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Augmentation Heat Transfer in a Circular Tube Using Divergent Nozzle as Insert

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Abstract-Augmentation techniques place a vital role in enhancement of heat transfer. The above techniques are classified as active, passive and compound techniques, In passive techniques insertion of twisted tape, coils, obstructions and conical nozzles etc are placed. In the present work insertion of divergent nozzles inside a plain tube is considered to predict the friction factor and heat transfer coefficient. Now a day's heat transfer enhancement is a big task without increasing the surface area, To do so different types of inserts are placed inside the tubes like twisted tapes, helical tapes etc. In the present study divergent nozzles are used as inserts placed in a plain tube at different pitch ratios (PR) = 2.0, 4.0, 6.0, 8.0 and 10.0 to enhance the heat transfer in a plain tube. The air is used as working fluid in the range of Reynolds number 9382 to 16921 based on the consideration of different mass flow rates of air (m_a)= 25kg/hr, 30kg/hr, 35kg/hr, 40kg/hr and 45kg/hr. Further, the heat transfer enhancement with insertion of divergent nozzle with pitch ratio (PR) = 2 is compared with insertion of twisted tapes of pitch ratio (PR)/twist ratio (TR) =2 in a plain tube.
Keywords - Divergent nozzle, plain tube, friction factor, Nusselt number, pitch ratio.

I. INTRODUCTION

Heat transfer enhancement is one of the key issues of saving energies and compact designs for mechanical and chemical devices. Heat transfer augmentation techniques are active, passive and compound techniques. Active techniques requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. Passive techniques generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior (except for extended surfaces) which also leads to increase in the pressure drop. Any two or more of these techniques (passive and/or active) may be employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by any of those techniques separately. Some of the authors paid attention to the augmentation heat transfer problems theoretically and also experimentally. Patoil and Vijay Babu [1] 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. [2]investigated experimentally the heat transfer and turbulent flow 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 [3] studied on the 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 are found to be 15% to 45% higher than that of the plain tube while for the ECDT combined with twisted tape insert is found to be 52% to 280% higher and pressure drop is found 6.8 times the plain tube. Moreover, ECDT combined with a twisted tape insert gives higher heat transfer rate and pressure drop than the ECDT alone around 23% to 35% and 98% to 125%, respectively. Yongsiri et al [4] 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 PR= 2.0, 4.0 and 7.0 are found to increase by 374%, 342% and 309% respectively, in comparision with the plain tube. Promvonge and Eiamsa-ard [5] studied on the enhancements of heat transfer characteristics in a uniform heat flux circular tube experimentally fitted with conical nozzles and swirl generator. They found that each application of the conical nozzle and the snail can help to increase considerably the heat transfer rate over that of the plain tube by about 278% and 206% respectively. The use of the conical nozzle in common with the snail leads to a maximum heat transfer rate up by 316%. Mohammed [6] 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 range of 5000 to 23000 under constant wall heat flux thermal boundary condition. Mohammed et al. [7] conducted experiments for enhancement of forced convection heat transfer by means of passive techniques for turbulent air flow through an aluminum test tube. Reynolds number range is from 6000 to 13500 with boundary conditions of constant heat flux. The experimental results at the same Reynolds number show that the divergent nozzle turbulators without perforation provides the highest heat transfer rate 317% and highest friction factor 17 times over that of plain tube. Halit Bas and Ozceyhan [8] studied on flow friction and heat transfer behavior of a twisted tape swirl generator inserted in tube experimentally. 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 considered in the range of Reynolds number from 5132 to 24,989, and the typical one clearance ratio is also tested for comparison. For all investigated cases, heat transfer enhancement (ζ) tends to decrease with the increase of Reynolds number and to be nearly uniform for Reynolds number over 15,000 and y/D lower than 3.0. The highest heat transfer enhancement is achieved as 1.756 for c/D = 0.0178 and y/D = 2 at Reynolds number of 5183. Yadav [9] studied on influences of the half length twisted tape insertion on heat transfer and pressure drop characteristics experimentally in a U-bend double pipe heat exchanger. The heat transfer coefficient is found to increase by 40% with half-length twisted tape inserts when compared with plain heat exchanger. It is also observed that the thermal performance of plain heat exchanger is better than half length twisted tape by 1.3-1.5 times. Naga Sarada et al. [10] investigated experimentally on the augmentation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid. The Reynolds number varied from 6000 to 13500. It was found that the enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width (26mm) and 33 to 39% for reduced width (22 mm) inserts.

