Experimental Study on Heat Enhancement of Helixchanger with Grooved Tubes

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Abstract- Shell and tube heat exchangers with helical baffles are used to improved performance by reducing pressure drop, flow induced vibration and fouling while maintains a higher heat transfer capability. In the present work an experimental Investigation has been carried out to know the thermal performance of Helix -changer with plain copper tubes or with grooved copper tubes of same size and Specification by using co-current flow. During this experimental investigation Attempts were made for both exchangers at same operating conditions and it was found that grooved copper tubes helix changer have a better thermal performance as compared to plain copper tubes helix changer at a particular angle, 25 degree. It was also investigated that the flow pattern inside the grooved tubes has better fluid particle mixing which leads to better heat enhancement. The grooved surface is a passive technique of heat enhancement, the flow pattern gives by these tubes has a significant increase in thermal performance of heat exchangers.

Keywords – shell and tube heat exchanger, helical baffle, grooved tubes, heat transfer, helix angle, HTRI

I. INTRODUCTION

Shell and tube heat exchangers are most widely used in various industries such as chemical process, power generation, oil refining, refrigeration and air – Conditioning. Among different type of heat exchangers, shell and tube heat exchanger have been commonly used in industries. It has been reported that more than35-40% of heat exchangers are of STHE type, due to their robust construction geometry as well as easy maintenance and possibility of upgrades [1].

Baffle is an important shell side component of STHEs. Besides supporting the tube bundles, the baffles form flow passages for the shell side fluid. The most commonly used baffles are segmental baffle, which forces the fluid in a zig-zag manner, thus improving the heat transfer but with a large pressure drop penalty. This type of exchanger has been developed [2-4] &probably is still the most commonly used types of STHE. The major drawbacks of STHE with segmental baffles are (I) it causes a large side pressure drop. (ii) It results in a dead zone in each component between adjacent segmental baffles, leading to increase of fouling resistance. (iii) zig-zag flow pattern also causes high risk vibration failure on tube bundle

To overcome the above mentioned drawbacks of conventional STHE, segmental baffled, a no. of improved structure were proposed for the purpose of higher heat transfer coefficient, low possibility of tube vibration and reduced fouling factor [4-7]. Moreover, the principal shortcomings of the conventional segmental baffle still remain in the above mentioned studies, even though the pressure drop across the heat exchanger has been reduced to some extent. A new baffle called helical baffle, provides further improvement. This type of baffle was first proposed by D.Kral & Nemcansky [8], where they investigated the flow pattern produced by helical baffle geometry with different helix angles. They found that these flow patterns were much close to plug flow conditions, which was expected to reduce shell side pressure drop and to improve heat transfer performance.

In this work (1) Helix changers were designed by HTRI software, (2) a simple and feasible method was developed to fabricate helical Baffles and grooved surface of copper tubes, (3) an experimental investigation has been carried out for both exchangers with same operating conditions at 25 degree angle.

Desirable feature of Heat exchangers-
The desirable features of a heat exchanger would be to obtain maximum heat transfer to Pressure drop ratio at least possible operating costs without comprising the reliability.

1.1 Higher heat transfer co-efficient and larger heat transfer area-
A high heat transfer coefficient can be obtained by using heat transfer surfaces, which promote local turbulence for single phase flow or have some special features for two phase flow. Heat transfer area can be increased by using larger exchangers, but the more cost effective way is to use a heat exchanger having a large area density per unit exchanger volume, maintaining the Integrity of the Specifications.

