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Performance analysis of V-jagged twisted tape insert for heat transfer in a circular tube

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Abstract

In the present work effect of V-jagged twisted tape insert on friction factor, heat transfer and enhancement were investigated in a circular tube. The experiments were carried out for one twist ratios (y=3.09) and two different width and depth of jag(we=10,de=8),(we=10,de=10) for different mass flow rates keeping heat flux constant with air as working medium. The pressure drop, friction factor, heat transfer for various inserts were determined. The results obtained were compared with plane tape and plane tube. Also to check the effect of material on heat transfer the experiments were conducted on the materials copper.

Keywords: V-jagged twisted tape, twist ratio, Reynolds No., Heat transfer

Introduction

Among many techniques (both passive and active) investigated for augmentation of heat transfer rates inside circular tubes, a wide range of inserts has been utilized particularly when turbulent flow is considered. There are many devices like coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc.[1]A twisted tape as a swirl generator is one of widely used devices for heat transfer enhancement. Functionally, a twisted tape induces swirl flow, enhances fluid turbulence and thus fluid mixing which directs toward reducing the thermal boundary thickness[2] Hsieh and Huang [9] conducted experimental studies for heat transfer and pressure drop of laminar flow in horizontal tubes with strip type inserts, and found that, friction factor increases for tubes with inserts as compared to bare tube values were typically between1.1 and 1.5 for 6500 < Re < 19500. S. Naga Sarada [10] carried out experiments for plain tube with/without twisted tape insert at constant wall heat flux and different mass flow rates. Which resulted in enhancement of heat transfer by 36 to 48% for full width and 33 to 39% for reduced width-22 mm inserts. Chinaruk Thianpong[4] investigated experimentally the influences of the perforated twisted tapes (PTs) on the heat transfer, pressure loss and thermal performance characteristics. The increase in heat transfer rate by using PT is found to be in range of 36–85%, over those of the corresponding plain tube. Salam [2] experimentally investigated tube-side heat transfer coefficient, friction factor, heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular-cut twisted tape insert. An average of 68% enhancement of heat flux was observed for tube with rectangular-cut twisted tape insert than that of smooth tube. C. Thianpong[3] have conducted experiments with perforated twisted tapes with parallel wings (PTT) for Reynolds number between5500 and 20500 in a heating tube to determine heat transfer and pressure drop characteristics of turbulent flow. Watcharin Noothong[8]have performed experiments with twisted tape inserts in a double pipe heat exchanger to determine flow friction characteristics. The experimental results revealed that the increase in heat transfer rate of the twisted-tape inserts is found to be strongly influenced by tape-induced swirl or vortex motion. Over the range investigated, the maximum Nusselt numbers for using the enhancement devices with y = 5.0 and 7.0 are 188% and 159%, respectively, higher than that for the plain tube. Snehal S. Pachegaonkar[11] analysed heat transfer and pressure drop characteristics of Double pipe heat exchanger with annular twisted tape insert, The Heat Exchanger with annular twist tape of angle 450 resulted in highest increase in Nusselt number over Plain double pipe Heat Exchanger and Heat Exchanger with annular twisted tape of angle 600. S. Eiamsa-ard [12] investigated experimentally, Influence of the oblique delta-winglet twisted tape (O-DWT) and straight delta-winglet twisted tape (S-DWT) arrangements in a tube using water as working fluid. To determine heat transfer, pressure drop. M.M.K. Bhuiya[7] have investigated experimentally augmentation of heat transfer for turbulent fluid flow through a tube by using double helical tape inserts. The effects of insertion of the helical tape turbulators with different helix angles (9°, 15°, 21° and 28°) onheat transfer and pressure drop in the tube for Reynolds number ranging from 22,000 to 51,000 were examined. It was found that the Nusselt number, friction factor and thermal enhancement efficiency increased with decreasing helix angles. Halit Bas[7] have studied Flow friction and heat transfer behavior in a twisted tape swirl generator inserted tube. The effects of twist ratios (y/D = 2, 2.5, 3, 3.5 and 4) and clearance ratios (c/D = 0.0178 and 0.0357) are discussed in the range of Reynolds number from 5132 to 24,989.P. Murugesan[8] investigated The effect of V-cut twisted tape insert on heat transfer, friction factor and thermal performance factor characteristics in a circular tube for three twist ratios (y=2.0, 4.4 and 6.0) and three different combinations of depth and width ratios (DR=0.34 and WR=0.43, DR=0.34 and WR=0.34,DR=0.43 and WR=0.34)

