IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727
PP 18-23
www.iosrjournals.org

Heat Transfer Enhancement through a Circular Tube Fitted with Swirl Flow Generator

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Abstract: *Experimental studies on friction factor and heat transfer characteristics for turbulent flow ofwater in a circular tube fitted with wire coil, screw tape inserts and combination of both under nearly uniform wall temperature conditions are reported in this article. The experimental results reveal that the use of inserts leads to considerable increase in heat transfer and friction loss over those of a plain tube. The Nusselt increases with the rise of Reynolds number for all inserts and average Nusselt number for a combination of wire coil and screw tape insert is found 155 times higher than that of a plain tube.*
Keywords –*Nusselt number, Reynolds number, screw tape, wire coil, turbulent flow*

I. Introduction

The process of improving the performance of heat transfer system or increase the heat transfer coefficient is referred to as heat transfer enhancement. This leads to reduce size and cost of heat exchanger. And its generally leads to additional advantage of reducing temperature driving force, which increases second law efficiency and decreases entropy generation. A general technique for enhancing heat transfer is passive method such as twisted tape insert. Passive methods are found more inexpensive as compared to other methods. Twisted tape is one of the most important members useful in laminar flow. Heat transfer enhancement techniques are commonly used in areas such as process industries, heating and cooling in evaporator, thermal power plant, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles etc. Passive techniques, where insert are use in the flow passage to increase the heat transfer rate, are advantages compared with active techniques, because the insert manufacturing process is simple and cheap and this can be easily employed in an existing heat exchanger.

The heat transfer rate can be improved by introducing a disturbance in a fluid flow but in the process pumping power may increases significantly and ultimately the pumping cost becomes high. Heat transfer enhancement in a tube flow by insert such as twisted tape is mainly due flow blockage, and its increase the pressure drop. And leads to increases various effect because of a reduced free flow area. Blockage also increases the flow velocity and increased the flow velocity in some situations leads to a significant secondary flow.

The technique of improving the performance of heat transfer system is referred to as heat transfer augmentation or intensification. This leads to reduce the size and cost of the heat exchanger. Heat transfer enhancement technology has been developed and widely applied to heat exchanger applications; for example, refrigeration, automotive, solar water heater process industry, chemical industry etc. Many techniques of active and passive techniques are available for augmentation. These details are discussed in detail by Bergles. Also heat augmentation techniques play a vital role for laminar flow, since the heat transfer coefficient is generally low in plain tubes. Bergles [1, 2] presented a comprehensive survey on heat transfer enhancement by various techniques. Among many techniques (both passive and active) investigated for augmentation of heat transfer swirl flow device) has been shown to be very effective, due to imparting of helical path to the flow. Vast Literature [3-22] is available on full length twisted tape and helical inserts straight and right-left inserts.

II. Design Analysis

2.1 Input parameters

The experimental study on passive heat transfer augmentation using twisted aluminium angles and twisted tapes were carried on in a double pipe heat exchanger having the specifications as listed below:-
Specifications–
Inner pipe ID = 21mm
Inner pipe OD=25mm
Outer pipe ID =42mm
Outer pipe OD =48mm
Material of construction= Cu.
Heat transfer length= 1.5m
Pressure tapping to pressure tapping length =2m