1.2 Lower Pressure drop-
Use of segmental baffles in a Heat Exchanger result in high pressure drop which is undesirable as pumping costs are directly proportional to the pressure drop within a Heat Exchanger. Hence, lower pressure drop means lower operating and capital costs

II .HELIXCHANGER

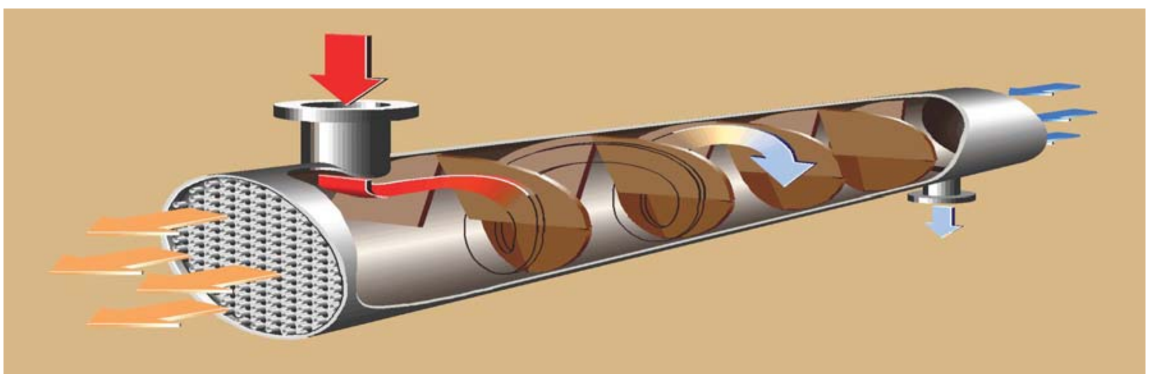

Figure 1. Shell and tube heat exchanger with helical baffles.

The concept of helical baffle heat exchangers was developed for the first time Czechoslovakia. The helical baffle heat exchanger also known as HELIXCHANGER is a superior STHE over conventional baffle exchangers. It provides the necessary characteristics to reduce flow dispersion and generate near plug flow condition. It also ensured a certain amounts of cross flow to the tubes to provide high heat transfer coefficient. The Shell side flow configuration offer a very high conversion of pressure drop to heat transfer.

The helix changer provides-
i. Improvement of shell side heat transfer.
ii. Less pressure drop for a given mass flow rates.
iii. Decreasing of fouling in shell side.
iv. Prevention of bundle vibration.
v. reducing by pass effect in shell side.

Advantages of helix changer-
i. High thermal & hydraulic performance.
ii. High thermal effectiveness.
iii. Lower fouling & cleaning ability.

iv. Vibration elimination.
v. Cost saving on total life cycle basis.
vi. Improving plant run length.

2.1Concept of Grooved tubes-

It is a passive heat enhancement technique generally uses surface or geometrical modification to the flow channel. These geometrical modifications promote higher heat coefficients by disturbing or altering the existing flow behavior. The flow pattern inside the grooved tubes has better fluid mixing particle which leads to better heat enhancement as compare to the plain tubes. Figure shows grooved copper tubes having sine surface of radius 2mm, pitch 100mm, outer dia. of tube 12.7 mm, length 740 mm.

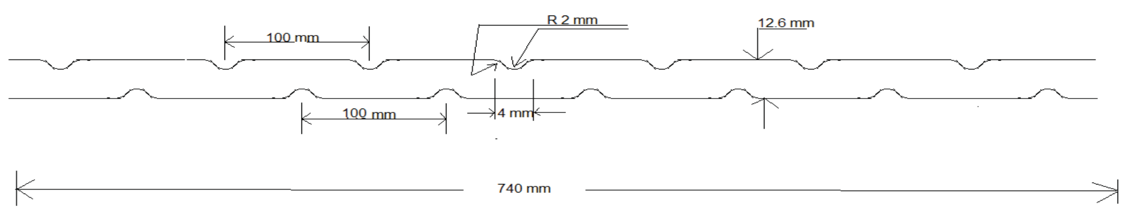

Figure 2.Grooved copper tube.