Experimental set-up

The schematic diagram of experimental set-up is given in Fig.2.The experimental facility includes a blower, an orificemeter to measure the volumetric flow rate, the heat transfer test tube (700 mm). The MS test tube 25.4 mm inner diameter (D1), 32 mm outer diameter (D2). The V-Jagged twisted tapes are tested in this experiment, with two different materials and two different width and depths-(8mm,10mm),(10mm.10mm), and two twist ratio (y/D =3.09,5.09). They are fabricated from Copper and Brass. The schematic figure of the test tube with V-Jagged twisted tape insert is given in Fig.2. A 0.24 hp blower is used to force air through the test tube. A electric winding is wound across the the test tube. A uniform heat flux is provided to the external surfaces of the tube, A variac transformer is used to control the heat flux, which controls the output power. In order to reduce the convective heat losses, the outer surface of the test tube section is covered with insulating material like wool. A 4-K type thermocouple is placed on the external surface of the test-tube to measure the surface temperature at the four locations. Te inlet and outlet temperature is also measured with help of 2

K type thermocouple.An manometer is used to measure the pressure drop across the test-tube. An orificementer which is placed at outlet of the tube is used to measure volumetric flow rate of air after it passes the test tube. For this purpose a separate U-tube manometer is placed across orificemeter. The volumetric flow rate of air supplied from the blower is controlled by varying control valve position. During the experiment the external surface of the tube will be heated and the readings of temperature, volumetric flow rate, pressure drop of the bulk air will be taken after the system reaches steady state condition. The Nusselt number, Reynolds number, friction factor, heat transfer enhancement are calculated based on the average outer wall temperatures and the inlet and outlet air temperatures.

Data analysis and calculation

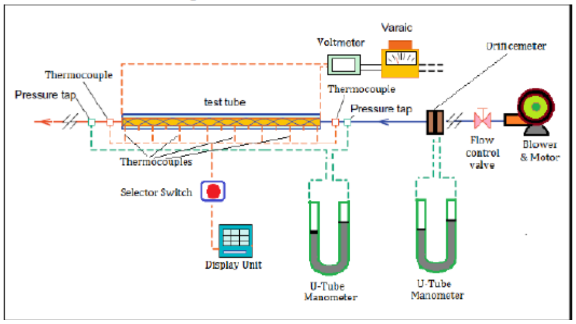

Fig. 1: Block diagram of Experimental setup.

The following data reduction equations will be used to determine heat transfer co-efficient and pressure drop.

A. Heat transfer calculations:

$Ts=(T2+T3+T4+T4)/4$

$Tb=(T1+T2)/2$

Equivalent height of air column$=(\rho_w * h_w)/\rho_a$

Discharge of air,$Q_a=C_d * A_0 * (2*g*h_{air})^{1/2}$

velocity of air ,$V=Q_a/A$

Reynold,s No,$Re=(VD)/\upsilon$

$Q=m*C_p*(T_6-T_1)$

$h = Q/ (T_s-T_b) * A$

$N_u=hd/k$

$$f= \frac{\Delta p}{\frac{L}{D} * \frac{\rho_a * v^2}{2}}$$

$$\eta = \frac{\frac{N_{ui}}{N_u}}{\left(\frac{fi}{f}\right)^{0.33}}$$

B. Validation of Plain tubes:

In this experiment the Nusselt No and friction factor for plain tube were found and compared with the Nusselt No and friction factor obtained from Dittus Boelter and Petukhov equations.

The equations are as below:

$Nuth=0.023Re^{0.8}Pr^{0.4}$

$Fth=(0.790 \ln Re-1.64)^{-2}$

The experimental values of Nusselt No. and friction factor of plain tube were compared with vaules obtained by above given corelations which is shown in fig. It was found that the values obtained were in good agreement with values obtained by Dittus Boelter and Petukhov equations. The results obtained were nearby same, thus this accuracy provides reliable results for heat transfer and friction factor in a tube with twisted tape inserts in this present study .The Reynolds Number was varied between 6000 to 10,000.The results of experiments conducted for V-jagged twited tape insert is discussed further in results and discussion.