2.2 Experimental setup

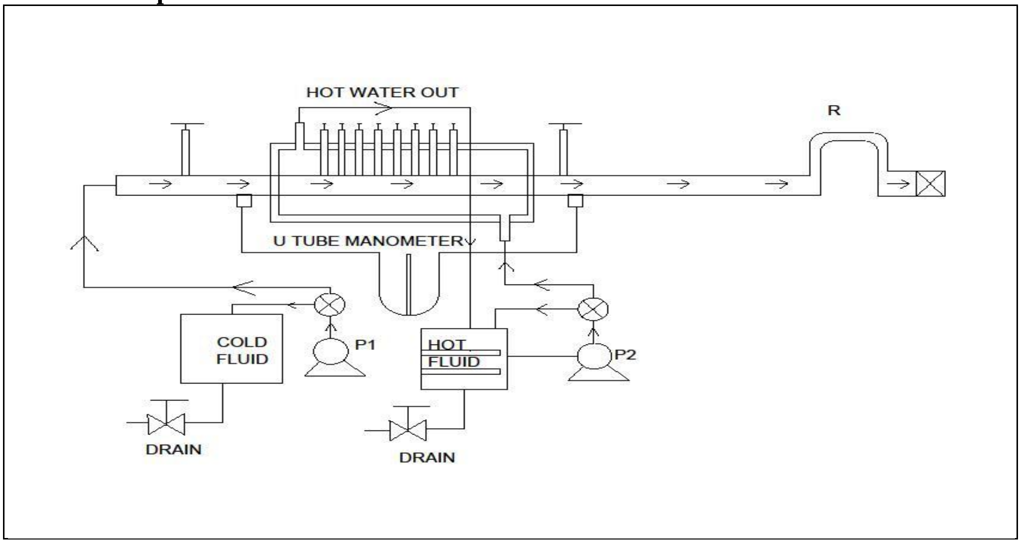

Fig . 1 Experimental Layout

Fig. 2 Photograph of Experimental setup.

There are two pumps of 1 HP and ½ HP used to circulate to hot water and cold water respectively. To control the flow of water the pressure relief valve are fitted at the outlet of the pump. The cold water pump is connected to copper pipe and hot water pump is connected to PVC pipe. The heaters are used of 3 KW for heating the water and maintain it at specific temp. There are two tanks used to stored cold water and hot water. The copper pipe is used for better heat transfer. The copper pipe having inner diameter is21mm and outer diameter is 25 mm and PVC pipe which is off inner diameter is 42mm and outer diameter is 48mm.

The copper pipe is used for better heat transfer which is insert inside the PVC pipe. The water coming out from the PVC pipe that is hot water can be used again and again at maintained specific temperature. The cold water coming out from the copper pipe is used as per required application.

Eight tapered are made on copper pipe of each 1mm at specific distance or equal distance from each other. Eight hole are made on PVC pipe such way that they co-inside and face to each other.

All the thermo-couple are properly insulated with a rubber seal so that it could sense temp at the tapered point only where it is connected. This will make that the flow flowing inside PVC pipe which does not affect the temperature of thermocouple. The whole assembly is make a seal pack so that there will be no leakage in it. All the thermocouple is connected to indicator which displayed the temp of thermocouple. There is knob of indication due to which we can find temperature of required thermocouple.

There is a U-Tube manometer is used to identify pressure difference of water at the inlet and outlet of copper pipe. Thermometer is used to determine temperature of hot and cold water at the inlet and outlet respectively. There are three insert made of wire type, screw type and combine type to put inside the copper pipe in order to disturb the flow that is make the flow turbulent .

2.3 Inserts used

The aluminium angles of size 19mm, thickness about 1mm and length 366cm were first cut into 3 equal length (122cm) .About 2.5 cm on each side was clipped into a flat tape and a hole of about 5mm was drilled in it. Then the ends were tightened in the clamps and fixed on the lathe – one end being fixed on the tool part side and the other on the chuck side. The chuck was then rotated slowly by hand, while the angle was being held in tension, to give it a desired twist. Four angle tapes with varying twist ratios were fabricated as shown in fig. The end portions of the fabricated tapes were cut and drilled to join the tapes by thin high tension wires. Three tapes with the same twist ratio and twist in the same direction were joined to give a length of around2m, which was sufficient for the heat exchanger used for the experimental study. The inserts tapes are shown in figure 3,4 and 5 respectively.

Fig. 3 Wire Type

Fig. 4 Screw Type Insert

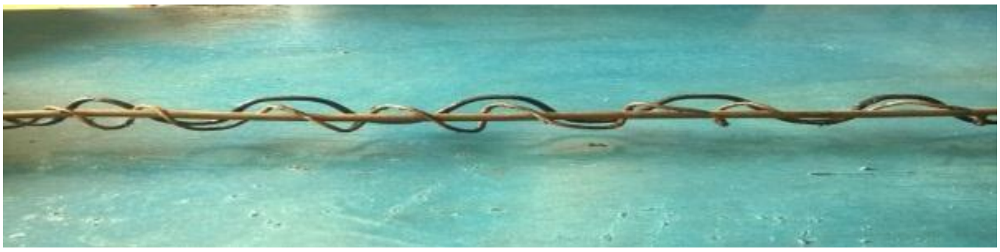

Fig. 5 Combination of screw and wire Insert

III. Experimental Procedure

As cold water pump start cold water start circulating inside the system. A pressure relief valve is used to remove air bubbles in the pipe and to control the flow of water. After removing the bubbles hot water pump is start after certain period of time. So that water will be properly flow in the system.

