ISSN 2395-1621

Heat Transfer Enhancement in Tube in Tube Heat Exchanger with Louvered Strip Inserts

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ABSTRACT

Heat exchanger is a device to transfer the heat energy from hot fluid to cold fluid, with high rate and minimum cost. Heat transfer enhancement has been always a significantly interesting topic in order to develop high efficient, low cost, light weight, and small heat exchangers. The energy cost and environmental issue are also encouraging researchers to achieve better performance than the existing designs. To increase the heat transfer rate, there are two ways, by using various types of inserts and by changing the shapes of heat exchangers. There are various types of inserts used in the heat exchanger tubes such as helical/twisted tapes, coiled wires, ribs/fins/baffles, and louvered strips. The main focus of present work is to perform thermal analysis of tube in tube heat exchanger using louvered strip and validate the results obtained from the experimentation work. The working fluids used are water on both sides of the two concentric pipes. The ranges of temperature covered are between 28°C to 65°C and mass flow rates of 200LPH on the cold side will be kept constant. The change in temperature is obtained by changing the mass flow on hot side of the exchanger. Parameters to be used are, louvered strip length (*l*) of 30mm, width(*w*) 3mm, depth *(d)* 2mm, at slant angle*(θ)* 15^0 and pitch *(p)* of 45mm, 50 mm, 55mm. The experimental results reveal that both heat transfer coefficient and friction factor in the louvered strip inserted tubes are greater than those in plain tube.

Keywords— **Louvered strip, Heat exchanger, Heat transfer enhancement, Heat Transfer coefficient**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Recently, Energy is essential for domestic industry development and it is the main problem issue in the world. A plenty of energy problems are necessary to be urgently improved and developed. Paying the attention and efficiently economically exploiting energy are the effective way to bring down energy problems. The heat exchange process has been involved in many engineering applications of production process in industrial factories and necessary, is the parameter of great interest temperature. Temperature is one of the most important factors to control production process in each section as well as the quality control of products. Therefore, the degree of temperature at various positions in production processes is significant. In this project work, the processes of extracting and transferring maximum heat to intermediate working fluid are focused. Heat exchanger plays the important role in heat exchange processes and is widely used in applications like double pipe heat exchanger such as; power plant, air-conditioning, petrochemical industry, refrigeration, process industry, solar water heater, chemical reactors, sell-and-tube heat exchangers and nuclear reactor. Accordingly, designing the heat exchange, suitable for each application, is very significant and important and it always has the limitation of heat exchanger size and fluid flow rate. As a result of such restrictions, heat transfer rate is quite low. The enhancement of heat transfer ability to achieve high performance of heat exchangers does reduce the size of the device and the initial investment as well as the area of installation. This project work gives the method of enhancing heat exchanger performance by using the ordinary technique, passive method. The passive method can be applied by installing the turbulent circulation generator. In the past, the heat transfer enhancement technique was performed in the widespread application. Those methods were, for instance, the insertion of twisted stripes and tapes, the insertion of coil wire and helical wire coil and the installation of tabulator in the heat exchangers [4]. The results of those studies had been shown that although heat transfer efficiencies were improved, the frictions of tube were considerably increased. The novel concept to augment heat transfer efficiency using small louvered strips was developed and investigated. The strips were arranged on the brass wire, installed inside the hot water tube. The stripes provided high turbulent and circulation flow, resulting in excellent rate of heat transfer. Figures 1 and 2 present the installation of the louvered strip with the brass core within the aluminium tube. All these methods of heat transfer enhancement techniques had and widely applied to several industrial and engineering applications.

The heat transfer augmentation techniques [11] are generally classified in three broad categories:

A. Active Method

This method involves some external power input for the enhancement of heat transfer and has not shown much potential owing to complexity in design. Some Examples of Active Method are Surface Vibration, Fluid Vibration, and Electrostatic Fields.

