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Estimation of Heat Transfer in Internally Micro Finned Tube

B. Usha Rani* and P.S. Kishore**

*** M.E Thermal, Department of Mechanical Engineering, College of Engineering (A), Andhra University***

*****Professor, Department of Mechanical Engineering, College of Engineering (A), Andhra University, Visakhapatnam.***

ABSTRACT

Internally finned tubes have received considerable attention because of the fact that they have been used widely in industrial applications. Internally finned tubes have found extensive use in heat exchangers. When improvement in the process of heating or cooling is required, then better design of fin compactness and spatial geometry is very essential. Several studies have been conducted to investigate the effect of fin characteristics on heat transfer. Most of the previous works have focused on limited cases of the number and length of internal fins. In the present work ,the tube is taken with outside diameter 1 inch(25.4mm) and the fins (called micro fins) of cross-section rectangle are attached inside the tube. Water is passed inside a tube with mass flow rates varying from 0.15kg/s to 0.19kg/s .Friction factor, Nusselt number, heat transfer coefficient are estimated from the theoretical analysis carried for two cases, that is increasing the non dimensional fin height (H) from 0.02 to 0.04 and increasing the helix angle (γ) 150 to 450 keeping other variable constant. The comparison was been made with smooth tube. Graphs are drawn to predict the behavior of an internal micro finned tube.

Keywords: micro finned tube, friction factor, heat transfer coefficient.

INTRODUCTION:

When additional metal pieces are attached to ordinary heat-transfer surfaces such as pipes or tubes, they extend the surface available for heat transfer. While the extended surface increases the total transmission of heat, this influence as surfaces is treated differently from simple conduction and convection. Fins are used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, Cooling fins is encountered in many situations to examine heat transfer as a way of defining some criteria.

Internal fins are one of the most widely used passive heat transfer enhancement techniques, especially in the chemical process and petroleum industries. The apparent advantages of fins are that they increase the heat transfer rate by providing additional surface area. However, fins placed in a tube cause complex flow patterns and increase flow resistance. As the number or the height of fins increases, flow friction increases, thus requiring greater pumping power to sustain a given mass flow rate. Therefore, to design a compact heat exchanger with internally finned tubes, one should optimize the fin geometry by accounting for both flow friction and heat flux. Convection heat transfer in internal micro fins has been for several geometries in literature. The theoretical and analytical investigations were performed for smooth and micro fin-tube in order to find the optimum geometric parameters for achieving maximum Nusselt number and heat transfer coefficient from the finned surfaces.

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Jensen and Vlankancic [1] suggested different governing processes between tall fin and micro-fin tubes. In their paper, a parameter, fin width s, was shown to have a strong influence on the results. Liu and Michael K. Jensen [2] performed parametric study on turbulent flow and heat transfer in internally finned tubes. For a rectangular fin profile, the effects of fin number N, fin width s, fin height H, and helix angle were numerically investigated for the conditions . Rectangular and triangular fins behave similarly, for some geometric conditions but the round crest fin has lower friction factors and Nusselt numbers 10% than the rectangular fin. However, when the numbers of fins are large, the round crest fin can have larger friction factors about 16 %. Carnavos [3] examined the overall performance in terms of circumferencetially averaged friction factors and heat transfer coefficients and examined the effects of three gross parameters: number of fins N, fin height H, and helix angle.

Munoz and Abanader [4]done analytical work on internal helically finned tubes for parabolic trough design by CFD tools. The application of finned tubes to the design of parabolic trough collectors has some losses such as the pressure losses and thermal losses and thermo-mechanical stress and thermal fatigue. The result showed an improvement potential in parabolic trough solar plants efficiency. Sazali [5] studied experimentally on a vertical internally finned tube subjected to natural convection heat transfer. The length of tube was 100mm. the tube taken for the experiment has inner diameter 80mm and the outer diameter 90mm. The tube contains four radial, straight, and equally spaced around the circumference of the tube. The result shows that the value of Nu increases for vertical cylinder with the increase in temperature under variable time. Wang et al. [6] numerically investigated heat transfer performance of internally finned tubes by realizable k–€ turbulence model with wall function method using FLUENT, by using three kinds of lateral fin profiles, S-shape, Z-shape and V-shape. The result showed that tubes with S-shape fins and Z-shape fins are exbhiting best profile as compared with V-shape fins, and moreover, tube with Z-shape fins had the best performance. Papadopoulous and Hatizikonstantinou [7] have done the numerical study of laminar fluid flow in a curved elliptical duct with internal fins. The study of the fully developed laminar incompressible flow inside a curved duct of elliptical cross-section with four thin and internal longitudinal fins is done using the improved cost volume process (CVP) method. The thermal results show that the heat transfer rate is increased by the internal fins and that it depends on the aspect ratio.