II. DESCRIPTION OF DIVERGENT NOZZLE INSERTED IN A PLAIN TUBE

A Copper plain tube of length(L)=200mm, is taken with inner diameter (D_i) and outer diameter (D_o) of 46.5mm and 48mm respectively. The thickness of the tube(t) =1.25mm. Divergent nozzles are of length 46mm and diameter of the nozzle varying from 25mm to 45mm is inserted in a plain tube. They are put at different pitch ratios (PR)=2, 4, 6, 8 and 10, where Pitch ratio (PR) is the ratio of convergent portion of nozzles to inner diameter of the plain tube. Air is taken as working fluid and passes through a tube at different mass flow rates (m_a) = 25kg/hr, 30kg/hr, 35kg/hr, 40kg/hr and 45kg/hr.

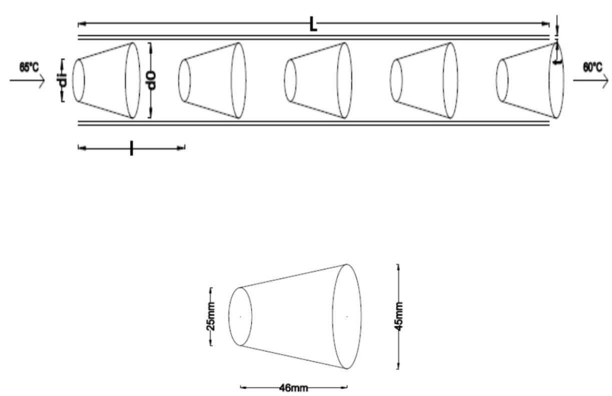

Fig 1 Schematic diagram of plain tube fitted with divergent nozzles.

III. THERMAL ANALYSIS OF THE PROBLEM

Divergent nozzles inserted inside a plain tube at different pitch ratios (PR) are used to enhance 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 9382 to 16921 at inlet temperature of 65^0C, heat transfer takes place from inside to surroundings of the tube due to temperature difference and finally exists outside of the tube at temperature of 60^0C. Below are the list of equations used in this problem.

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A. Plain Tube

$$\text{Mass flow rate } (m_a) = \rho \times A \times V \qquad (1)$$

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

A is area of tube, m^2

V is velocity of air, m/s

$$\text{Reynolds number (Re)} = \frac{V \times Di}{\nu} \qquad (2)$$

Where D_i inner diameter of the tube, m

ν kinematic viscosity, m/s^2

$$\text{Friction factor} \quad (f) = 0.184 \times Re^{-0.2} \qquad (3)$$

Where Re is Reynolds number

Nusselt number

$$(Nu) = 0.023 \times Re^{0.8} \times Pr^{0.3} \qquad (4)$$

Where Pr is Prandtl number

B. Plain Tube Fitted With Divergent Nozzle

$$\text{Mass flow rate } (m_a) = \rho \times A \times V \qquad (5)$$

Where ρ is absolute density of air kg/m^3

A is area of tube, m^2

V is velocity of air, m/s

$$\text{Reynolds number (Re)} = \frac{V \times Di}{\nu} \qquad (6)$$

Where D_i inner diameter of the tube, m

ν kinematic viscosity, m/s^2

Friction factor is calculated by the equation of Promvonge P. and Eiamsa-ard (5)

$$(f) = 6049 \times Re^{-0.71} \times (l/Di)^{-0.5} \qquad (7)$$

Where Re is Reynolds number

Nusselt number is calculated by the equation of Promvonge P. and Eiamsa-ard (5)

$$(Nu) = 0.19 \times Re^{0.71} \times Pr^{0.3} \times (l/Di)^{-0.2} \qquad (8)$$

Where Pr is Prandtl number

l/D_i is pitch ratio (PR)

Where l indicates length of the nozzle and distance between two nozzles.

