EXPERIMENTAL STUDY ON HEAT TRANSFER AND FRICTION FACTOR CHARACTERISTICS IN LAMINAR FLOW THROUGH TUBES OF SHELL AND TUBE HEAT EXCHANGER FITTED WITH TWISTED TAPES WITH BAFFLES

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Abstract

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)Typical twisted tapes and 2)twisted tape with baffles (TTWB). Experiment was carried out by using these two types of inserts in the tube side. This paper deals with only 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 for baffled twisted tape, baffles are positioned at equal intervals, at an angle 45^0 with normal axis of twisted tape. The heat transfer and pressure drop in case of twisted tape and twisted tape with baffles are found to increase by 110 to 120% and 130 to 140% respectively than that of plain tube.

Keywords: *Shell and tube heat exchanger, twisted tape, twisted tape with baffles, heat transfer coefficient, and pressure drop.*

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1. 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. 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.

1.1 Literature Survey

The literature survey shows different passive techniques for enhancing thermal performance of heat exchanger. Manglik and Bergles [1] given 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.

2. DETAILS OF TWISTED TAPES WITH BAFFLES

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. Fig.1, Fig.2 and Fig.3

shows the detailed view of insert which are used in this experiment.

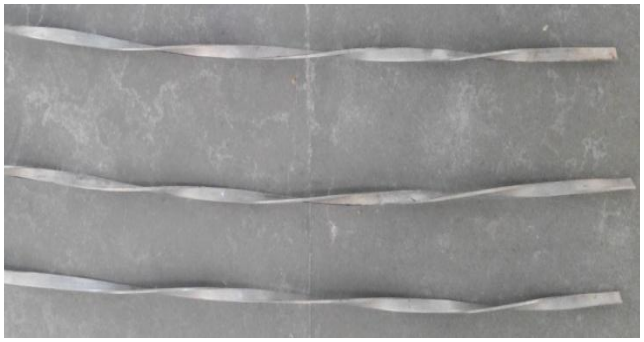

Fig-1: Typical twisted tapes

Fig-2: Twisted tapes with baffles.

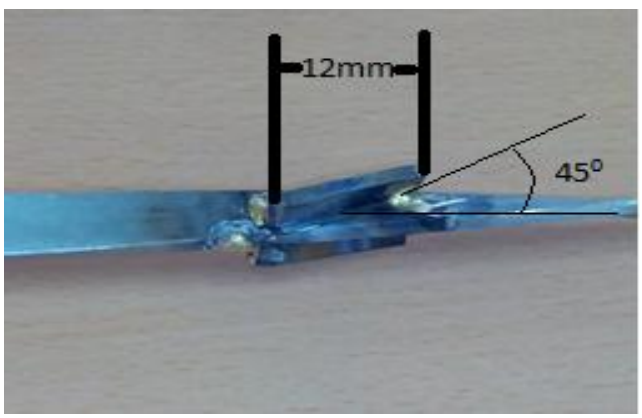

Fig-3: Detailed view of baffles.

3. EXPERIMENTAL SETUP

Fig.4 shows 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.

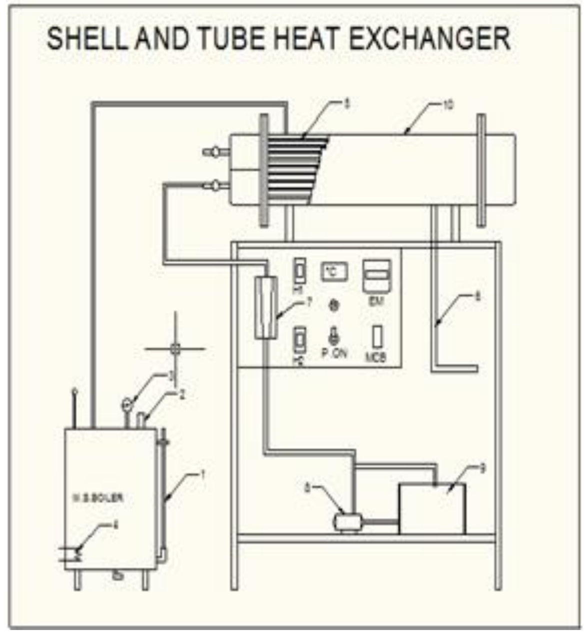

Fig-4: Line diagram of set up

Fig-5: pictorial view of set up.