III. EXPERIMENTAL STUDY & PROCEDURE

In the current paper, comparative thermal performance analysis of helixchanger with plain copper tubes or with grooved copper tubes by using co-current flow at a fixed angle 25 deg. has been carried out. During this experimental investigation attempts were made for both exchangers at same operating conditions to determine the thermal performance. Their results clearly indicate the significant increase in thermal performance of heat exchanger with grooved tubes helixchanger.
The process hot fluid was heat-up in the hot water reservoir which has two heating element of capacity 2 KW and heated to prescribed limit. This process fluid was supplied to the tube side part and then to the copper tube of outer diameter of 12.7mm with the help of a pump (0.5 HP) and through the hot flowmeter with different rate of flow . After passing this process fluid through the test section this fluid is fed to the hot water reservoir by a by-pass valve. Similarly, the process cold fluid was supplied to the shell part over the copper tubes by a pump of 0.5 HP and through cold flowmeter with different rate of flow. In the test section the temperature of the process fluid at different location is measured by the use of RTD PT-100 sensor. The total numbers of sensors are 05 used in the test section

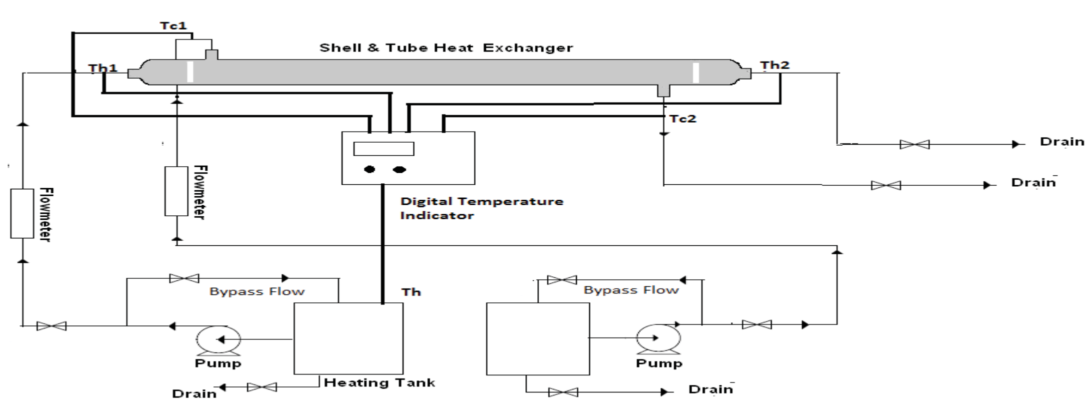

Figure 3. Experimental set-up layout.

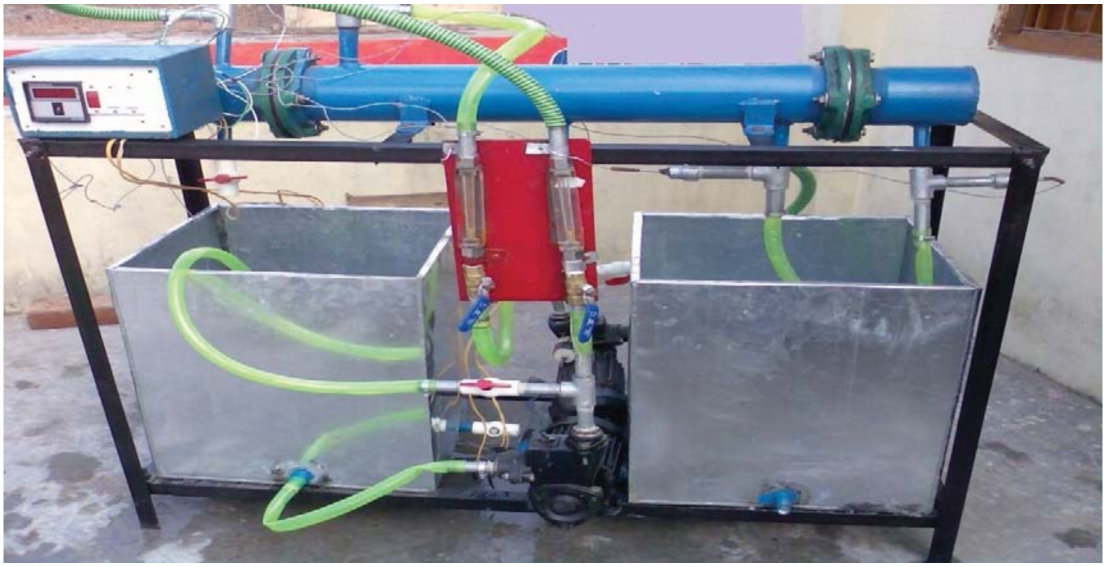

Figure 4. Photographic view of Experimental set up.

