International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-3 Issue-1, October 2013

Experimental Investigation on Convective Heat Transfer Analysis in a Circular Tube with Internal Threads of Different Pitches

Pradip Ramdas Bodade, Dinesh Kumar Koli

Abstract - The present work focus on Experimental investigation of heat transfer and friction factor characteristics of horizontal circular pipe using internal threads of pitch 1 cm and 0.5cm with air as the working fluid. The flow regime is selected for this study with the Reynolds number range 17,000 to 30,000. The horizontal aluminum pipe was subjected to constant and uniform heat flux. The experimental data obtained were compared with those obtained from plain Horizontal pipe. The effects of internal threads of varying pitch on heat transfer and friction factor were presented. Based on the same pumping power consumption, the pipe with internal threads possesses the highest performance factors for turbulent flow. The heat transfer coefficient enhancement for internal threads is higher than that for plain pipe for a given Reynolds number. The use of internal threads improved the performance of horizontal circular pipe.

Keywords-Enhancement, internal threads, heat transfer and turbulent flow.

I.INTRODUCTION

The operation of many engineering systems results in generation of heat. This unwanted by product cause serious overheating problems and sometime lead to failure of system. The heat generated within the system must be dissipated to it's surrounding in order to maintain the system at it's recommended working temperature and functioning effectively and reliably. Turbulent flow in complex geometries receives considerable attention due to its importance in many engineering applications and has been the subject of interest for many researchers. Some of these include the energy conversion systems found in some design of process industries, cooling of evaporators, thermal power plants, air conditioning equipment radiators of space vehicle and automobiles and modern electronic equipments. The present experimental study investigates the increase in the heat transfer rate between a pipes heated with a constant uniform heat flux with air flowing inside it using internal threads of varying pitch. As per the available literature, the enhancement of heat transfer using internal threads in turbulent region. the present work has been carried out with turbulent flow (Re number range of 17,000-30,000) as the flow problems in industrial heat exchangers involve turbulent flow region. The experiments are conducted on test rig initially without using any internal threads and with using internal threads of different pitches (p= 1cm & 0.5 cm) and various heat transfer characteristics are calculated.

Manuscript published on 30 October 2013.
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An extensive experimental studies of turbulent flow and heat transfer past baffles in heat exchangers has been performed by various authors. Soo Wban Abn and Kang Pil Son [1]. "found that the heat transfer can be enhanced by the use of rough surfaces and it depends upon properties and size of the fluid molecules They measured the friction factor and heat transfer enhancement on smooth duct and compared it with results. Hamidou Benzenine , Rachid Saim and Hamidou Benzenine , Rachid Saim and Said Abboudi, Omar Imine [2] found that the heat transfer can be enhanced by the use transversal waved baffles. the baffles induced with an decreases the friction of about 9.91 % in the case of α=15°, more than 16% in the other cases. Concerning the pressure drop of the baffles was insured improvements starter from 10.43% in all cases compared with the baffles of plane form. Rajendra Karwa and B. K. Maheshwari [3]. **"** They studied the the heat transfer and friction in an asymmetrical rectangular duct with some solid and perforated baffles with relative roughness.The friction factor for the solid baffle was found between 9.6-11.1 times than smooth duct which decreases in perforated baffle. Prashanta Dutta and Akram Hossain [4]. **"**They Studied the effect of local heat transfer and friction factor in a rectangular pipe with inclined and perforated baffles. The effect of baffle size, position, and orientation were studied for heat transfer augmentation. The conclusion of this study is that the heat transfer and friction factor is maximum in two inclined baffles than the single baffle. Kang-Hoon Ko and N.K.Anand[5]. "They studied the effect of local heat transfer in a rectangular pipe with porous baffles. Some merits of porous baffle are, (a) more heat escape (b) due to light weight it is used in aerospace application. The conclusion of this study is that the heat transfer increases 2 to 4 times than the solid baffle. Waleed Mohammed Abed and Mohammed Abed Ahmed [6]. **"**They Studied the effect of heat transfer and Pressure drop in a duct with corrugated surface. The heat transfer coefficients obtained from the channel with the corrugated surface are higher than those with the plain surface. The pressure drop also increased on corrugated surface. **S.** Naga Sarada, A.V. Sita S. Naga Sarada, A.V. Sita Rama Raju, K. Kalyani Radha and L. Shyam Sunder [7] They used coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc. In order to enhance heat transfer in internal flow, tape is inserted in channel. They reported better performance of the helical twisted insert in comparison to the twisted tape insert. Modification of twisted tape was made by focusing in increase of heat transfer rate rather than the reduction of friction loss.

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TANG Xinyi and ZHU Dongsheng [8].“studied the turbulent flow and heat transfer enhancement in ducts or channels with rib, groove or rib-groove tabulators.the combination of crossed and discontinuous ribs grooves array was used to enhance heat transfer with less pressure loss and the better thermal performance is expected. Ameer A. Jadoaa [9] The heat transfer rate and pressure drop characteristics of turbulent flow of air through uniformly heated circular tube fitted with drilled cut conical rings with three space ratios (X=5.4, 6.4, and 8.4) have been studied experimentally. The flow characteristics are governed by space ratio (the ratio of the distance between drilled conical ring and the inner diameter of tube) The results show that the process of drilling of the conical ring inside tube gives high rates of heat transfer more than that in the conical ring without drilling. Teerapat chompookham et al. [10] In their experimental investigations they studied the effect of combined wedge ribs and winglet type vortex generators (WVGs) on heat transfer and friction loss behavior for turbulent air flow through a constant heat flux channel. the highest increase in both heat transfer rate and friction factor while the staggered wedge rib. Shyy Woei Chang, Ker-Wei Yu, and Ming Hsin Lu [11] investigated the effect of three test tubes fitted with single, twin, and triple twisted-tapes on heat transfer. The tubes fitted with twin and triple twisted-tapes could offer the higher values of heat transfer augmentation with the similar levels of performance factor as those found in the tube fitted with single twisted tape.

