AUGMENTATION HEAT TRANSFER IN A CIRCULAR TUBE USING CONICAL RING AND TWISTED TAPE INSERT

V. Tirupati Rao, Student of M. Tech. Thermal Engineering
A. Rupesh Venkata Ramana, M. Tech. Assistant Professor
Dr. T. Dharma Raju Ph. D., Professor, Department of Mechanical Engineering
Adarsh College of Engineering, Kakinada, Andhra Pradesh, India

ABSTRACT

Augmentation techniques place a major role in enhancement of heat transfer. In the present study a circular tube fitted with conical-ring turbulators and a twisted-tape swirl generator placed in a plain tube at different pitch ratio's=1.0,2.0,3.0,4.0,5.0 to enhance the heat transfer in a plain tube. The air is used as working fluid in the range of Reynolds number 7696 to 15410 based on the consideration of different mass flow rates of air(m_a)=20 kg/hr,25kg/hr,30kg/hr,35kg/hr,40kg/hr. Two twisted-tapes of different twist ratio's Y=2.5 and 4.5 are introduced in each run. The maximum heat transfer rate of 370% is found for using the conical-ring and the twisted tape of Y=2.5. The correlations for Nusselt number and Friction factor evaluation criteria to assess the real benefits in using the turbulator and swirl generator of the enhanced tube are determined.

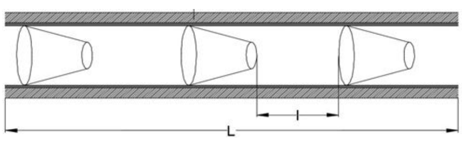
Key words – *conical ring, Nusselt number, twist ratio, pitch ratio, friction factor.*

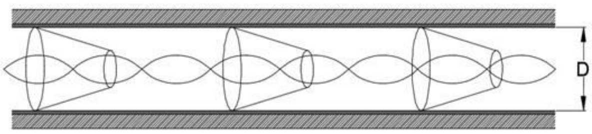
I. INTRODUCTION

Heat exchanger is a device facilitating heat transfer between two or more fluids .it is extensively used in several industries, such as thermal power plants, chemical processing plants, air conditioning equipment, refrigerators, radiator for space vehicles as well as automobiles etc. Industrial heat transfer equipments generally are operated in turbulent/swirl flow conditions where their performance in terms of energy transfer rate is high, compared with laminar flow by virtue of the high degree of turbulence in turbulence/swirl flow. Also in turbulent flow ,a high intensity of turbulence will enhance the rapid mixing of fluid properties, and the mixing can help to increase the effective area of heat transfer leading to higher heat transfer rates. Heat exchangers have been classified in many different ways .the design of heat exchanger is complicated, requiring a consideration of different modes of heat exchangers a heat transfer enhancement concept in which swirl was introduced in the flow was proposed by Kreith and Margolis [1]. Gambill and Bundy [2] claimed that twisted –tapes are also effective in high prandtl number fluids because for such fluids it provides high heat transfer rate. Zozulya and Shkuratov[3] reported that a smooth decrease in pitch of a twisted tape results in an improved heat transfer rate. Al –Faled and chakroen[4] found that there is an optimum tape width, depending on the twist ratio and Reynolds number, for the best thermo –hydraulic characteristics and the tight-fit tape yields a better performance over the loose fit -one . Yakut and sahin[5] studied the effect of conical-ring turbulators on the turbulent heat transfer . Patoil and vijay Babu [6] studied on heat transfer enhancement in a circular tube and square duct. In their paper, emphasis is given to works dealing with twisted tape, and screw tape inserts. Eiamsa-ard and Promvonge[7] investigated experimentally the heat transfer and turbulent floe friction characteristics in a circular wavy –surfaced and constant heat flux tube with a helical -tape insert. these experiments are based on Reynolds number at the tube inlet ,ranging from 3000 to 9200.they calculated that wavy surfaced tube combined with the helical tape provides higher heat transfer rate and friction factor than the wavy surfaced tube alone around 57% and 125% respectively. Abdullah[8] studied on heat transfer and pressure Drop characteristics in an eccentric converging-diverging tube [ECDT] with twisted tape inserts. The Nusselt number for the eccentric converging-diverging tube re found to be 15% 45% higher than that of the plain tube. Yongsiri et al [9] studied on the augmentation of heat transfer using nozzle turbulators and swirl generator in the uniform heat flux tube as the conventional passive enhancement method. The maximum Nusselt numbers for using both the enhancement devices with P.R=2.0,4.0 and 7.0 are found to increase by 374% ,342% and 309% respectively in comparison with the plain tube. Mohammed[10] performed experimental investigations on the augmentation of turbulent flow heat transfer in a horizontal tube fitted with combined conical-ring turbulators and twisted-tape swirl generator. The air is the working fluid for Reynolds number in the range of 5000 to 23000 under constant wall heat flux thermal boundary conditions.

