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Influences of twisted Square Jagged Tapes insert on heat transfer characteristics and friction factor in turbulent flow with the effects of nano-partical of Tio2 in heat transfer augmentation for smooth tube pipe heat exchanger

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ABSTRACT

Experimental investigation on heat transfer and friction factor characteristics of micro-fined tube fitted with full-length twisted tape and left-right twisted tape inserts has been presented. Turbulent heat transfer in tube was investigated numerically for pure water and water titanium oxide(Tio2) ratios at fixed Reynolds number was compared. The experimental data obtained were compared with those obtained from plain tube published data . The empirical correlation for Nusselt number ,friction relating Reynolds number and twist ratio was formed for twisted tape inserts and found to fit the experimental data. The effects of nano-partical in heat transfer augmentation for smooth tube was discussed and relative nusselts number was compared . Result show that the heat transfer enhancement is promoted extremely by increasing the volume fraction of nano-particles . The work includes the determination of friction factor and heat transfer coefficient for various twisted wire inserts with varying twists and different materials. The Reynolds number is varied from 5000 to 16000. Correlations for Nusselt number and friction factor are developed for the twisted wire inserts from the obtained results. The results of varying twists in square jagged tape with different pitches have been compared with the values for the smooth tube. The thick twists copper insert shows increase in Nusselt number values by 63% however there is increase in friction factor by only 18% as compared to the smooth tube values.

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I. INTRODUCTION

For heating and cooling applications such as air conditioning and refrigeration systems, heat recovery processes food and dairy processes, chemical process plants heat exchangers are widely used in various industrial processes. To make the equipment compact and to achieve maximum efficiency using minimum power we require design skill . Techniques for heat transfer augmentation are relevant to several engineering applications. Today, the high cost of energy and material has resulted in producing more efficient heat exchange equipment. Furthermore, sometimes we need for small heat exchanger in specific applications, such as space application, through an augmentation of heat transfer. Therefore, an augmentation technique may result in a considerable saving in the material cost by increasing efficiency . The heat exchangers used in sugar factory, marine applications,automobiles and in chemical industries may corrodes and becomes week, due to such problem a heat exchanger becomes older, the resistance to heat transfer increases owing to scaling are common. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow thereby breaking the viscous and thermal boundary layer. However, in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years and are discussed under the classification section.

II. Influences of Twisted Square Jagged Tapes Insert on Heat Transfer

A. Present experimental work

The experimental study of heat transfer augmentation using perforated twisted tape inserts for various twists with ferrous as a material were carried on in a single phase flow heat exchanger having the specifications as listed below :

Fig.1 Actual Experimental set up for forced convection

B. Experimental Set up

The set up having test section with tube in tube heat exchanger. Inside tube is of Copper and outside tube is of Stainless Steel. Four thermocouples are connected to the test section, two at the inlet and two at the outlet of hot and cold water respectively. Two rotameters are connected at inlet of cold and hot water to measure the flow rates. Also control valves and bypass valves are provided at inlet of both the rotameters. Two centrifugal pumps are used to circulate the cold and hot water. Two tanks are used for storing the hot water and cold water. Electric heater is attached to the hot water tank having capacity of 1500watt. To measure the pressure difference between inlet and outlet of test section of hot fluid inverted U-tube manometer is used. Different twisted tape inserts are used. The current meter is used to measure the velocity of flow through inserted tube.

C. Experimental Set up:

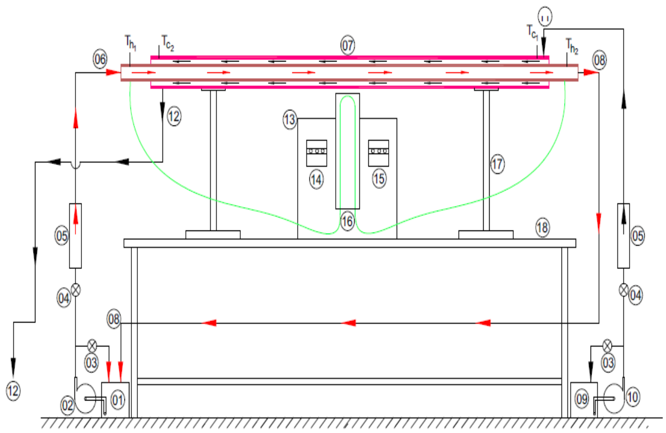

Fig .2 Schematic diagram of forced convection set up

01	Hot water tank	07	Test Section	13
02	Hot water pump	08	Hot water outlet	14
03	By pass valve	09	Cold water tank	15
04	Flow control valve	10	Cold water pump	16
05	Rotameter	11	Cold water inlet	17
06	Hot water inlet	12	Cold water outlet	18