Andrew et al. [8] conducted the numerical study to investigate the fluid flow and heat transfer characteristics of a square micro channel with four longitudinal internal fins. 3-D numerical simulations were performed on the micro channel with variable fin height ratio in the presence of a developed laminar flow. Results obtained for the average local Nusselt number distribution along the channel length is as a function of the fin height ratio. The analytical study was carried out for different fin heights and flow parameters. Aziz and Fang [9] measured the heat transfer rate for different fin profiles such as rectangular, trapezoidal, and concave parabolic (finite tip thickness). Results are obtained from the comparison, based on the relationship between the dimensionless heat flux, the fin parameter, and dimensionless tip temperature for all three geometries.

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DESCRIPTION AND WORKING OF INTERNALLY MICRO FINNED TUBE:

A circular tube of external diameter 1 inch (25.4 mm) and internal diameter 24 mm is taken. The tube is attached with micro fins of 54 in number and of rectangular cross –section on the inside surface of the tube .Water is used as medium to flow inside tube. The fins are made of aluminum which is having high thermal conductivity and light in weight. The fin heights are taken from 0.2 to 0.4. The orientation i.e helix angle (γ) of the micro fin attached the inner surface of tube is varied from 150 to 450.The below Fig. 1 gives the geometry of an internal finned tube .

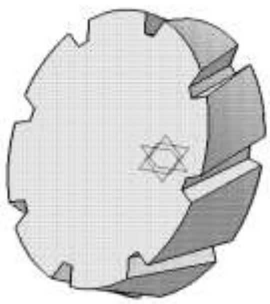

Fig.1 The geometry of an internally finned tube

Hot water is used as a medium to flow inside the tube with an inlet temperature of 600C.The heat produced by hot water is taken away by means of convection to the fin and later on it is conducted through a rectangular micro fin to the surface of the tube. The effect of friction factor, Nusselt number and heat transfer on an internally micro finned is obtained by varying the non dimensional fin height (H)=2e/di, where fh is fin height and di is internal diameter and the helix angle from 150 to 450. As the tube is fitted with internal fins, this provides as a medium and as a passive augmentation technique to enhance the heat transfer by of taking away the heat from water to the surface of the tube.

ANALYSIS OF INTERNALLY FINNED TUBE :

The following equations are used for the analysis

3.1 Smooth Tube:

Mass flow rate (ma)= ρ×A×V (1)

where,

ρ =density, kg/m3

V =velocity, m/s

Reynolds number (Re)=(V × di)/ν (2)

where,

di = Internal diameter of the tube in mm

V = velocity of the water in m/s

ν = kinematic viscosity in m2/s

Friction factor (using correlation of Filonenk)

fst = [1.58 lnRe - 3.28]- 2 (3)

Nusselt number (using correlation of Gnielinski)

Nust = 0.012Pr0.4[Re0.87-280] (4)

where,

Re is Reynolds number

Pr is prandtl number

3.1.1 Evaluation of Friction Factor for Internally Micro Finned Tube

Nominal flow area of an internally finned tube

An = πdi2/4 (5)

where,

di = Internal tube diameter in m

Actual flow area of an internally finned tube

Afin = An-Nfhs (6)

where,

N = Number of fins

fh = fin height, m

s = mean fin thickness, m

Modified non-dimensional axial pitch

Pw = Nsinγ/π (7)

where,

γ=fin helix angle, deg

Non-dimensional inter-fin flow area

AW = (π/N - s/di) (8)

The characteristic length for flow is taken

(LCSW/di) = [1-A(SW)b(H)c(W)d] (9)

where,

A=1.577,b=0.64,c=0.53,d=0.28 for H≤0.0 as developed by Edwards and Jensen friction factor for micro fins is taken as

f=[(LCSW/di)-1.25(An/Afin)1.75-0.015/ fst[(LCSW/di)-1.25(An/Afin)1.75-1]exp(-Re/6780)] fst

as developed by Valkancic and Jensen (10)