By using the thermometer inlet temp is measured of hot water and cold water. Thermocouple is used to sense the temp and display it on indicator. Eight readings of thermocouple are taken at particular point by adjusting the knob. In taken reading there will be a small deviation. Again temp is measured of hot and cold water at outlet by using thermometer. Pressure difference is measured by using U-tube manometer.

The flow rate of cold and hot water is measured at outlet in terms of L/S.After completing this process pressure relief valve is adjusted to change the flow of water and whole process is carried out and again for no of times.

There are three insert wire type insert, screw type insert and combine type insert which are respectively puts inside the copper pipe. Similar process is carried out by one by one insert is given.

IV. Result & Discussion

In this section experimental results of isothermal friction factor, Nusselt number and Reynolds number for plain tube and tube fitted with screw tape, wire coil inserts and combination of both are presented.

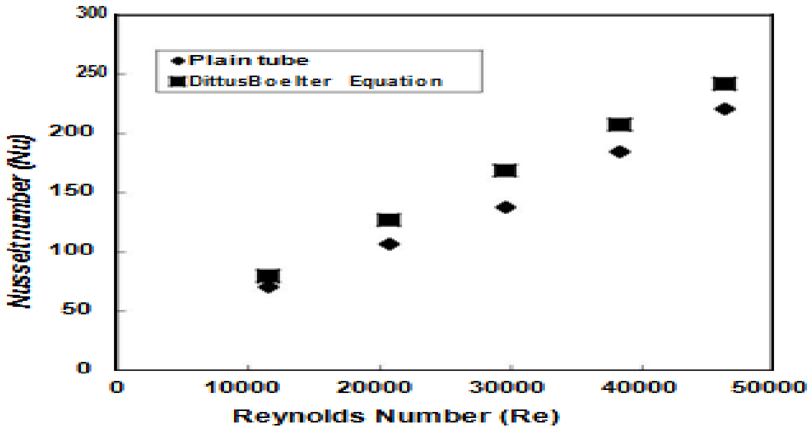

Fig. 6 Comparison of Reynolds number with Nusselt number for plain tube.

Figure 6 indicates the variation of Reynolds number with Nusselt number for plain tube. The experimental values of Nusselt number are agreed reasonably well with DittusBoetter Equation with a discrepancy of less than 13%.,

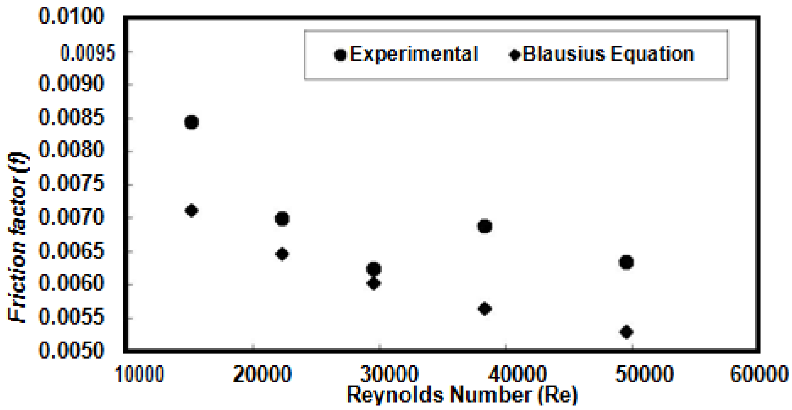

Fig. 7 Comparison of Reynolds number with Friction factor for plain tube

Figure 7 shows the comparison of experimental and theoretical friction data for the plain tube under turbulent flow condition. It is confirmed from the same figure that the experimental friction factor agrees reasonably well with the available correlation of plain tube, with a discrepancy of less than 11%.