D. Experimental procedure

1. Refer to the Fig A and make all the cable connection carefully.
2. Switch ON the water heater wait until water temperature reaches 80
3. Switch on temperature display
4. Start cold water pump
5. Adjust flow rate of cold water at 100 LPH
6. Start hot water pump
7. Adjust flow rate of hot water at 100 LPH and keep it constant
8. The temperatures will keep on rising continuously. When steady state is reached, note all the temperatures (T1 to T4)
9. Now Adjust flow rate of hot water at 200 LPH
10. The temperatures will keep on rising continuously. When steady state is reached, note all the temperatures (T1 to T4)
11. Repeat step 9 and 10 for hot water flow rates at 300,400,500,600,700,800 and 900 LPH
12. Switch off pumps ,wate heater and temperature display .

E. Specifications of inserts

I Material: Ferrous

i. Width of twisted tape = 9 mm

ii. Twist ratio 7, 6, 4.

iii. Length of insert = 100cm

iv. Thickness of inserts = 3mm

Fig.3 Ferrous square jagged Twisted tape coated with red oxide (y=7) (Enlarged view)

Fig.4 Ferrous square jagged Twisted tape coated with red oxide (y=6)(Enlarged view)

Fig.5 Ferrous square jagged Twisted tape coated with red oxide (y=4)(Enlarged view)

III. SAMPLE CALCULATIONS AND NUMERICAL METHODOLOGY

1) Properties of Water

a) Properties of hot water – calculated at mean bulk temperature Tbh= $(T_{h1}+T_{h2})/2$

b) Properties of cold water Tbc=$(T_{c1}+T_{c2})/2$

2) Heat given by hot water Qh= mh* Cph* (Th1-Th2)

3) Heat given by cold water Qc= mc* Cpc* (Tc2-Tc1)

4) Average heat transfer Qavg. = $(Q_h+Q_c)/2$

5) Overall heat transfer coefficient Qavg. =Δ Tm* As* U

a) Surface area of tube As= πdiL

b) Logarithmic mean temperature difference

□Tm = $(\Delta T_1 - \Delta T_2)/\ln((\Delta T_1/\Delta T_2)$

□□□T1 = Th1 – Tc2

□□□T2 = Th2 – Tc1

6) Nusselt Number of cold water flowing through the annular space.

Nuo= $0.023(Reo)^{0.8}(Pr)^{0.3}$

$$Reo = (\rho U_0 Dh)/\mu$$

Dh= Di – do

Continuity equation – mc = $\rho A_0 U_0$

7) Heat transfer coefficient of cold water flowing through the annular space.

Nuo= (hoDh)/K

h_0 =

8) Heat transfer coefficient of hot water flowing through the tube.

$$1/U = 1/hi + 1/h_o$$

hi= $1 / [(1/U)+(1/h_o)]$

9) Experimental Nusselt Number of hot water flowing through the tube.

Nui = $(h_i d_i)/K$

10) Theoretical Nusselt Number of hot water flowing through the tube (DittusBoelter equation).

$$Nui = 0.023(Rei)0.8(Pr)0.3$$

11) Experimental Friction Factor

a) $\Delta P = \rho gh$ b) $\Delta P = fL\rho U_i^2/ 2d_i$

12) Theoretical Friction Factor

$$f = 0.0055 *[1+[50+[10^6/R_e]]^{0.33}]$$

IV. RESULT & DISCUSSION

A. The Experimental Validation with Results

The friction factor and Nusselt number could be evaluated experimentally with the help of experimental rig and performance accuracy was determined by conducting preliminary experiments with plain tube without insert, and results compared with standard empirical relationships and previous research work for laminar flow and turbulence flow. The purpose was to check the reliability of the apparatus touser.