3.1.2 Evaluation of Nusselt Number for Internally Micro Finned Tube

Nominal surface area (SAn) = πdiL (11)

where ,

L= length of the tube in m

Number of turns (n) =length/pitch= L/diTanγ (12)

Actual surface area of finned tube

(SAact) = SAn+2 fh N√(πdin)2+L2 (13)

(fgeometry) = (SAact/SAn) [1-0.059(PW)-.03(AW)0.66] (14)

as developed by Valkancic and Jensen

Nusselt number for internal micro finned tube

Nu = [(LCSW/di)-1.25(An/Axs)0.8(fgeometry)] Nust (15)

as developed by Valkancic and Jensen

3.1.3 Evaluation of Heat Transfer for Micro Internally Finned Tube

Heat transfer coefficient of tube

h = Nu.k/di (16)

RESULTS AND DISCUSSION :

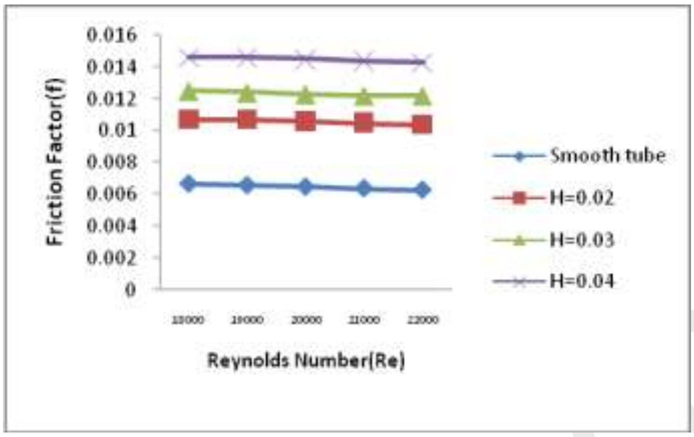

FIG.2 Variation of Friction Factor for Non Dimensional Fin Height

The above Fig 2 is plotted between Reynolds number and friction factor. It was found that as Reynolds number increases there is decrease in friction factor for a particular Reynolds number. However it was found that the friction factor increases with increase in non-dimensional fin height (H).

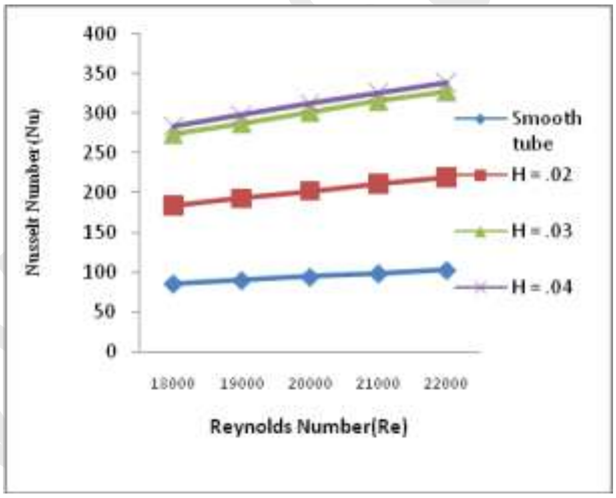

Fig.3 Variation of Nusselt Number for Fin Non-Dimensional Fin Height

The graph Fig 3 shows the increase in Nusselt Number with increase in Reynolds number. It was found that as Reynolds number reaches a higher value, Nusselt number also increases to higher value. However the Nusselt number predicts higher values at non-dimensional fin height which is H=0.04. It was also found that Nusselt number with non-dimensional fin height (H) predicts more than smooth tube values.