The basic experimental procedure is as follows:
(1) Filling the system with enough water;
(2) Keeping the water valves in full-open state, and running the cool water pump, the hot water pump and the electric heater in turn;
(3) Regulating the water flow rate in the hot water loop to a certain value through adjusting the water valve;
(4) Regulating the hot water temperature in the tank to a certain stable value through adjusting the power regulator that controls the input power of the heater.
(5) Recording the temperatures of the water entering and leaving the heat exchanger (the time interval of the data acquisition system is set as 1s), and meantime, observing the water flow rate in the hot water loop for every minute;
(6) After one experimental condition is completed, repeating steps (3)-(5) for the other conditions.

The amount of heat transfer (Q=K*W* in unit) between the hot water flow inside the tubes and cold water outside the tubes can be calculated by Eq. (1) according to the experimental data.

$$Q = mh*cph*(th1-th2) \qquad (1)$$

Where, mh mass flow rate of hot water in kg/sec; cph, specific heat of water, J/kg ^{0}C; th1, th2, inlet and outlet temperature of hot water in ^{0}C.

The heat transfer coefficients (U= w/m2^{0}C) can be written as;

$$U= Q/A\Theta m \qquad (2)$$

Where, A is total flow area of copper pipes, m^2 ; Ɵm, is mean temperature difference between hot water and cold water; ^{0}C and calculated by Eq. (3)

$$\Theta m = (Q1-Q2)/(InQ1/Q2) \qquad (3)$$

Where, Q1= th1-tc1; Q2 = th2- tc2, where tc1, tc2, temperature of cold water at inlet and outlet, respectively.

The enhancement ratio (*ER: %*) is used to evaluate the heat transfer enhancement assisted by the grooved tubes.

$$ER = Ug-U/U*100 \qquad (4)$$

Where, Ug and U represents, respectively, overall heat transfer coefficient of grooved tube helixchanger and plain tube helixchanger.

IV.RESULTS

4.1. Influence of water flow rate on Heat Transfer Rate-

The heat enhancement brought by the grooved tubes may be influence by water flow rate passing through heat exchanger. In this experimental study, the hot water flow rate inside plain tube helixchanger or grooved tube helixchanger was changed to examine in figure 5.It is clear that the heat transfer has an obvious increase by using grooves. The results also show that the enhanced ratio of heat transfer due to grooves increasing with increasing mass flow rate of hot water (inside tubes). The enhanced ratio for the heat transfer is about 10-27% on different flow rates (0.5, 0.75, 1 kg/sec), as the hot mass flow rate increase rate of heat transfer and overall heat transfer coefficient increase respectively. It is also concluded that there is significant temperature drop in grooved tube as compare to the plain tube helixxchanger with the same operating conditions for both. It indicates that the effect of grooves produce turbulence in flowing fluid which leads to better heat enhancement over plain tube. Therefore it is reasonable to suppose that with the same operating condition heat enhancement of grooved tube helixchanger has better over plain tube helixchanger and it also concluded that heat transfer would increase with increasing flow rate.

