Experimental Analysis of Heat Transfer in a Tube using Conical and Helical Spring Insert

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Abstract:

An experimental investigation was carried out for measuring tube side heat transfer coefficient, friction factor and pressure drop of water for turbulent flow in circular tube fitted with conical spring insert and helical spring insert. A copper tube of 22.22 mm internal diameter and 20.22 mm outer diameter and 1000mm test length was used. An aluminum conical spring insert and helical spring insert with same length 100mm and 3mm of wire diameter was inserted in smooth tube. A uniform heat flux condition was created by wrapping nichrome wire around the test section and glass wool insulation was used around the tube. Outer surface temperatures of the tube were measured at five different points of the test section by T-type thermocouples. Two thermocouples were used for measuring the inlet and outlet temperature. The flow rate was varied at range of 4LPM to 12LPM with Reynolds numbers were varied in the range of 4500 to 14500 with constant uniform heat flux for smooth tube and for tube with insert. The experimental result demonstrate that the use of conical convergent-divergent spring inserts leads to higher heat transfer rate than the smooth tube, and helical spring inserts. In the turbulent flow, the effect of conical convergent-divergent spring insert increases the friction factor compared to the helical spring insert.

Keywords: *Conical Spring Insert, Friction Factor, Heat Transfer, Helical Spring Insert, Pressure Drop*

1. Introduction

The technology of enhanced heat transfer has received strong attention over the past 3–5 decades; heat transfer augmentation techniques can be applied mainly in the design of more compact heat exchangers found in various industries, especially refrigeration, automotive and chemical processes[2].To improve the performance of heat exchanging devices for reducing material cost and surface area and decreasing the difference for heat transfer thereby for reducing external irreversibility, lot of techniques have been used. Among different passive means to increase heat transfer coefficient, rectangular-cut twisted tape inserts are promising.. Experimental investigation of heat transfer and friction factor characteristics in a tube fitted with rectangular-cut twisted tape insert were studied by Bodiussalam et al., 2013Experimental investigation of heat transfer and friction factor for laminar flow in circular tube fitted with full-length helical screw element o different twist ratio. They conclude heat transfer coefficient increases with twist ratio increases were studied by P. Sivashanmugam et al., 2006[4].Heat transfer enhancement for laminar and transitional flow in a circular tube fitted with wire coil insert were studied by Alberto Garcia et al.,2007[1]. Charachtrastic of heat transfer and friction characteristics in around tube using air as the test fluid were experimentally investigated by Promvonge, 2008[2].

1.1 Different Methods of Heat Transfer Enhancement

Active method: This method involves other external power inputs for heat transfer enhancement; some examples of effective methods include induced cam pulsation and reciprocating plungers, the use of a magnetic field to disrupt the seeded light particles in a flowing channel, etc.

Passive method: Passive methods of heat transfer increase, as previously stated, do not require any external input. One way to increase the heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids in the convective heat transfer. Using this method induces the swirl in the bulk of the liquids and disturbs the real boundary layer in order to increase the active surface area, residence time and therefore the coefficient of heat transfer in the existing system.

Following Methods are generally used,

1. Inserts
2. Extended surface
3. Surface modifications
4. Use of additives.

Nomenclature

A Area of the heated region of tube (m2)
A_f Flow area (m2)
Cp Specific heat of water at constant pressure (J/kg.K)
D_o Tube outer diameter (m)
f Friction factor (-)
h Heat transfer coefficient (W/m2.K)
k Thermal conductivity of water (W/m.K)
L Effective tube length for heat transfer (m)
m Mass flow rate of water (kg/s)
Q Heat transfer rate (W)
T Temperature ($_o$C)
Nu Nusselt number (-)
PrPrandtl number (-)
Re Reynolds number (-)
Δp Pressure drop (N/m2)

2. Experimental description

2.1 Experimental set up

The test section was made from 1000 mm of copper tube (22.22 mm ID and 20.22 mm OD), of which 1000mm was considered to be the test section. Aluminum conical spring inserts and helical spring insert was made by 3mm wire diameter. Conical spring inserts and helical spring insert was made 100mm length which gave pitch 10 mm respectively. To provide the heating energy, the nichrome resistance wire was spirally wrapped uniformly on the outer surface of the test section. Heating element tape was used between the tube and heating wire for electrical insulation. The outer surface of the test tube was well insulated to minimize convective heat loss to the surroundings, and necessary precautions were taken to prevent leakages from the system. To measure the tube's outer surface temperatures, five T-type thermocouples were placed at five equally spaced points in the test section. ARota meter of 25 L/min capacity was provided to measure the water flow rate. For measuring the pressure drop across the tube, a U-tube manometer was used.

