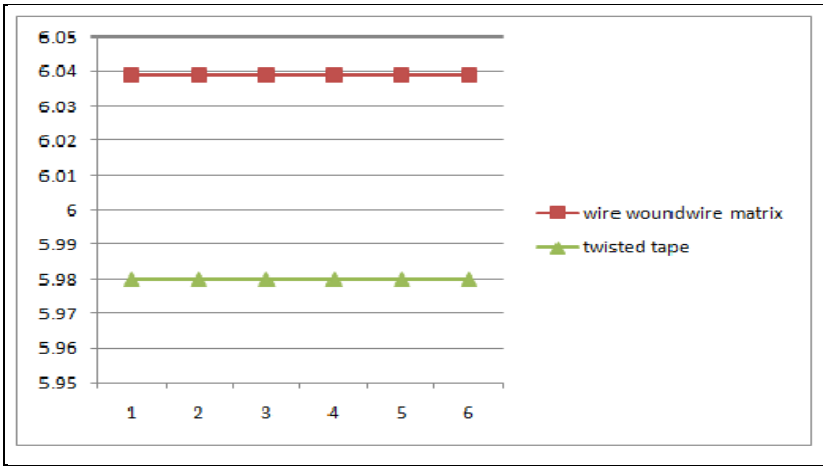

Fig-4 Variation in pressure drop

By above plot it can conclude that there is no such difference in pressure drop, but still it can be said that the pressure drop in case of wire wound wire matrix is more compared to that of incase of twisted tapes. Increase in pressure drop leads in opposition to flow in the tube, so more pressure drop needs more power to pump the water into the tube.

iii) Variation in Friction Factor

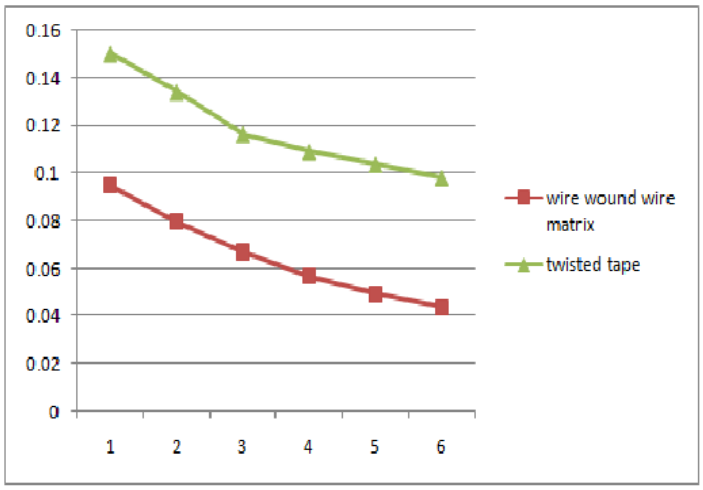

Fig-4 Variation in friction factor

The above graph shows the variation in friction factor, which shows that the friction factor is more in case of twisted tape used as pipe inserts and less in case of wire wound wire matrix used as pipe inserts.

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