a).Enfluence of Heat transfer characteristics for smooth tube

Figure shows the relation between Nusselt number v/s Reynolds number. The curve shows that Nusselt number is a function of Reynolds number. The values are in close agreement with the Dittus-Boelter equation with a maximum differance of 20 %

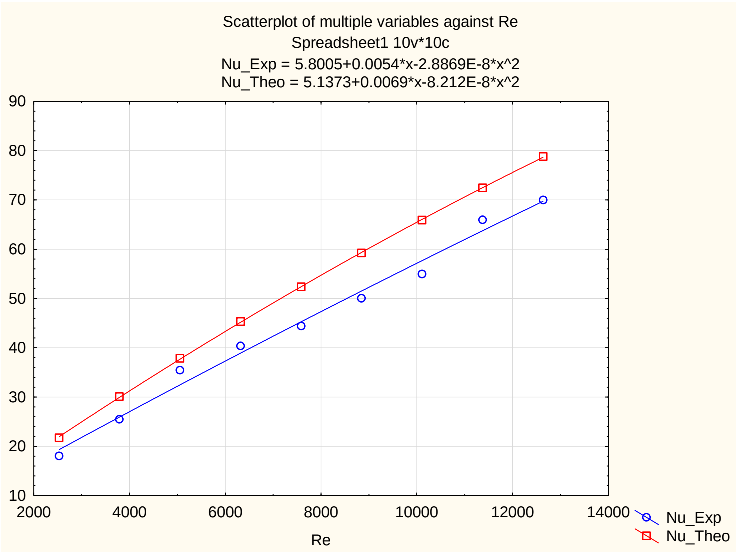

Fig.6 Nusselt number v/s Reynolds number for plain tube

b. Friction factor results for smooth tube

Figure shows the relation between friction factor and Reynolds number for turbulent flow in the tube without twisted tape insert, for smooth tube flow conditions. This proves that the experimental test rig is validated and further experimentation can be carried out. Friction factor obtained from the experimental investigation

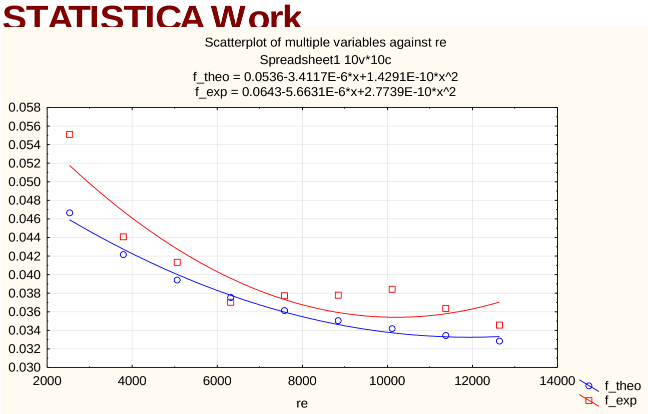

Fig. 7 Friction factor v/s Reynolds number plot for plain tube

B. Mathematical Comparison Of "Plain Tube" And "Tubes With Different Twisted Tapes with different twist ratio :

Figure indicates the relation between Nussult number and Reynolds number for plain tube and tube with different Twisted Tapes, the Figure concludes that the Nusselt number is function of Reynolds number, as Nusselt number increases with increase in Reynolds number. Hence, convective heat transfer rate is more with higher Reynolds number.
Further, it can be concluded that, twisted tapes with closer twist (with lesser twist ratio) give increased Nusselt number for a particular Reynolds number. Heat transfer rate is better with twisted tapes of minimum twist ratio. Perforated tapes shown greater Nusselt number compared with plain twisted tapes.