2.2 Experimental procedure

After complete the fabrication of the experimental setup. Firstly I fill the water tank by using the tap water and then start the water pump. Set the current and voltage range in ammeter and voltmeter respectively so that it gives the uniform heat flux to the tube at wall temperature range of 40^0C to 41^0C. the flow rate of the working fluid with different range like 4 lpm, 6 lpm, 8 lpm, 10 lpm and 12 lpm. The setup would continue until the steady state is reached. Take the reading of smooth tube. Take the reading of pressure drop across the test tube section by using the U-tube manometer. The experimental procedure repeated with changing the valve of the inlet working fluid at different flow rate, till the steady state is achieved.

In first phase, helical spring inserts are used in tube as shown in fig.2 and in second phase conical convergent spring inserts are use in tube as shown in fig.3 and in last phase conical convergent-divergent spring inserts are used in tube as shown in fig.4. Four inserts are inserted in tube with same distance.

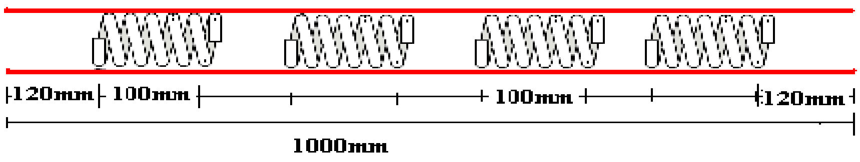

Fig: 1helical spring insert in tube

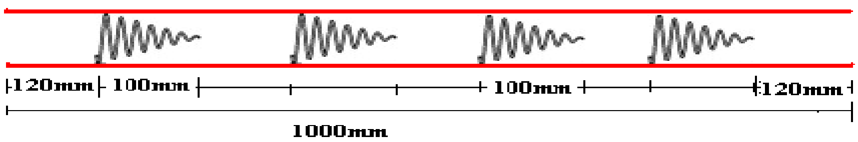

Fig:2conical convergent spring insert in tube

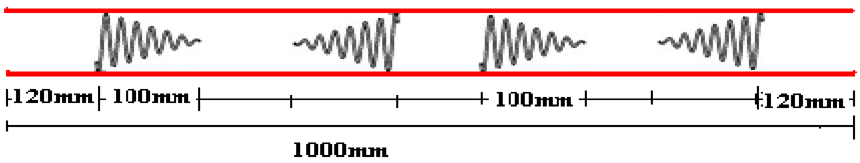

Fig: 4 conical convergent-divergent spring insert in tube

3. Data reduction.

Heat transfer rate by the tube to water was calculated by measuring heat added to the water. Heat added to water was calculated by,

$Q=m\ Cp\ (T_{out}-T_{in})$

Heat transfer coefficient was calculated by,

$$Q = Ah(T_w - \frac{T_{out} + T_{in}}{2})$$

Where, $A=\pi dl$

Tube surface temperature calculated from the average of five local tube surface temperatures

$$T_W = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{5}$$

The bulk temperature was determined from

$$T_b = \frac{T_{out} + T_{in}}{2}$$

Theoretical Nusselt number calculated from Gnielinski, 1976, correlation

$$Nu_{th} = \frac{(f/8)(Re-1000)Pr}{1+12.7(f/8)^{1/2}\left(Pr^{2/3}-1\right)}$$

where from Petukhov, 1970,

$$f = (0.79 \ln Re - 1.64)^{-2}$$

$$Re = \frac{\rho U_m d_i}{\mu}$$

$$Pr = \frac{\mu C_p}{k}$$

$$Nu = \frac{h d_i}{k}$$

Friction factor, f can be calculated from

$$f = \frac{\Delta p}{(L\ /d\ )\left(\rho U_m{}^2/2\right)}$$

Δp is the pressure drop across tapings.

4. Result and discussion.

Data on heat transfer and friction were collected for the smooth tube. The data were taken to check the validity of the set up and measurement techniques over the range of Reynolds number 4500 to 14500.