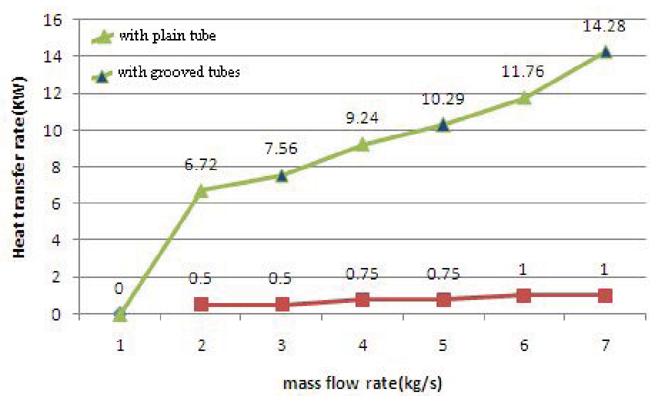

Figure 5.Effect of different mass flow rates on heat transfer on plain and grooved tube helixchanger

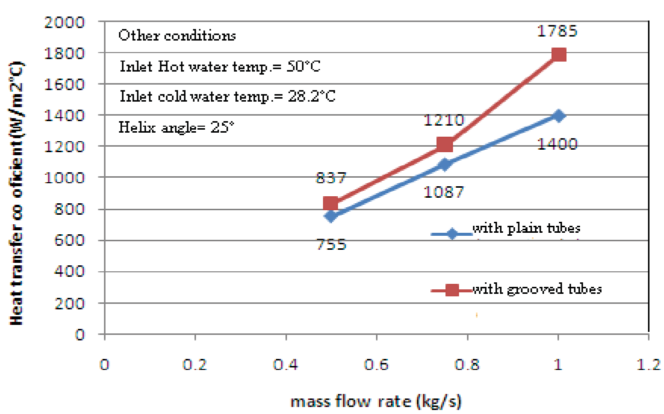

Figure 6.Effect of different mass flow rates on heat transfer coefficient on plain and grooved tube helixchanger

4.2 Influence of Inlet hot water temperature on heat transfer enhancement-

Hot water temperature produces significant effect on heat transfer coefficient, which influences the efficiency of heat transfer. It is found that enhanced heat transfer efficiency of both, plain tube and grooved tube helixchanger changes with the inlet temperature of hot water. But grooved tube helixchanger has better heat transfer rate over plain tube helixchanger with same operating conditions. The peak point of enhanced ratio occurs at about 60 ^{0}C where enhanced ratio is about 14%. Temperature may be the most important parameter to be considered in maximizing heat transfer rate. This is because temperature affecting properties of liquid such as viscosity, thermal conductivity, and density & specific heat etc. Increasing liquid temperature, on one hand will decrease viscosity of liquid and make it easier to have good heat transfer rate. In this experimental study, temperature 60 ^{0}C exist a favorable liquid temperature that maximizes the enhanced ratio for grooved tube helixchanger over plain tube helixchanger. Further study ought to be made on this issue and reasonable model be established for guidance.

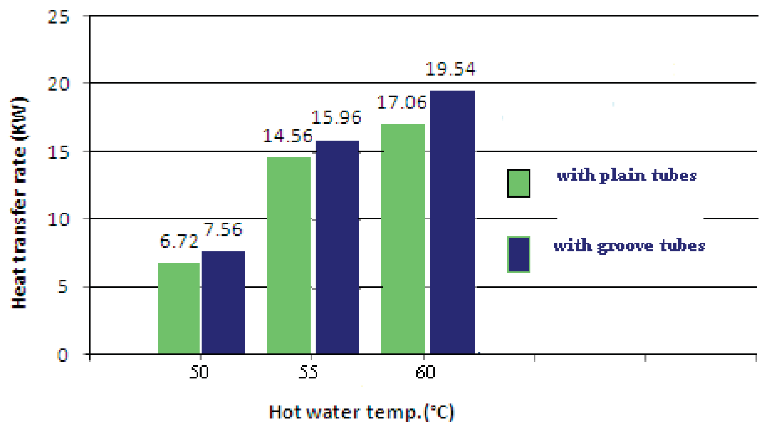

Figure 7.Effect of inlet hot water temperature on Heat transfer rate in plain and grooved tube helixchanger