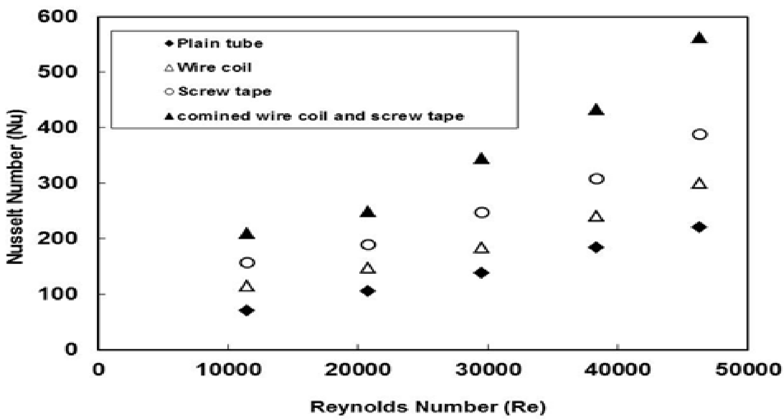

Fig. 8 Variation of Reynolds number with Nusselt number for various insert

Figure 8 depicts the variation of Nusselt number with Reynolds number for plain tube and tube fitted with various inserts. It is observed from this figure that Nusselt number increases with increase Reynolds number. At given Reynolds number Nusselt number is found higher than that of a plain tube. The higher Nusselt number is observed for combined wire coil and screw type at given Reynolds number, indicating an enhanced heat transfer coefficient due to forced convection. The reason is that strong swirling effects generated from the use of combined inserts, leads to better heat transfer by reducing the boundary layer thickness.

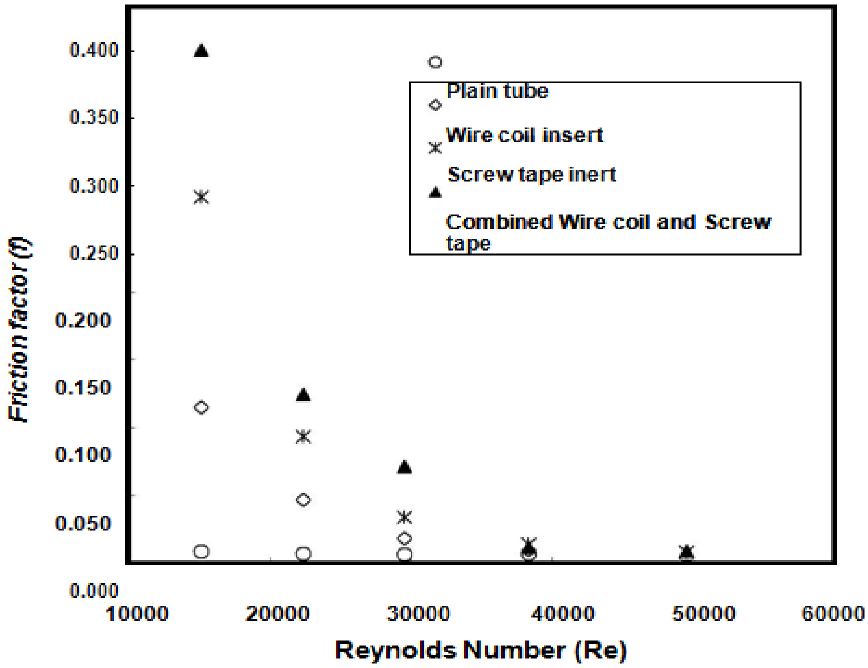

Fig. 9 Variation of Reynolds number with Friction factor for all inserts.

Figure 9 presents the variation of friction factor with Reynolds number for plain tube and tube fitted with various inserts. It is seen from this figure that friction factor decreases with increase Reynolds number. The friction factor for a tube fitted with inserts is higher than plain tube, combined inserts leads to a higher friction factor. The reason is that strong swirling effects generated from the use of combined inserts, leads to higher velocity that elongates the flow path, causing higher friction loss as observed.

V. Conclusion

The present work addresses an experimental investigation of heat transfer and friction factor characteristics of a circular tube fitted with inserts under nearly uniform wall temperature conditions. The comparison of friction factor and Nusselt number results of a plain tube and tube fitted with various inserts have been conducted.

The major findings of this investigation are summarized as follows:

I. The friction factor and Nusselt number are found higher than that of plane tube for above inserts.
J. The friction factor decreases and Nusselt number increases with increasing Reynolds number, for a plain tube and tube fitted with inserts.
K. Combined insert offer a high friction factor and Nusselt number at given Reynolds number. This happens mainly due to greater surface area and high swirl flow.
L. The average heat transfer enhancement for a tube fitted with wire coil, screw insert and combined insert is observed 40, 85 and 155 times higher than that of a plane tube.

Acknowledgement

This work has been conducted by final year students of Mechanical Engineering Department under the guidance of Dr. S.V. Patil (Principal, RMP, Ambav). Authors are thankful to the Management of Rajendra Mane Polytechnic, Ambav for providing all facilities and cooperation throughout this work

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