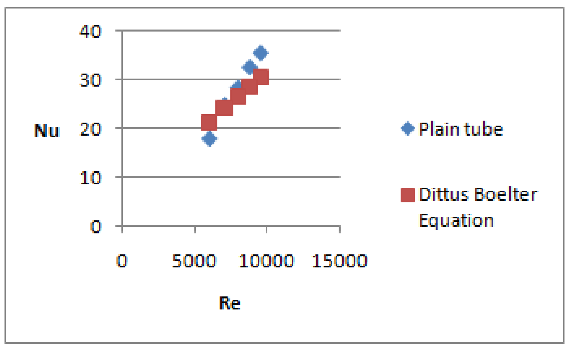

Fig. 2: Validation results for Nusselt Number.

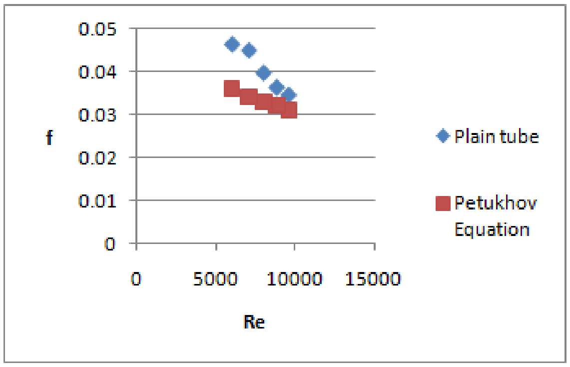

Fig. 3: Validation results for Friction factor.

Results and discussions

It is observed that the Nusselt no increases with increase in Reynolds No. as shown in Fig 5.The maximum value of Nusselt No was obtained by V-jagged twisted tape(we=10mm,de=8mm) as compared to other twisted tape. The Nusselt No varied between 20% to 42% as compared to plain tube. This is due to high turbulence created by the V-jaggs provided on the twisted tape,which results in better mixing of flow, and increase in Heat transfer enhancement. The variation of friction factor with Reynolds No with V-jagg twisted tape is represented in Fig 6 . It shows that friction factor decreases gradually with increase in Reynolds No. It is maximum for the V-jagg twisted tape (we=10mm,de=8mm) as compared to other twisted tape. It is clear from Fig 5 that Nusselt No increases when V-Jagg twisted tape are inserted, it is also seen that greater enhancement is observed at minimum Reynold No and for the tape with Jagg of (we=10mm,de=8mm).

The maximum Enhancement observed is 1.11 for V-jgged Insert having (we=10mm,de=8mm).It is seen that Enhancement decreases gradually with increase in Reynold's No. for all V-jagg inserts. It is also observed that minimum depth of the Jagg gives the better result.It is also seen that for Jaggs of (we=10mm de=8mm) and (we=10mm,de=10mm) graphs are of decreasing order for a given pitch for Reynold,s No 4000 to 9500.The Nusselt No varied between 20% to 44% for jagg of (we=10mm,de=8mm) and varied between 20% to 32% for jagg of (we=10mm, de=10mm) as compared to plain tube.

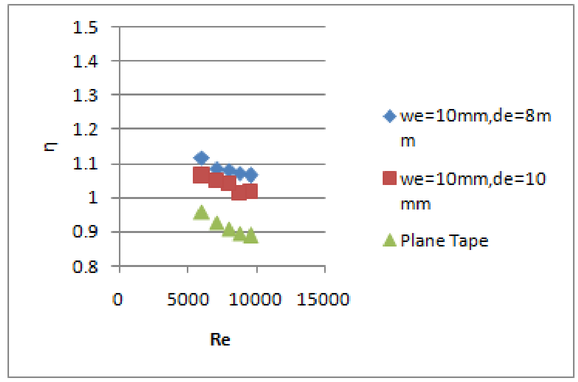

Fig. 4: Variation of Enhancement for different inserts.