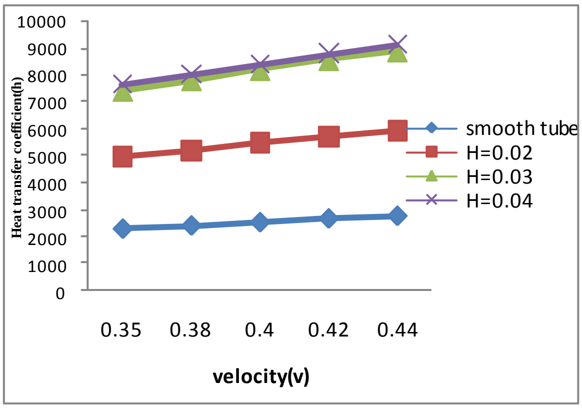

Fig.4 Variation of Heat Transfer Coefficient for Fin Non-Dimensional Fin Hights

As seen from graph Fig 2 and 3 shows the similar variation i.e for increase in velocity the heat transfer coefficient increases. Here also velocity increases, heat transfer coefficients predicts higher values for non-dimensional fin height compared to smooth tube.

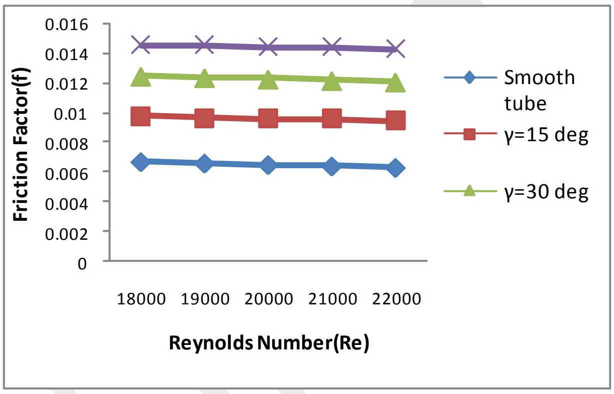

Fig.5 Variation of Friction Factor With Reynolds Number for An Helix Angle

Fig.5 shows the variation of friction factor with Reynolds number. It was seen from the graph that the change in helix angle(γ) as an effect on friction factor. However the helix angle at γ =450 predicts higher values.

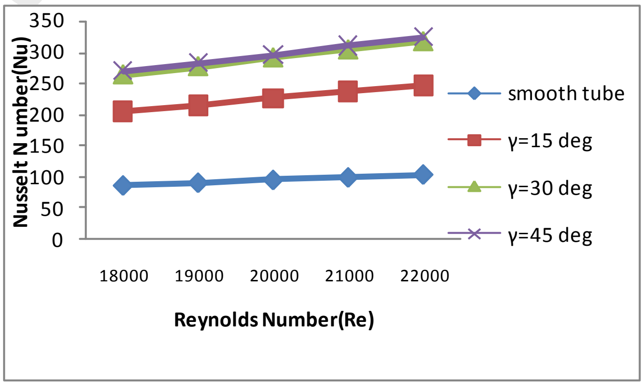

Fig. 6 Variation of Nusselt Number with Reynolds Number for An Helix Angle

Fig 6.5 shows the plot between Nusselt number and Reynolds number. For increase in mass flow rate, Nusselt number predicts higher at higher helix angle to that of the smooth tube.

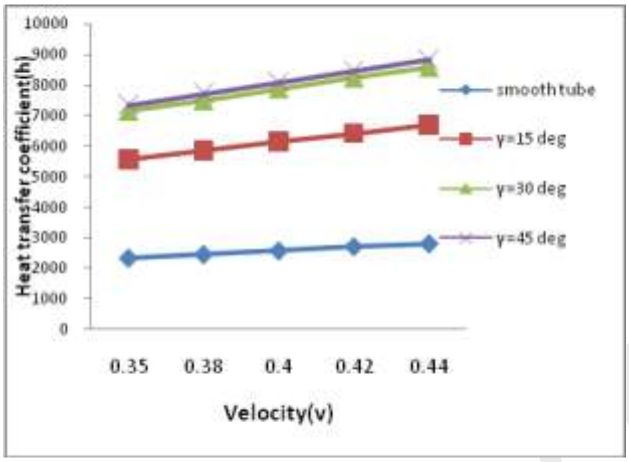

Fig.7 Variation of Heat Transfer Coefficient for Different Helix Angles

The graph Fig.7 shows the increase in heat transfer coefficient with increase in velocity.As the velocity of water increases for internally micro finned tube for helix angle (γ=450) ,heat transfer coefficient increases at helix angle of 450. The heat transfer predicts lower values.