4. EXPERIMENTAL PROCEDURE:

Initially experiment is carried out without any inserts in the tube. Both the tanks are filled with the clean water, water in the hot water tank is heated at require temperature by using external heater, then pump sends the hot water to tubes of shell and tube heat exchanger, the volume of flow rate can be controlled by the bypass valve provided at near to the pump. After certain time interval cold water is pumped to the shell of heat exchanger, however the flow of cold water is controlled by bypass valve. Hot water was flowing into the tube at some flow rate, and cold water in the shell of heat exchanger with. Care must be taken that flow in the tube side must be greater than that of shell side. The thermocouples mounted at inlets of shell and tube side, measure the temperature as T1 and T3 respectively. After stabilization of flow, the temperatures of thermocouples at exit of shell and tube are measure as T2 and T3 respectively. The test was run in the computer system that gives the inlet and exit temperatures, flow rates, heat transfer coefficients and pressure drop at both shell and tube side by using LAB VIEW software.

There after the tubes were fitted by the typical twisted tapes and same procedure was followed. After readings obtained the twisted tapes are replaced by modified or twisted tapes with baffles and readings are taken. Finally the comparison is done between plain tubes, tubes with twisted tapes, tubes with tapes with baffles (TTWB).

5. RESULTS AND DISCUSSIONS

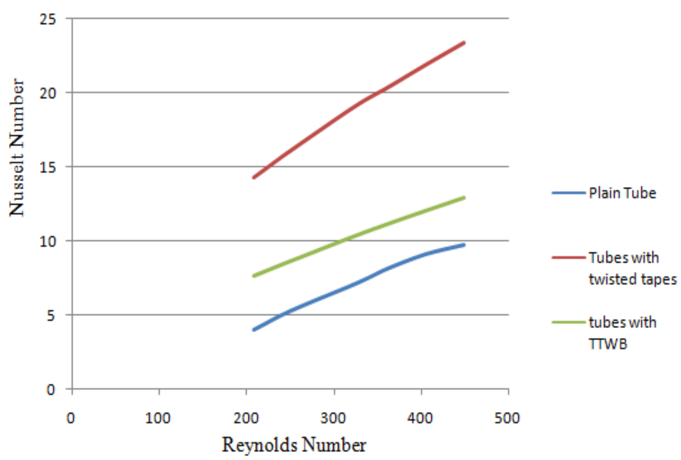

Chart-1: Nusselt number v/s Reynolds number.

For plain tubes, the Nusselt number goes on increasing as Re goes on increase. For an identical Re number the Nusselt number for tubes with typical twisted tapes is increased be 126% compared to that of plain tubes and for same Re Nusselt number on the tube with TTWB increased by 158% compared to that of plain tube. That is shown in chart-1.

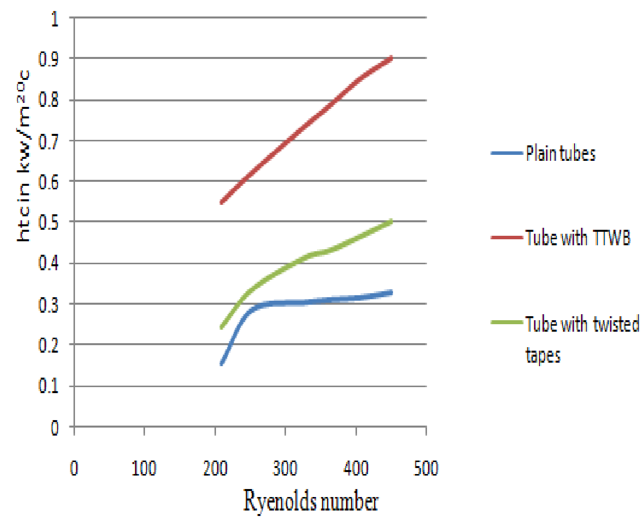

Chart-2: Heat transfer coefficient v/s Reynolds number.

Heat transfer coefficient for plain tube flow goes on increasing with increase in Reynolds number. For a particular Re the heat transfer coefficient of flow in tubes fitted with typical twisted tapes is increase by 134% of that of plain tubes, and for same Reynolds number the heat transfer coefficient increased by 167% compared to that of plain tube, shown in chart-2.