C. Plain Tube Fitted With Twisted Tape

$$\text{Mass flow rate } (m_a) = \rho \times A \times V \quad (9)$$

$$\text{Reynolds number (Re)} = \frac{V \times Di}{\nu} \quad (10)$$

Friction factor is calculated by the equation of HolitBas and VeyselOzceyhan (8)

$$(f) = 12.32 \times Re^{-0.45} \times (y/Di)^{-0.65} \quad (11)$$

Where Re is Reynolds number

y/D_i is twist ratio(TR)

Nusselt number is calculated by the equation of HolitBas and VeyselOzceyhan (8)

$$(Nu) = 0.6 \times Re^{0.57} \times Pr^{0.3} \times (y/Di)^{-0.45} \quad (12)$$

Where Pr is Prandtl number

IV. RESULTS AND DISCUSSION

The values got from the above are shown plotted as graphs depicting their behavior as mentioned below.

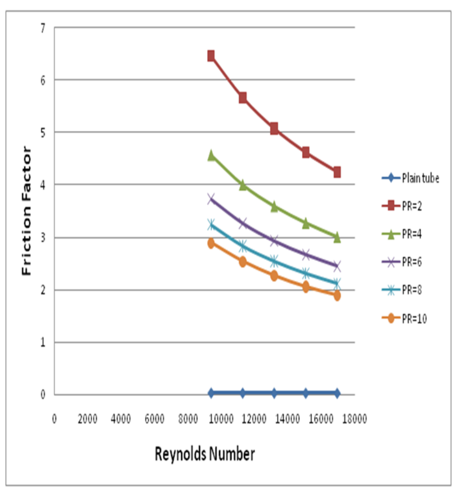

Fig 2. Variation of Friction factor with Reynolds number

Figure 2.shows the variation of Reynolds number with friction factor. As Reynolds number increases from 9382 to 16921, friction factor decreases. Friction factor with pitch ratio (PR) = 2 for a divergent nozzle predicts higher values than with pitch ratio (PR) = 10. As the pitch ratio increases the friction factor attains the value of plain tube.

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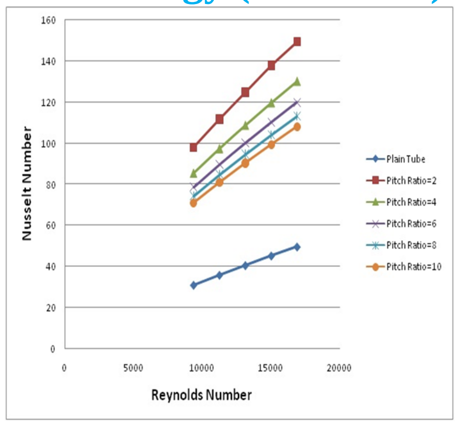

Fig 3. Variation of Nusselt number with Reynolds number

Figure 3.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 (PR) of 2 with divergent nozzle insert , the Nusselt number gives higher values.

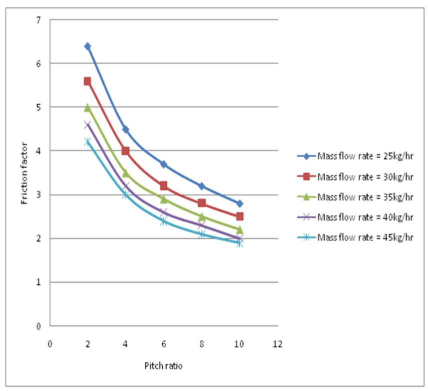

Fig 4. Variation of Friction factor with Pitch ratio

the above figure Fig 4. it was found that pitch ratio using divergent nozzle inserthas an effect on friction factor. As per the above figure, it was found that at lower mass flow rates and for different pitch ratios the friction factor predicts higher values rather than at high mass flow rate and for different pitch ratios. In addition it was also found that the friction factor tends to increase as mass flow rate of air decreases.

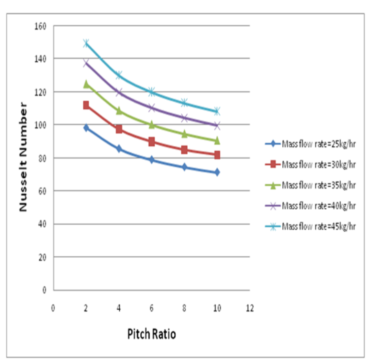

Fig 5. Variation of Pitch ratio to Nusselt number

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Figure 5.shows variation between Nusselt number with respect to pitch ratio implies that as pitch ratio for divergent nozzle insert in a plain tube increases Nusselt number tends to decrease. However the Nusselt number increases as mass flow rate of air increases.