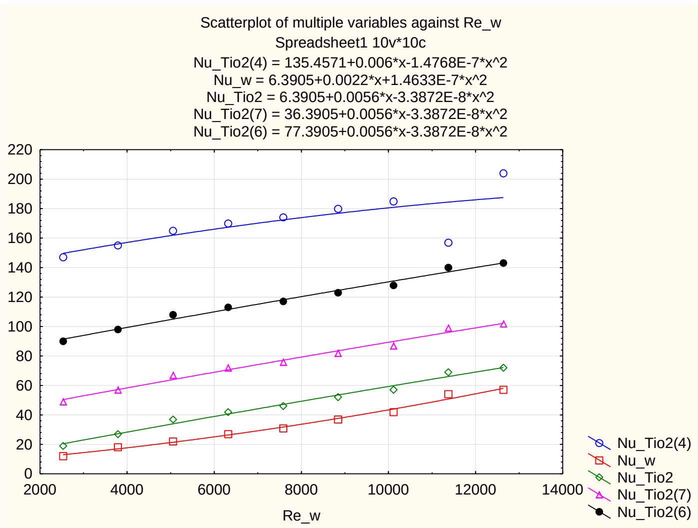

Figure 8 Comparison Of "Plain Tube" And "Tubes With Different Twisted Tapes with different twist ratio

Figure shows the relation between friction factor and Reynolds number for plain tube and tube with various inserts, the Figure concludes that the friction is minimum when the twisted tape is not inserted. Further, with the increase in twist, i.e. with the decrease in twist ratio, the friction factor goes on increasing for a particular Reynolds number. Perforated tapes show lesser friction factor compared with plain twisted tapes.

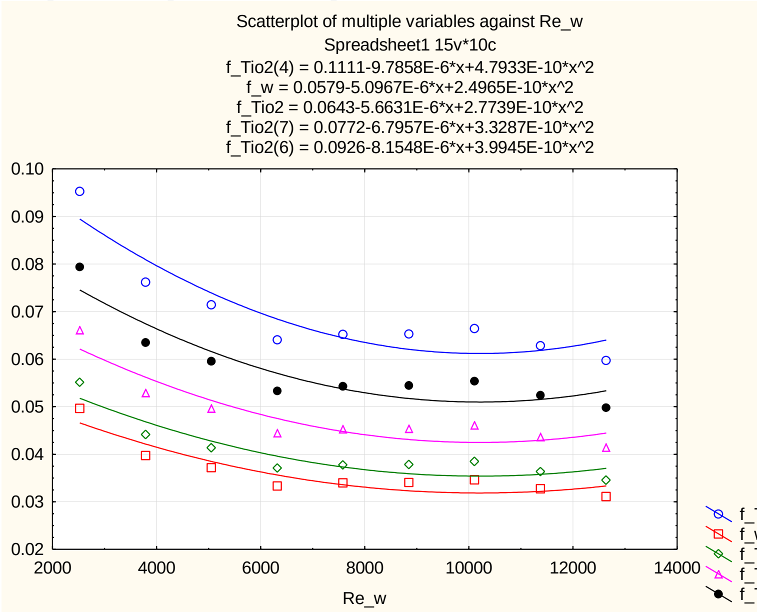

Figure 9 the relation between friction factor and Reynolds number for plain tube and tube with various inserts

The curves are very steep for lesser values of Reynolds number. This is due to the fact that, for lower values of Reynolds number, the viscous force dominates the inertia force. For lower Reynolds number, less than 550, the curves are more leaning and the friction factor is comparatively high

V.CONCLUSION

Experimental mathematical calculations of heat transfer and friction factor characteristics of circular tube fitted with full-length square jagged twisted tape inserts of different twist ratio has been presented. Calculations and curve fitting is drawn with graphs and mathematical correlations are obtained. The results obtained were considerable enhancement in heat transfer and that the heat transfer is more with minimum twist ratio.

□□Maximum increase in Nu for plain twisted tape with y = 7 was found to be 33 %

□□Maximum increase in Nu for plain twisted tape with y =6 was found to be 48 %

□□Maximum increase in Nu for plain twisted tape with y = 4 was found to be 63%

V.

□□Friction factor is increased by 18 % with y=4 in Square jagged twisted tape.

□□Friction factor is increased by 15 % with y=6 in Square jagged twisted tape

□□Friction factor is increased by 12 % with y=4 in Square jagged twisted tape

It is concluded that heat transfer increase by 63% while frction factor increases by 18% so with less pumping power more heat transfer can achieved

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