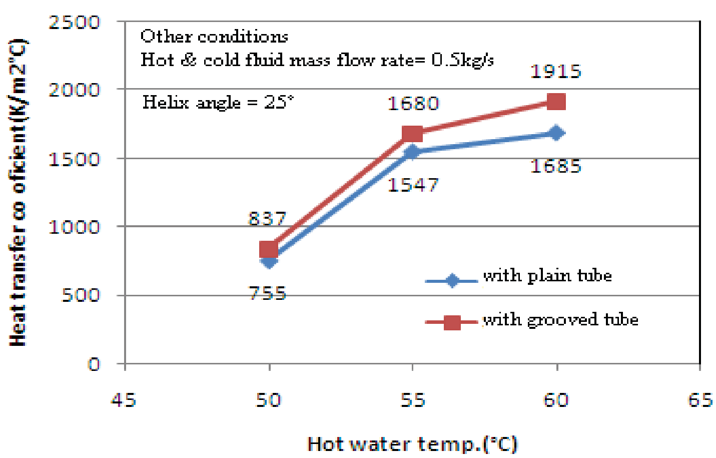

Figure 8.Effect of inlet hot water temperature on Heat transfer coefficient in plain and grooved tube helixchanger

4.3 Influence of grooves on heat transfer enhancement-

Temperature drop is directly related to the mass flow rate and groove pattern on tubes. As indicated in figure 7 grooved tube helixchanger , when same operating conditions is taken for both helixchanger, there is a significant temperature drop in grooved tube helixchanger which work in the enhancement of heat transfer. Taking this study for example, at mass flow rate 0.5 Kg/sec and temperature 50 ^{0}C, the transfer coefficient increase in grooved tubes as compare to plain tubes due to significant temperature drop, about 10% increase in enhanced ratio. When the flow rate of hot fluid is increased to 0.75Kg/sec and 1 kg/sec, enhanced ratio rises 12% and 27% respectively. Therefore it is supposed that the enhanced ratio would further increase if the mass flow rate of hot water increases.

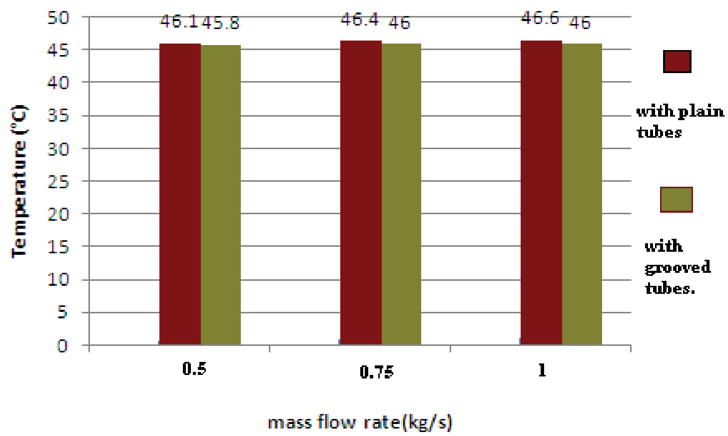

Figure9. Variation of temperature with mass flow rate in plain and grooved tube helixchanger

V. CONCLUSION

This study mainly presents some experimental results of heat transfer enhancement of helixchanger assisted by grooved tubes over plain tubes at same operating conditions. The enhancement may be influence by conditions like the fluid temperature, the fluid mass flow rate as well as groove pattern. The effect of groove on the heat enhancement will be more evidence when the fluid mass flow rate is more. The influence of fluid temperature is mainly related to grooves as compare to plain tubes. It can also be concluded that grooves produces a significant drop in temperature of fluid by leading turbulence i.e. mixing of fluid which enhancing heat transfer rate. It is certain that higher the temperature, the higher enhanced ratio will be achieved.

The new technology of heat transfer enhancement by using grooves on tubes, which is a passive heat enhancement technique, is still far from the practical application with helix baffle. According to the experimental results, different flow behavior leads to different degree of heat transfer enhancement. The groove pattern on tubes will increase turbulence degree of movement of fluid which leads to better heat enhancement over the plain tube helixchanger.

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