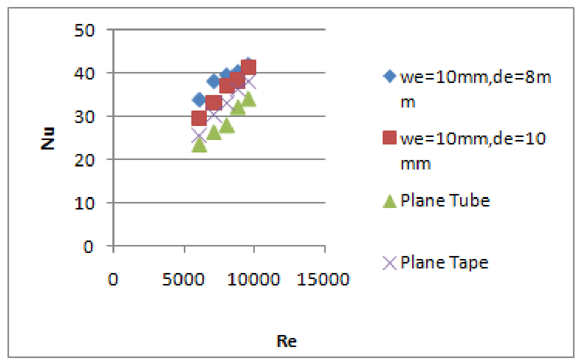

Fig. 5: Variation of Nusselt No for various inserts.

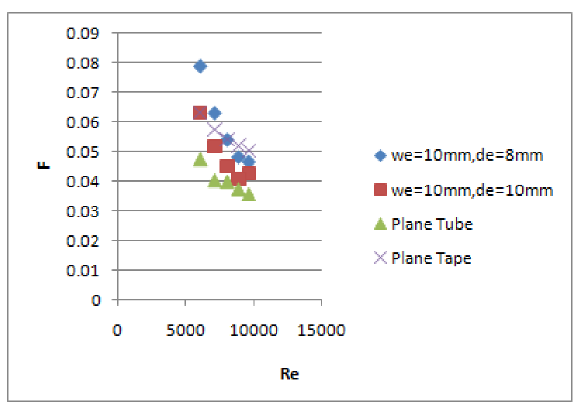

Fig. 6: Variation of friction factor for various inserts:

Conclusions

The present study deals with an experimental investigation on effect of heat transfer rate by using V-jagged twisted tape in a circular tube using air as working medium and by varying the mass flow rate and keeping constant heat flux rate .From this experimentation following conclusions can be drawn

1. The enhancement of heat transfer as compared to plain tube varied Between 16% to 19% For Jagg of we=10mm,de=8mm and between 11% to 14% for jagg of we=10mm,de=10mm.
2. It is observed that reduction in depth of Jagg causes increase in Nusselt No as well as increase in friction factor. Maximum friction factor rise was about 66.66% for jagg (we=10mm de=8mm) and 33% for Jagg(we=10mm,de=10mm) as compared to plain tube.

Thus, enhanced performance can be achieved using V-jagged twisted tape as compared to plain tube and increase turbulent flow in a circular tube.

Future Scope:

1. Change the tape material from copper to Brass, Aluminium.
2. Change the Shape of Jagg.
3. Change the depth of the Jagg.

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Nomenclature

A0 - area of orifice, (m2)
A - test section inner tube area, (*p*/4 D2) (m2)
Cp - specific heat of air, (J/kg K)
Qa - air discharge through test section (m3/sec)
D - Inner diameter of test section, (m)
H - pitch, (mm)
w - width of wavy tape insert,(mm)
H/D - twist ratio
fth - friction factor(theoretical) for plain tube
f - friction factor(experimental) for plain tube
fi - friction factor obtained using tape inserts
h - experimental convective heat transfer coefficient, (W/m2K)
hw - manometer level difference,(m)
hair - equivalent height of air column, (m)
k - thermal conductivity, (W/mK)
L - length of test section, (m)
m - mass flow rate of air, (Kg/sec)
Nui - Nusselt number (experimental) with tape inserts, (hD/k)
Nu - Nusselt number (experimental) for plain tube
Nuth - Nusselt number for plain tube (theoretical)
Pr - Prandtl number
p - pitch, (m)
ΔP - pressure drop across the test section, (Pa)
Q - total heat transferred to air (W)
Re - Reynolds number, (*r* V D/*m*)
T1, T8 - air temperature at inlet and outlet, (_k)
T2, T3, T4, T5 - tube wall temperatures, (_K)
Ts - average Surface temperature of the working fluid, (_K)
Tb - bulk temperature, (_K)
V - air velocity through test section, (m/sec)
v **-** Kinematic viscosity of air, (m2/sec)
m **-** dynamic viscosity, (kg/m s)
h **-** Over all enhancement
ρ**w -** density of water, (Kg/m3)
ρ**a -** density of air (Kg/m3)

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