B. Passive Method

This method does not need any external power input and the additional power needed to enhance the heat transfer is taken from the available power in the system, which ultimately leads to a fluid pressure drop. The heat exchanger industry has been striving for improved thermal contact (enhanced heat transfer coefficient) and reduced pumping power in order to improve the thermo hydraulic efficiency of heat exchangers. Some Examples of Passive Method are by using Treated Surfaces, Rough Surfaces, some of are by using different inserts like louvered strip, twisted strip etc.

C. Compound Method

If two or more techniques can be utilized simultaneously to produce an enhancement larger than that produced by only one Technique than it can be said as Compound Method. A compound method is a hybrid method in which both active and passive methods are used in combination. The compound method involves complex design

II. EXPERIMENTAL SETUP

The apparatus and measuring devices were shown in figure 1. The temperature at inlet and outlet areas of hot and cold tubes inside the concentric tube heat exchanger was measured using RTD thermocouple, whereas U-tube manometer was used to measure their pressure. Pumps were used to feed hot and cold waters to the cold and hot water tube of double pipe heat exchanger and their flow rates was measured by Rotameter. In this system, the hot and cold waters were kept and their temperatures were controlled within the hot water tank and cold water tank. In experimentation, after the hot water attained and controlled at the temperature of 64^0 C throughout experimental duration. The hot water was supplied to the heat exchanger. Simultaneously, the cold water, kept within water tank, was fed to the heat exchanger. The hot and cold waters returned to storing tanks, after heat transfer between them had been operated. During the process, inlet and outlet pressures were measured using U-tube manometer. All of data were collected and brought to calculate convection average heat transfer coefficient, Nusselt number.

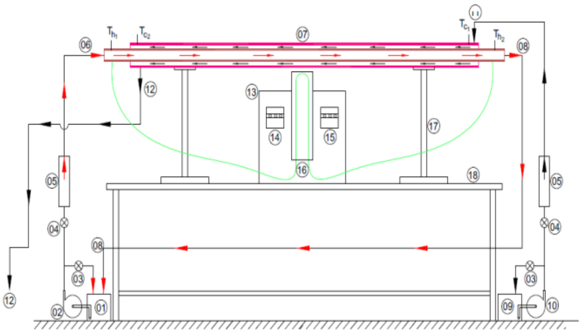

Fig.1: Schematic arrangement of experimental setup

During experimentation three louvered strips of different pitch were used for comparison with standard plain tube. The louvered strip is shown in figure 2 .The louvered strips are of different pitches 45 mm, 50 mm, and 55 mm. with slant angle of 15^0 for all three strips in heat exchanger.

Fig 2: Louvered strip

III.THEORECTICAL ANALYSIS

The hot water flows through inner tube and cold water flows through outer tube in a counter flow double pipe heat exchanger. The hot and cold water inlet outlet temperatures are taken for various hot side flow rates and constant cold flow rates. The readings were taken for plain tube as well as louvered strip inserts. The result table includes inner tube convective heat transfer coefficient, mass flow rate, velocity, Reynolds number, bulk hot water temperature, average heat transfer rate. Depending upon the various results collected from the above parameters various plots are done for turbulent flow 5000 to 35000 Reynolds number. All the thermo-physical properties are calculated as mean bulk temperatures

The heat transfer rate for cold water in the test section, Q_C can be expressed as

$$Q_C = m_c C_{pc} (T_{co} - T_{ci}) \quad (1)$$

Where, m_c is the flow rate of cold water, C_{pc} is the specific heat of water; T_{co} and T_{ci} are outlet and inlet cold water temperatures respectively.

The heat transfer rate for hot water in the test section, Q_h can be expressed as

$$Q_h = m_h C_{ph}(T_{ho} - T_{hi}) \quad (2)$$

Where, m_h is the flow rate of hot water, C_{ph} is the specific heat of water; T_{ho} and T_{hi} are outlet and inlet hot water temperatures respectively.