II. DESCRIPTION OF COMBINATION OF CONICAL-RING AND TWISTED TAPE INSERTED IN A PLAIN TUBE

A copper plain tube of length (L)=600mm,is taken with inner diameter (Di) and outer diameter(Do) of 46mm n 50mm respectively. The thickness of the tube(t)=2mm.conical-rings are of length 46mm and diameter of nozzle varying from 21mm to 46mm is inserted in a plain tube. They are put at different pitch ratio’s (P.R.)=1,2,3,4.5. Where pitch ratio (P.R.) is the ratio of convergent conical ring length to inner diameter of the plain tube. Air is taken as working fluid and passes through a tube at different mass flow rates (ma) =20kg/hr,25kg/hr,30kg/hr,35kg/hr,40kg/hr. In the analysis ,the conical-ring turbulators and twisted-tape used in the present are depicted in Fig.1 The conical-ring was made of aluminium with 46mm(1.0D) in length n its small end diameter(d) was 21mm(0.45D) with a 2mm uniform thickness. The twisted-tapes made of steel strip its twist ratio’s of Y=y/w=2.5 and 4.5 were used for this investigation. The twist ratio is defined here in as the ratio of the pitch (or) one twist length(y,180^0) to the tape width(w).The various characteristics of the flow, the Nusselt number and the Reynolds numbers were determined.





Conical ring arrangement conical ring turbulator and twisted tape

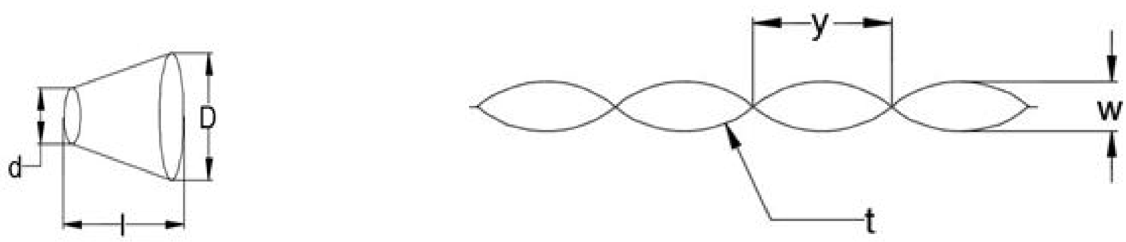


Fig 1 : tube fitted with conical ring turbulator and twisted tape insert

III. THERMAL ANALYSIS OF THE PROBLEM

Conical rings and twisted tapes inserted in a plain tube at different pitch ratio's (P.R.) are used to enhance the heat transfer coefficient without increasing the area. Air is used as a working fluid which passes through a circular tube at the range of Reynolds number 7696 to 15410, heat transfer takes place from inside to surroundings of the tube due to temperature difference. Below are the lists of equations used in this problem.