CONCLUSION :

Heat transfer analysis on the internal rectangular micro fins attached to the inside surface of the tube is studied. Based upon the results obtained by varying the mass flow rate from 0.15kg/s to 0.19kg/s taking Reynolds number 18000 to 22000 and temperature of water at 600C, the following conclusions are arrived by varying the non-dimensional fin height (H) and varying the helix angle (γ).

I. Varying the non dimensional fin height (H) as 0.02,0.03 and 0.04

1. Friction factor is found to increase by 37%(H=0.02), 46%(H=0.03) and 54%(H=0.04)with respect to smooth tube.
2. Nusselt number is found to increase by 53%(H=0.02), 68%(H=0.03) and 70% (H=0.04)with respect to smooth tube.
3. Heat transfer coefficient is found to increase by 53%(H=0.02), 68% (H=0.03)and 70%(H=0.04) with respect to smooth tube.

II. Varying the fin helix angle (γ) as 15^0,30^0 and 45^0

4. Friction factor is found to increase by 31%($\gamma=15^0$), 41% ($\gamma=30^0$)and 51%($\gamma=45^0$) with respect to smooth tube.
5. Nusselt number is found to increase by 58%($\gamma=15^0$),67%($\gamma=30^0$) and 68%($\gamma=45^0$), with respect to smooth tube.

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6. Heat transfer coefficient is found to increase by 58%($\gamma=15^0$),67% ($\gamma=30^0$) and 68% ($\gamma=45^0$) with respect to smooth tube.
7. Varying the helix angle (γ) predicts higher value of heat transfer than varying the non dimensional fin height (H).

Nomenclature

A	area,m2
d	tube diameter , m
fh	fin height , m
f	friction factor
H	non-dimensional fin height ,2e/di
h	heat transfer coefficient ,W/m2k
k	thermal conductivity, W/m k
L	Length, m
N	number of fins
Pr	Prandtl number
Re	Reynolds number
S	mean fin thickness, m
pw	inside heat transfer area, m2
Aw	modified non-dimensional axial pitch

Greek symbols

γ	fin helix angle, deg
ν	Kinematic viscosity.m2/s

Subscripts

Act	actual
c	characteristic
xs	actual
fin	inner fin

n nominal

i inner

n nominal

o outer

st smooth

w wall

REFERENCES :

i. Michael K.Jensen, Alex Vlakancic., Experimental Investigation of Turbulent Heat Transfer and Fluid Flow in Internally Finned Tube, Journal of Heat Transer, Vol 42 , pp 1343-1351, 1999.

ii. Xiaoyue Liu, Michael K.Jensen., Geometry Effects on Turbulent Flow and Heat Transfer in Internally Finned Tube, Journal of Heat and Mass Transer, Vol 123, pp 1035-1044 ,2001 .

iii. T.C.Carnavos, Heat Transfer Performance of Internally Finned Tubes in Turbulent Flow, Journal of Heat Transfer ,Vol 1, pp.32-37,1979 .

iv. J.Munoz , A.Abanader , Analysis of Helical Finned Tubes for Parabolic Rough Designed CFD Tools, Applied Energy, Vol. 88, pg. 4139-4149 ,2011.

v. N.Sazali , Experimental Study of Natural Convection Heat Transfer in a Vertical Internally Finned Tube, Vol 1, pp 120-127 , 2009 .

vi. Q.Wang , M.Zeng ,M. Lin, Effect of Lateral Fin Profiles on Turbulent flow and Heat Transfer Performance of Internally Finned Tubes, Applied Thermal Energy,vol.29, pp. 3006-3013 , 2009

vii. P.K.Papadopoulous, P.MHatzikonstantinou , Numerical Study of Laminar Fluid Flow in a Curved Elliptical Duct With Internal Fins, International Journal of Heat and Fluid Flow, Vol. 29, pp. 540-544 , 2009.

viii. J.L.Andrew , N.Ramesh , Chandratilleke T.T., Laminar Convective Heat Transfer Rate in a Micro Channel With Internal Longitudinal Fins, International Journal of Thermal Sciences, Vol. 48 , pp. 1908-1913, 2009.

ix. A.Aziz , T.Fang, Alternative Solution for Longitudinal fins of Rectangular, Trapezoidal and Concave Parabolic Profiles, Energy Conversion and Management, Vol. 51, pp. 2188-2194, 2010.