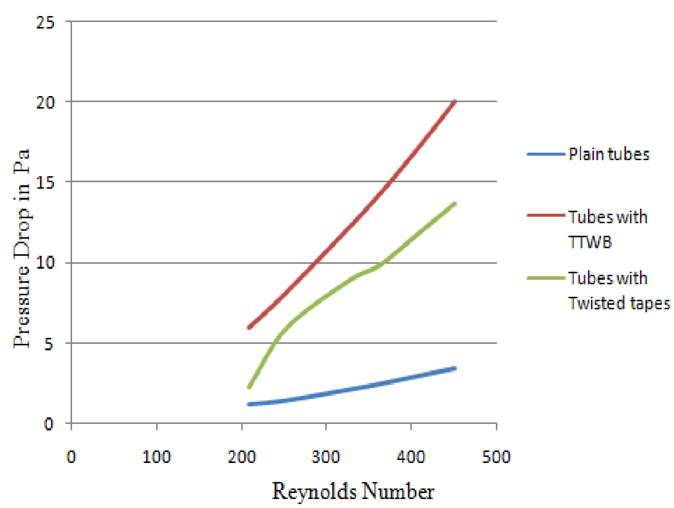

Chart-3: Pressure drop v/s Reynolds number.

Chart-3 shows that the variation of pressure drop with respect to the Reynolds number. Comparison between plain tube and tubes with typical twisted tapes gives that there is increase in the pressure drop by the amount of 130% and comparison between tubes fitted with TTWB and plain tube gives 160% increase in pressure drop.

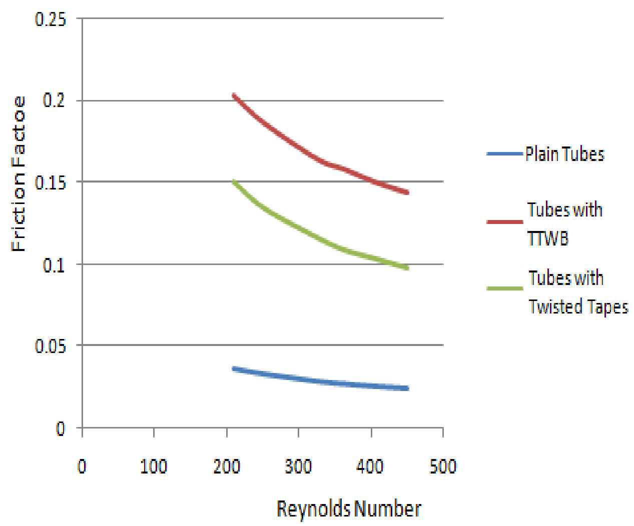

Chart-4: Friction factor v/s Reynolds number.

Chart-4 gives the friction factor variation in the plain tubes, tubes with typical twisted tapes and tubes with TTWB. By observing the chart we can say that the friction factor for same Re has higher value in case of tubes with TTWB compared to tubes with typical twisted tapes and plain tubes. The friction factor goes on reducing as Re goes on increasing, for same Re the tubes with TTWB yields 150% more friction factor compared to that plain tubes.

6. CONCLUSIONS

For the heat exchangers operating under laminar flow condition where flow rate is low, the twisted tapes with baffles are attractive to increase the heat transfer coefficient and pressure drop. Experimental study were done by using twisted tapes with baffles inclined at 450 to the normal axis of twisted tape fitted in the tubes of shell and tube heat exchanger for the Reynolds number ranging from 200 to 600, and results are.

Nusselt number for same flow rate in tubes with TTWB is incesed compared to that of plain tubes as well as tubes with typical twisted tapes.

Heat transfer coefficient for tubes fitted with TTWB is highest compared to that of plain tubes as well as tubes with typical twisted tapes for same Re and flow rate.

Pressure drop value is found higher in TTWB compared to that of in plain tubes and tubes with typical twisted tapes for same flow rate and Re.

So we can conclude that by using twisted tapes with baffles on tubes, the thermal performance of the shell and tube heat exchanger perating under laminar conditions can incresed by 150 to 160% that of plain tube.

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