A. PLAIN TUBE

Mass flow rate (m_a) = ρxaxv

Where ρ= absolute density of air, kg/m^3

a = area of the tube, m^2

V = velocity of air, m/sec

Reynolds number (R_e) = VxD_i/υ

Where D_i = inner diameter of tube,m

υ = kinematic viscosity, m/sec^2

$$\text{Friction factor(f)} = 0.184xR_e^{-0.2}$$

Re=Reynolds number

$$\text{Nusselt number(Nu)} = 0.023xR_e^{0.8}xpr^{0.3}$$

Pr= prandtl number

B. PLAIN TUBE FITTED WITH CONICAL RING

Friction factor is calculated by the equation of Promvonge P. and Eiamsa'ard

$f = 6049x\ R_e^{-0.71}x\ (l/D_i)^{-0.5}$

Nusselt number is calculated by the equation of Promvonge P. and Eiamsa'ard

$$Nu= 0.19x\ R_e^{0.71}x\ Pr^{0.3}x\ (l/D_i)^{-0.2}$$

C. TWISTED TAPE

Friction factor is calculated by the equation of HolitBas and VeysselOzceyham

$$f= 12.32\ x\ R_e^{-0.45}\ x\ (y/D_i)^{-0.65}$$

Where, y/D_i= twist ratio (T.R.)

Nusselt number is calculated by the equation of HolitBas and VeyselOzceyhan

$$Nu= 0.6\ x\ R_e^{0.57}\ x\ Pr^{0.3}\ x\ (y/D_i)^{-0.45}$$

D. COMBINATION OF CONICAL-RING AND TWISTED TAPE

Friction factor is calculated by the equation of Promvonge P. and Eiamsa'ard

$$f =24.87\ x\ R_e^{-0.43}\ x\ (d/D)^{-3.99}\ x\ Y^{-0.16}$$

Nusselt number is calculated by the equation of HolitBas and VeysselOzceyham

$$Nu= 1.356\ x\ R_e^{0.433}\ x\ Pr^{0.4}\ x\ (d/D)^{-1.23}\ x\ Y^{0.053}$$

IV. RESULTS AND DISCUSSION

In the following sections, results of the effects of conical-ring combined with twisted-tape(y=2.5 and 4.5) on heat transfer rate and flow friction are presented. Verification of the heat transfer and friction of the plain tube is performed by comparing with the combination of conical-ring and twist-ratio Y=2.5 and 4.5.