Since, there are some heat losses on the outer surface of the test section. The average heat transfer rate (Q_{ave}) is calculated.

$$Q_{ave} = (Q_c + Q_h)/2 \quad (3)$$

The theoretical Nusselt number is calculated from Dittus- Boelter correlation [12]

$$Nu = 0.023\, Re^{0.8} Pr^{n} \quad (4)$$

Where n= 0.3 for cooling of fluids
n= 0.4 for heating of fluids

For fluid flows in a concentric tube heat exchanger, the heat transfer coefficient (hi) is calculated from

$$Q_{ave} = UA_i\,(\Delta T_{LMTD}) \quad (5)$$

Where
$A_i = \pi D_i L$

The tube side heat transfer coefficient is then determined (by neglecting of the thermal resistance in the aluminium tube wall) using

$$(1/U) = (1/h_i) + (1/h_o) \quad (6)$$

Where the annulus side heat transfer coefficient (h_o) is estimated by using the correlation of Dittus-Boelter [12]

$$N_{uo} = (h_o D_h/k) = 0.023\, Re^{0.8} Pr^{0.3} \quad (7)$$

Then, $h_o = (k/D_h)\, N_{uo}$

Where, $D_h = D_o - D_i$

Reynolds number and friction factor can be calculated by following equations.

$$Re = (\rho V D)/\mu \quad (8)$$

$$f = (\Delta P) / ((\rho V^2/2)(L/D))$$

IV. EXPERIMENTAL RESULT & DISCUSSION

a In this section, the following results are, respectively presented, the validation of plain tube, effect of dimple tube, and effect of pitch ratio

A. Validation of Test tube

The experimental results were compared with the past correlation of Dittus-boelter [12] which the correlations were formulated for smooth-surface circular tube or plain tube. Figure 3 shows the plot of Nusselt number versus Reynolds number and the present work is compared with the standard correlation; it shows similarity, and however the experimental values are lower than correlation.

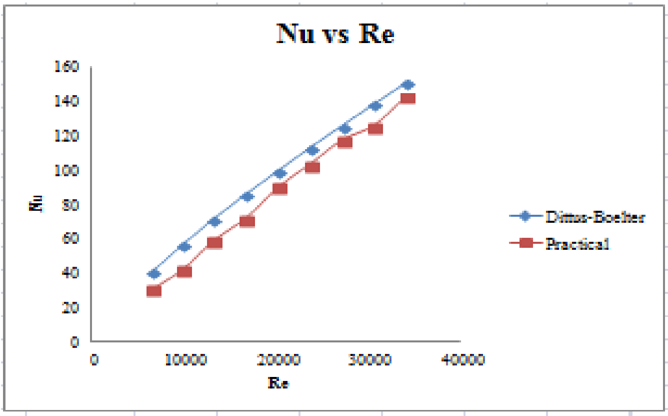

Fig 3: Nusselt number validation

Figure 4 shows the graph of Nusselt number versus Reynolds number of three different pitches 45mm, 50mm and 55mm compared to smooth tube the Nusselt number of 45mm pitch is higher than that of other two

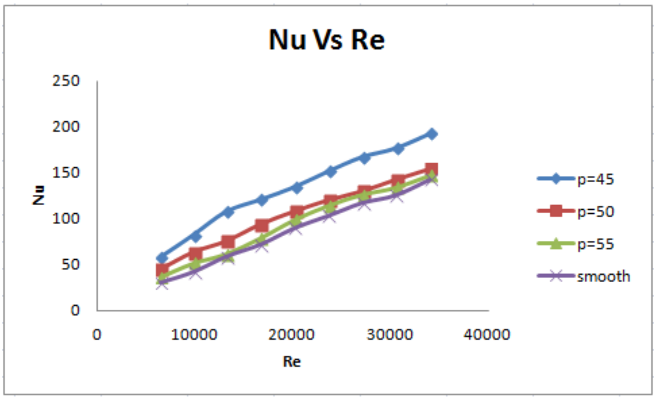

Fig 4: Nusselt number versus Reynolds number

Figure 5 shows the plot of Heat transfer coefficient versus Reynolds number, the 45mm pitch gives more heat transfer coefficient than the others.