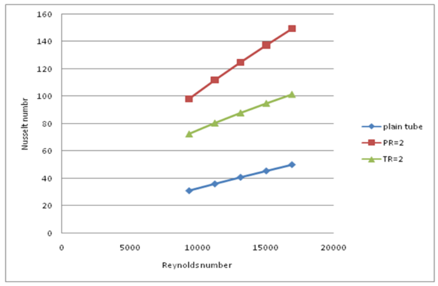


Fig 6. Variation of Nusselt number with Reynolds number

In Figure 6.Nusselt number increases as Reynolds number increases. The rate of increase of Nusselt number is high in plain tube fitted with divergent nozzle at pitch ratio (PR) = 2 than that of plain tube fitted with twisted tape at twist ratio (TR) = 2.

V. CONCLUSIONS

Friction factor decreases with increasing Reynolds number for different pitch ratios from 9382 to 16921. As pitch ratio increases from 2 to 10 friction factor decreases. Friction factor increases by 123%, 58%, 29% and 11% at pitch ratios 2,4,6 and 8 compared to pitch ratio 10.

Nusselt number increases with increasing Reynolds number for different pitch ratios from 9382 to 16921. As pitch ratio increases from 2 to 10 Nusselt number decreases. At pitch ratio of 2 , 4, 6, 8 and 10 Nusselt number increases by 215% , 174% , 153%, 139% and 128%.

Friction factor decreases with increase in mass flow rate. As pitch ratio increases from 2 to10, friction factor decreases for different mass flow rates. Friction factor decreases by 52%, 33%, 19.5%, and 8.7% at mass flow rates(m_a) = 45kg/hr, 40kg/hr, 35kg/hr and 30kg/hr compared to 25kg/hr.

Nusselt number increases with increasing mass flow rate. As pitch ratio increases from 2 to10, Nusselt number decreases. Nusselt number increases by 52%, 39.8%, 27% and 13.9% at 45kg/hr, 40kg/hr,35kg/hr and 30kg/hr compared to 25kg/hr.

At pitch ratio (PR) =2, Nusselt number increases by 35.51%, 39.03%, 42.08%, 44.77% and 47.69% at different Reynolds numbers 9382 to 16921 than that of twisted ratio(TR)=2