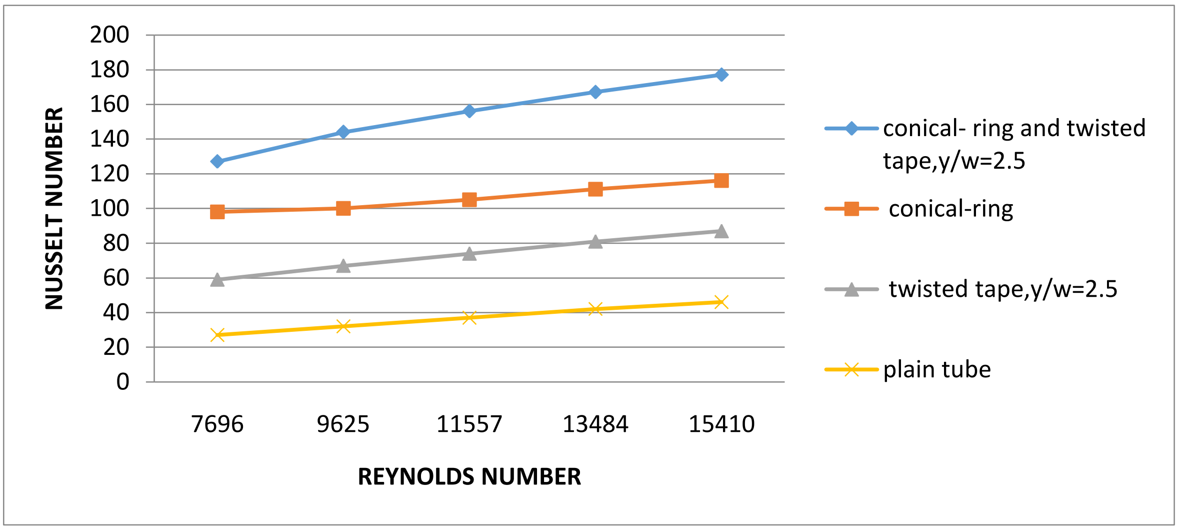


Fig 2

Fig.2 shows the variation of Reynolds number with the Nusselt number for various twist ratio's. It is seen that the Nusselt number increases with increasing Reynolds number and reduction of twist ratio. Both twist ratio's provide a considerable increase in heat transfer rate over the plain tube. A close examination reveals that the heat transfer rate from using both conical-ring and twisted-tapes higher than that from using conical-ring alone. In general, the conical-ring turbulator is employed to create a re-circulating flow near the wall regime leading to redeveloping of thermal boundary layer while the twisted-tape swirl generator to generate swirl flow about the core-region. A combination of the conical-ring and twisted-tape is used as a means of enhancing heat transfer by both of reverse flow and swirl flow in a circular tube.

Heat transfer is increased

(i) The conical-ring is combined with the twisted-tape, and
(ii) The twisted-tape ratio is small(Y=2.5) to produce a higher swirl flow.

The average Nusselt numbers for employing the conical-ring combined with the twisted –tape for Y=2.5, and 4.5 respectively. The conical-ring combined with twisted-tape for Y=2.5 and 4.5.the maximum Nusselt numbers are found to be 30% and 25% over that for using the conical-ring alone and to be about 370% and 350% over the plain tube.

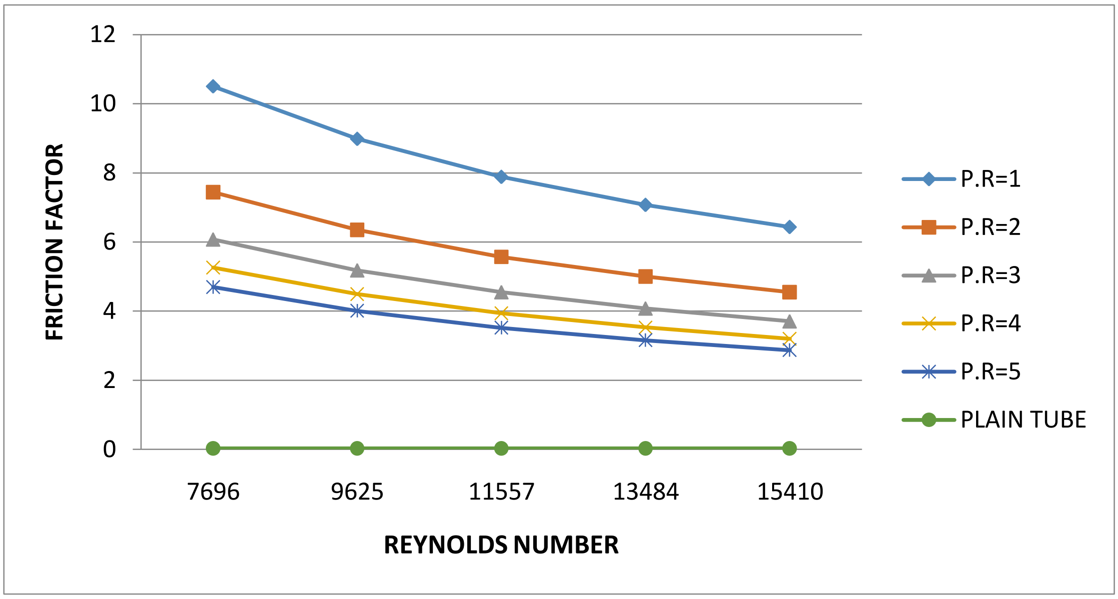


Fig 3

Fig 3. Shows the variation of Reynolds number with friction factor. As Reynolds number increases from 7696 to 15410 ,friction factor decreases. Friction factor with P.R.=1 for a conical-ring predicts higher values than with P.R=5. As pitch ratio increases the friction factor attains the value of plain tube.