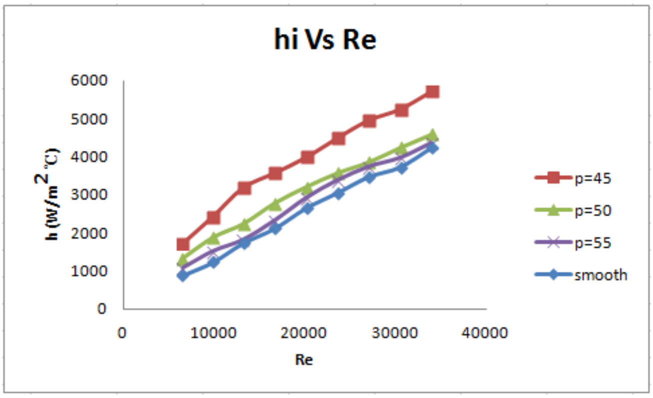

Fig 5: Heat transfer coefficient versus Reynolds number

Figure 6 shows a plot of Nu/Nu $_{plain}$ versus Reynolds number it gives that the Nusselt number is decreasing non-linearly and pitch of 45mm gives maximum value.

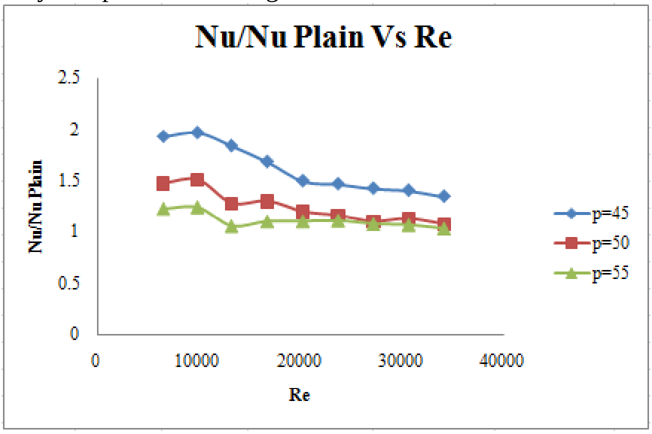

Fig 6: Nu/Nu $_{plain}$ versus Reynolds number

The plot of pressure drop versus Reynolds number is shown in figure 7. It shows pressure drop is increases with increasing Reynolds number.

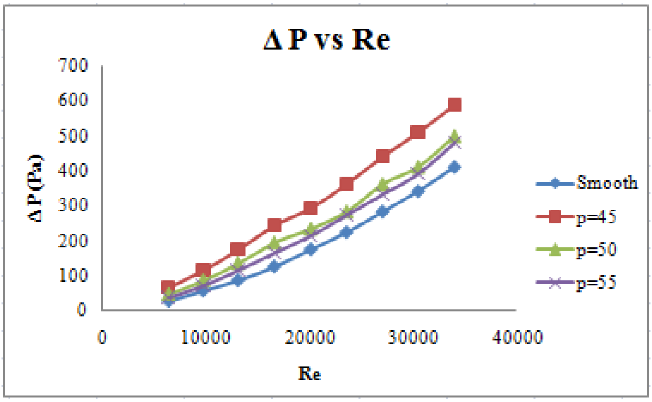

Fig 7: Pressure drop versus Reynolds number

The friction factor is compared with the standard correlation of Blasius [12] and Petukhov [12]. Figure 8 shows that it is decreases with increase in Reynolds number i.e. friction factor is inversely proportional to Reynolds number