VI. NOMENCLATURE

a area of the plain tube, m^2

Cp Specific heat capacity, J/kg K

d diameter of the nozzle, m

D diameter of the plain tube, m

f friction factor of the plain tube,

h heat transfer coefficient, W/m^2K

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

Greek letters

μ absolute viscosity, kg/ m-s

ν kinematic viscosity, m^2/s

ρ density, kg/m^3

Subscripts

a air

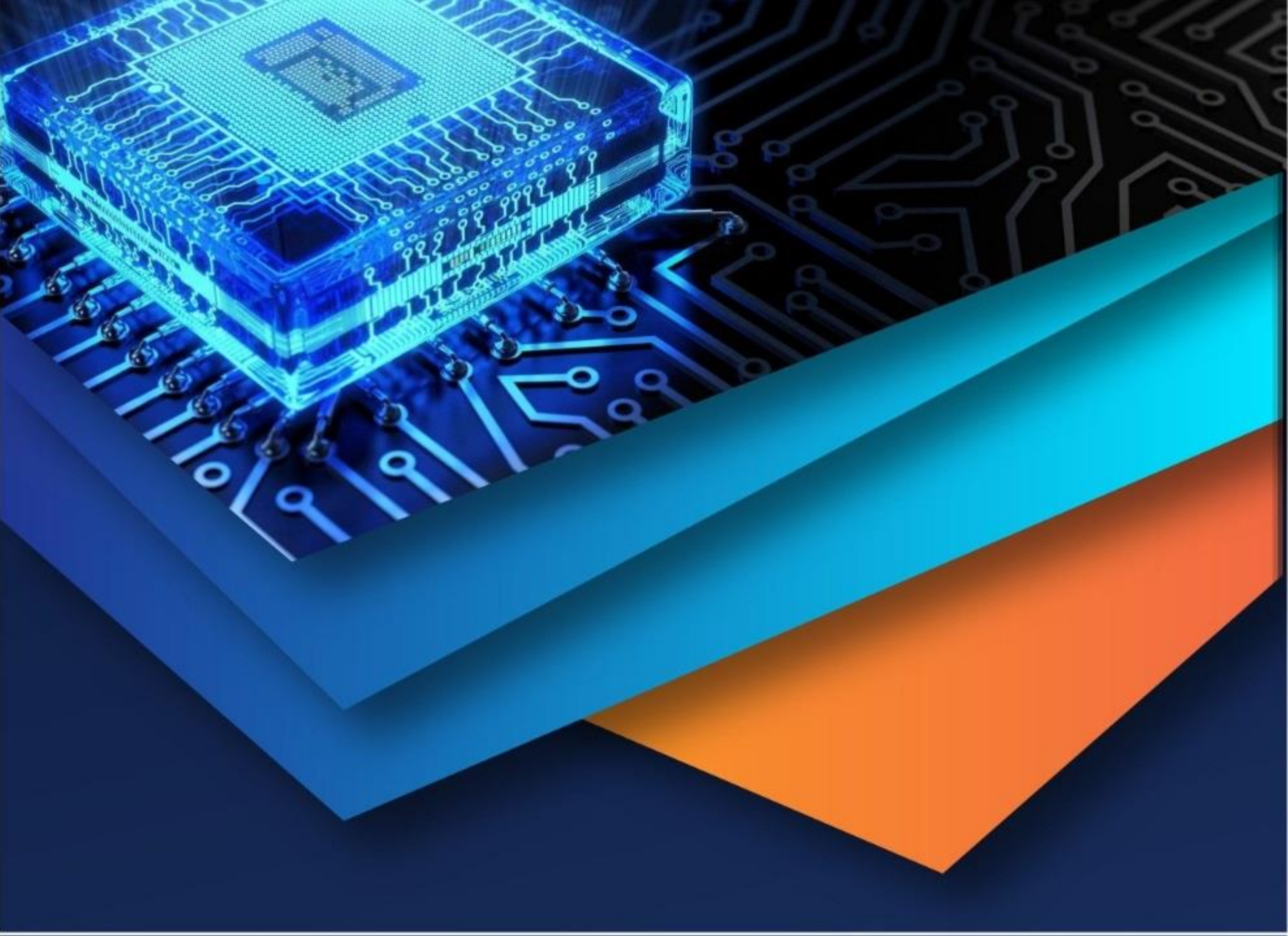
b bulk

i inner/inlet

o outer/outlet

REFERENCES

[1] Suhas V. Patoil and Vijaybabu P.V., Heat Transfer Augmentation in a Circular Tube and Square Duct fitted with Swirl Flow Generators, International Journal of Chemical Engineering and Applications, Vol.2, No.5, pp 326-331, Oct 2011.
[2] 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, pp 29-36, 2007.
[3] Dr. Mohammed Najm Abdullah, Heat Transfer and Pressure Drop in Turbulent Flow through an Ecentric Converging – Diverging Tube with Twisted Tape Inserts, Journal of Engineering and Development, Vol.16, No.2, pp 178-192, June 2012.
[4] KittisakYongsiri, 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 (SEE 2006), pp 21-23, November 2006, Bangkok, Thailand.
[5] Promvonge P. and Eiamsa-ard S., Heat Transfer Enhancement in a Tube with Combined Conical Nozzle Inserts and Swirl Generator, Energy Conversion and Management, Vol.47, pp 2867-2882, 2006.
[6] 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, pp 226-239, 2011.
[7] Dr.Akeel Abdullah Mohammed, Bashar Ali Mohammed and RaheemJewiMuhee, Heat Transfer Enhancement in a Tube Fitted with NozzleTurbulators , Engineering and Technology Journal, Vol.32, Part (A), No.10, 2014.
[8] HolitBas and VeyselOzceyhan, Heat Transfer Enhancement in a Tube with Twisted Tape Inserts placed Separately from the Tube Wall, Experimental Thermal and Fluid Science Vol.41, pp 51-58, 2012.
[9] Anil Singh Yadav, Effect of Half Length Twisted Tape Turbulators on Heat Transfer and Pressure Drop Characteristics inside a Double Pipe U-Bend Heat Exchanger, Jordan Journal of Mechanical and Industrial Engineering, Vol.3, pp 17-22, March 2009.
[10] Naga Sarada S., Sita Rama A.V., Kalyani Radha K., and Shyam Sunder L.; Enhancement of Heat Transfer using Varying Width Twisted Tape Inserts, International Journal of Engineering , Science and Technology, Vol.2, No.6, pp 107-118, 2010.



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