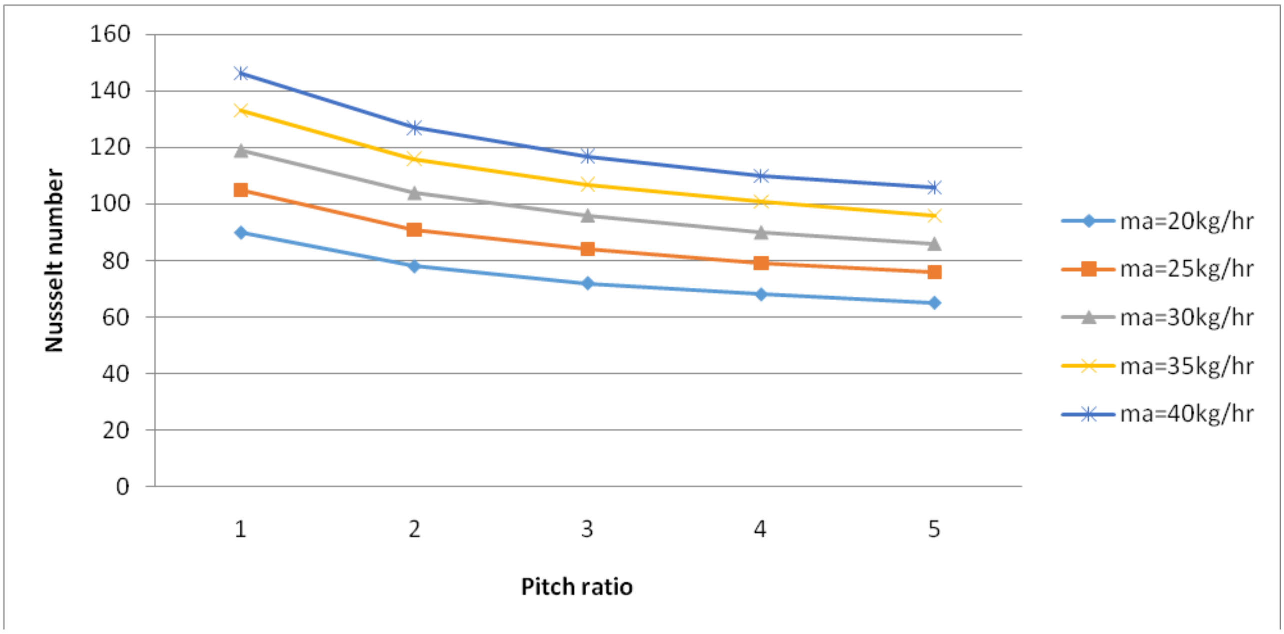


Fig 4

Fig 4 .shows variation between Nusselt number with respect to pitch ratio implies that as pitch ratio for conical ring insert in a plain tube increases Nusselt number tends to decrease. However the Nusselt number increases as mass flow rate of air increases.