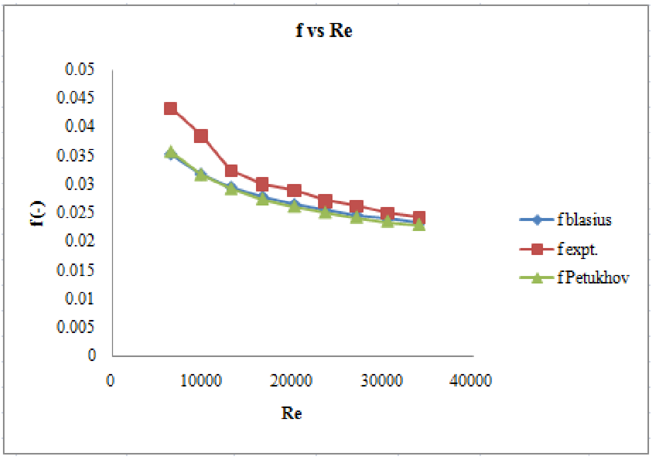

Fig 8: Friction factor validation

The friction factor is going to increase with the pitch. At 45 mm pitch the friction factor becomes maximum as shown in figure 9 and 10.

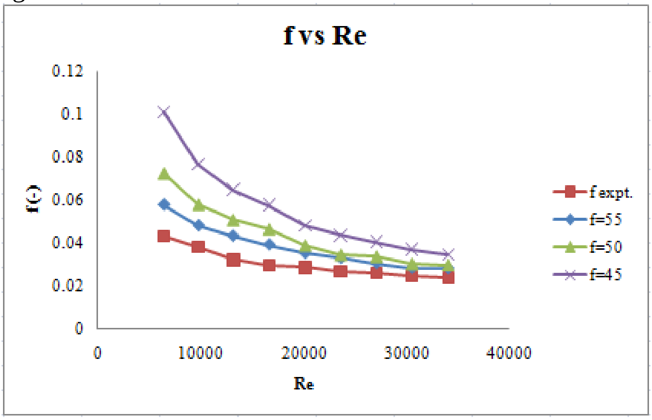

Fig 9: Friction factor versus Reynolds number

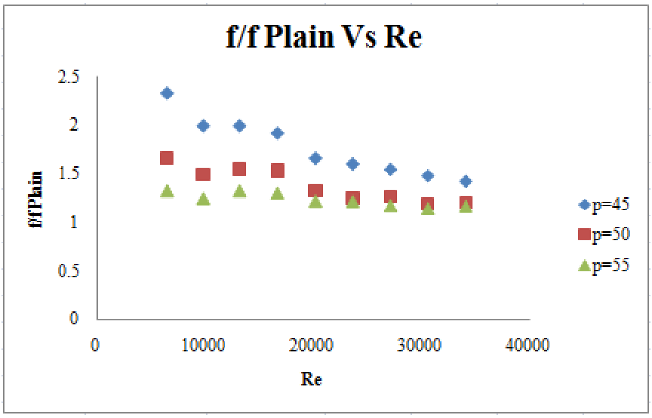

Fig 10: f/f $_{plain}$ versus Reynolds number

V.CONCLUSION

An experimental study of fully developed turbulent flow with louvered strip inserts in tube has been performed. The effect of the pitch with constant angle on the heat transfer rate has also been investigated. Following results can be concluded.

1) By inserting louvered strip the heat transfer rate is increases. With the pitch of 45mm the heat transfer is maximum than the pitch of 50mm and 55mm for Reynolds number range of 5000-35000.

2) The heat transfer rate increases approximately by 25.9% for pitch of 45 mm and then decreases 7% for 50 and 3% for 55 mm pitch.
3) By using louvered strip insert the friction factor is approximately increases by 57% for 45mm pitch and then decreases 40% for 50mm and 25% for 55 mm pitch.

ACKNOWLEDGMENT

The motivating factor for this project was the inspiration given to me by my honorable guide Prof. P.M. Khanwalkar. He has given many valuable suggestions and guided me by encouraging generously throughout. I wish to convey my gratitude to my guide. His mild mannered demeanor, his tolerance in dealing the problems and his encouragement has been a constant source of inspiration for me. He had contributed to a great measure in mounting all the hurdles faced by me during the completion of the project. I gratefully acknowledge our Principal Dr.S.D.Lokhande and P.G. Head Dr. Y.P. Reddy for making available the necessary facilities required for my project. At last I thank all those who directly or indirectly helped me in completing this project successfully.

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