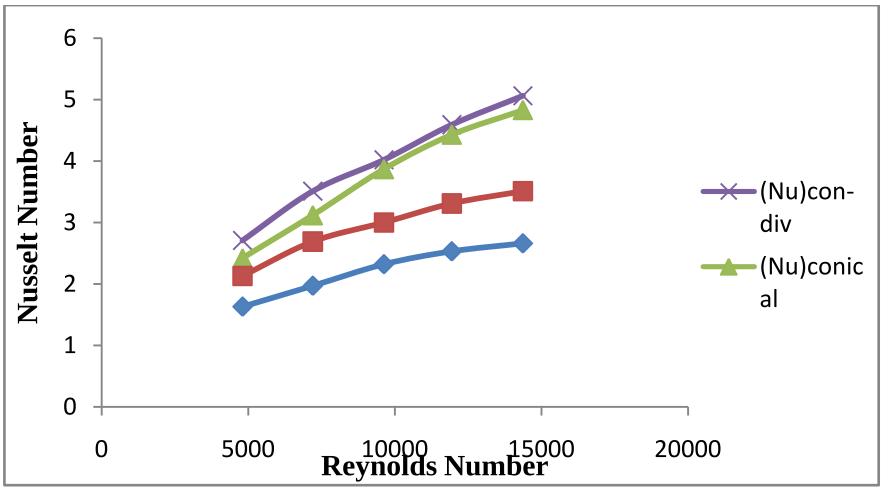

Fig: 5 verification of Nusselt number with Reynolds number

In the fig5, it is observed that the use of conical convergent-divergent spring inserts leads to higher Nusselt number than the smooth tube for all arrangementAs the number of Reynolds increases, the water flow creates more friction, which increases the heat transfer speed. As heat transfer coefficient is directly proportional to Nusselt number, Nu=hDh/K i.e increase in heat transfer coefficient increases the Nusselt number. Maximum Nusselt number was obtained than the conical convergent spring inserts and helical sprig inserts. An average of 77% enhancement of Nusselt number was observed for conical convergent-divergent spring inserts than that of smooth tube.

Figure 6 shows the variation of friction factor with Reynolds number. Frication factor for smooth tube, conical spring inserts and helical spring insert decreased with increases of Reynolds number.

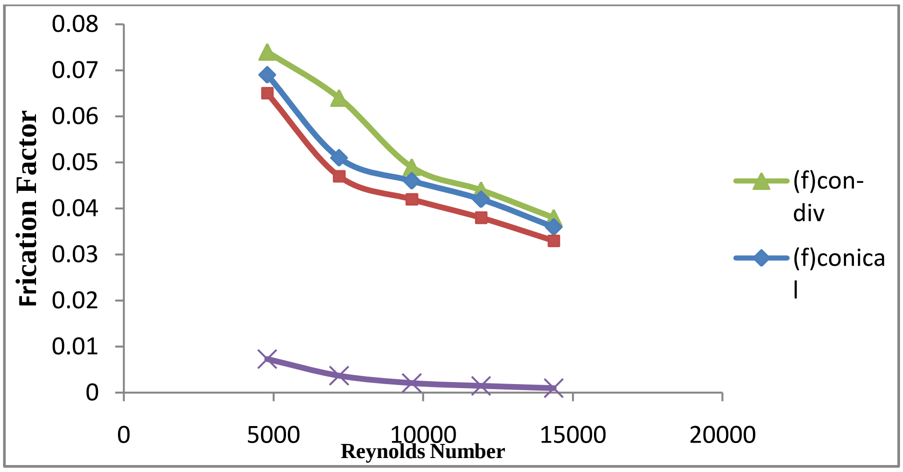

Fig: 6 verification of friction factor with Reynolds number

The higher value of friction factor in conical convergent-divergent spring inserts followed by conical convergent spring inserts and to the helical spring inserts. It is observed that as Reynolds increases there is decrease in friction factor. This is because friction factor is inversely proportional to the velocity. So as velocity increases (i.e. Reynolds number increases) friction factor will decrease.

5 Conclusions

An experimental investigation was carried out for measuring the Nusselt number, heat transfer coefficient and friction factor of water for turbulent flow in circular tube inserted with conical spring insert and helical spring insert.

a) The Nusselt number increases with increases of Reynolds number. The experimental value of Nusselt number increases in conical convergent-divergent spring inserts was 77%, conical convergent spring inserts 66% and in helical spring inserts 31 % than the smooth tube.

b) An average of 77 % enhancement of heat transfer coefficient was observed for conical convergent-divergent spring inserts than that of smooth tube.

c) The friction factor decreases with increases Reynolds number. Maximum friction factor was observed in conical convergent-divergent spring insets followed by conical convergent spring inserts and to the helical spring inserts as compared to smooth tube.

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