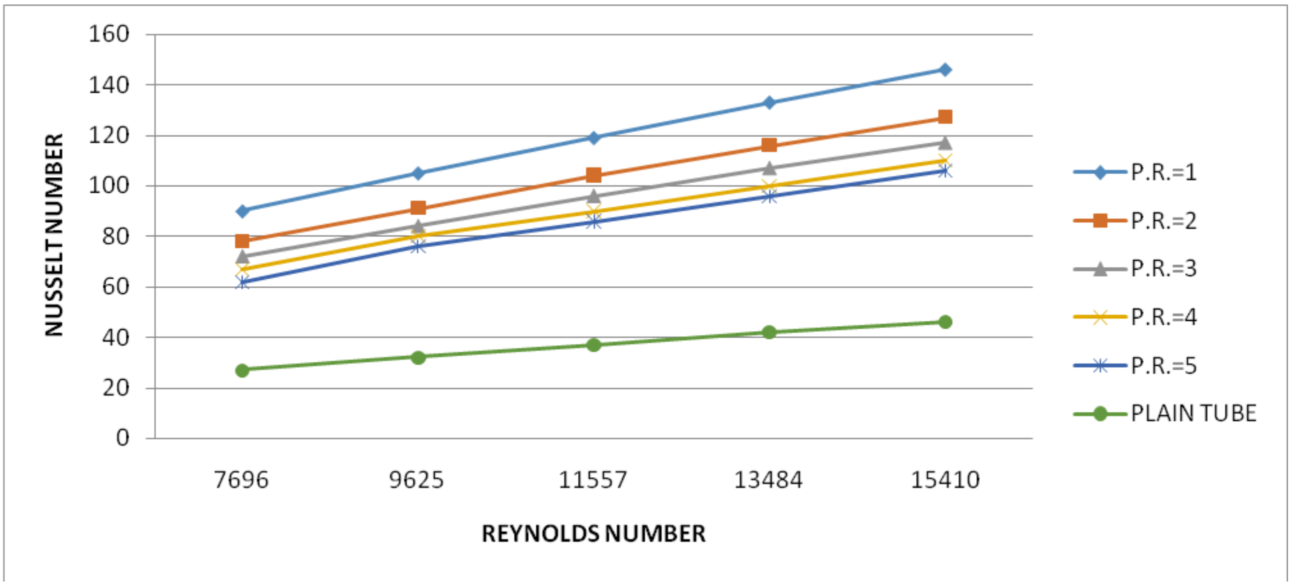
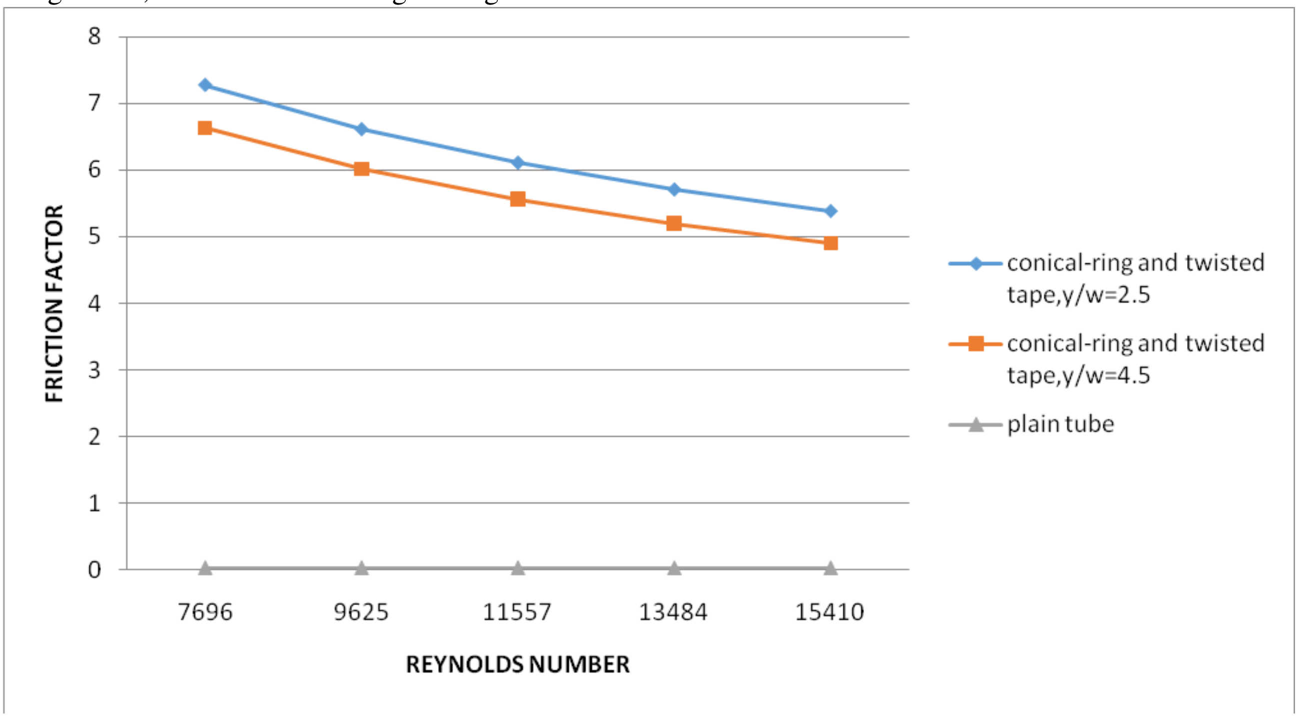


Fig 5

Fig 5 .shows the increase of Nusselt number as Reynolds number increases. The rate of increase of Nusselt number is less at low Reynolds number compared with at high Reynolds number for a pitch ratio(P.R.) of one (1) with conical ring insert , the Nusselt number gives higher values



.

Fig 6

The effect of using the conical-ring turbulator is common with the twisted-tape on the flow friction is presented in Fig 6 . The maximum increase in friction factor of the conical-ring and twisted-tape is about 242times above the plain tube. The difference of friction factors from using different twist ratio is small. The trends of the friction for each case are similar and gradually decrease with increasing Reynolds number.

V. . CONCLUSION

The results of heat transfer and friction characteristics with combined conical-ring and twisted tape insert have been reported. It is found that the smaller twist ratio is, the larger heat transfer foe all Reynolds numbers. The maximum heat transfer rates from using both the conical ring and twisted tape for Y=2.5 and 4.5 respectively, are found to be 325% and 312% over the plain tube. However, the friction factor from using both devices also increases considerably.

NOMENCLATURE

a area of plain tube,m^2

C_p Specific heat capacity, J/kg K

d diameter of the nozzle, m

D diameter of the plain tube, m

f friction factor of the lain tube,

h heat transfer coefficient, w/m^2 K

K thermal conductivity of air,W/m K

L length of the plain tube, m

M mass flow rate of air, kg/s

Nu Nusselt number,

Pr Prandtl number,

Re Reynolds number,

T temperature of the air,^{0}C

T thickness of the plain tube, mm

V velocity, m/s

Y Twist ratio,(y/w)

Y Length of twist (based on 180^0),m

W tape width, m

Greek letters

μ absolute viscosity, kg/m-s

ν kinematic viscosity,m^2/s

ρ density, kg/m^3

Subscripts

a air,

i inner/inlet

o outer/outlet

REFERENCES

1. F.kreith, D.Margolis, heat transfer and friction in turbulent vortex flow, applied science resource 8 (1959) 457-473.
2. W.R. Gambill, R.D. Bundy, high flux heat transfer characteristics in turbulent swirl flow subjected to large transverse temperature gradients, AIchE journal 91 (1963) 55-59.
3. N.v.zozulya, I.Y.shkuratov, effect of length of twisted-tape turbulence promoter and its initial twisting pitch on augmentation of heat transfer inside a tube, heat transfer. Soviet research 6 (1974) 98-100.

4. S.AI-Fahed,W.chakron,Effect of tube tape clearance on heat transfer for fully developed turbulent flow in a horizontal isothermal tube, international journal heat and fluid Flow 17(2)(1996)173-178.
5. K.Yakut,B.sahin,Flow-induced vibration analysis of conical-rings used of heat transfer enhancement in heat exchanger, Applied energy 78(2004)273-288
6. Suhas v. patoil and vijayababu p. v. Heat transfer Augmentation in circular tube and square duct fitted with swirl flow generators, international journal of chemical engineering and applications,vol.2,no.5,pp326-331,oct2011.
7. Eiamsa-ard S. and promvonge p., Enhancement of heat transfer in a circular wavy surfaced tube with helical tape inserts, international Energy journal, vol.8,pp29-36,2007.
8. Dr.mohammed najm Abdullah, heat transfer and pressure drop in turbulent flow through an eccentric converging-diverging tube with twisted tape inserts, journal of engineering and development,vol.16,no.2,pp178-192,june2012.
9. Kittisak yongsiri Eiamsa-ard S. chinaruk thianpong and promvonge p., effect of turbulent decaying swirl flow on heat transfer enhancement in a tube, international conference on sustainable energy and environment (see2006), pp 21-23,November 2006, Bangkok, Thailand.
10. Dr.Akeel Abdullah Mohammed, heat transfer and pressure drop characteristics of turbulent flow in a tube fitted with conical ring and twisted tape inserts, engineering and technology journal, vol.29,no.2, pp226-239, 2011.