II.EXPERIMENTAL WORK

I EXPERIMENTAL SETUP

The apparatus consists of a blower unit fitted with a pipe, which is connected to the test section located in horizontal orientation. Nichrome bend heater encloses the test section to a length of 50 cm. Three thermocouples T_2, T_3 and T_4 at a distance of 15 cm, 30 cm and 45 cm from the origin of the heating zone are embedded on the walls of the pipe and two thermocouples are placed in the air stream, one at the entrance (T_1) and the other at the exit (T_5) of the test section to measure the temperature of flowing air as shown in Fig.1. The pipe system consists of a valve, which controls the airflow rate through it and an orifice meter to find the volume flow rate of air through the system. The two pressure tapings of the orifice meter are connected to a water U-tube manometer to indicate the pressure difference between them. Input to heater is given through dimmer stat. Display unit consists of voltmeter, ammeter and temperature indicator. The circuit was designed for a load voltage of 0-220 V; with a maximum current of 10 A. Difference in the levels of manometer fluid represents the variations in the flow rate of air. The velocity of airflow in the tube is measured with the help of orifice plate and the water manometer fitted on board.

II.Procedure

Air was made to flow though the test pipe by means of blower motor. A heat input of 100 W was given to the nichrome heating wire wound on the test pipe by adjusting the dimmer stat. The test pipe was insulated in order to avoid the loss of heat energy to the surrounding. Thermocouples 2 to 4 were fixed on the test surface and thermocouples 1 and 5 were fixed inside the pipe. The readings of the thermocouples were observed every 5 minutes until the steady state condition was achieved. Under steady state condition, the readings of all the five thermocouples were recorded. The experiments were repeated for three different test pipes of varying pitch with varying airflow rate.The fluid properties were calculated as the average between the inlet and the outlet bulk temperature. Experiments were carried out at constant heat input and constant mass flow rate, for all the four test pipes with varying pitch.

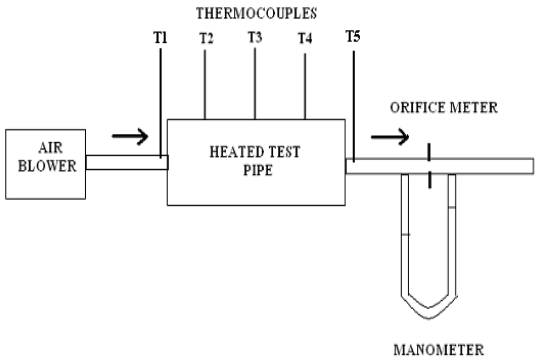

Fig.1.Schematic diagram of Experiment Setup

Fig.2.Actual diagram of Experimental setup

Fig.3 Test pipe with different pitches

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III SEQUENCE OF OPERATION

A series of experiments carried out with Circular duct. A suction mode blower is used to draw the air in Circular duct. The heated test section is 50cm long. At the inlet $T_{b1}$is the inlet bulk temperature measured by thermocouple and T_{b5} exit bulk temperature.

The heat transfer rate

$Q = m \times cp \times (T_{b5} - T_{b1}) = h \times A \times (T_w - (T_{b1} + T_{b5})/2)$

While the experimentation procedure is firstly validated by running the experiment through Circular duct without any internal threads.

The experimentation is divided into three stages.

I. Experimentation is carried out without internal threads.
II. Experimentation is carried out with internal threads(p=1cm).
III. Experimentation is carried out with internal threads (p=0.5cm).

IV Data reduction

The data reduction of the measured results is summarized in the following procedures:

$T_s = (T_2 + T_3 + T_4)/3$ - (Equation I)
$T_b = (T_1 + T_5)/2$ - (Equation II)

Discharge of air,

$Q = C_d \times \sqrt{2gh}$ - (Equation III)

Where C_d= coeff. of discharge

Velocity of air flow,

$V = (Q/A)$ (Equation V)
Where A = area of circular duct $(\pi/4) \times (D_h)^2$

Mass flow rate (m)

$m = \rho AV$ (Equation VI)

heat transfer coefficient (h)

$Q = h \times A_s \times (T_w - (T_{b1} + T_{b5})/2)$ - (Equation VII)

Where A_s= Convective heat transfer area $\pi \times D_h \times L$

Reynolds's Number (Re)

$Re = (\rho \times Dh \times v)/\mu$ - (Equation VIII)

Nusselt Number (Nu)

$Nu = h \times D_h \times /k$ - (Equation IX)

Pressure drop (ΔP)

$\Delta P = \rho \times g \times h$ - (Equation X)

Friction factor (f)

$f = (\Delta P \times 2 \times D_h)/(L_t \times \rho \times v^2)$ - (Equation XI)

Thermal enhancement factor (η)

η= (h with internal threads)/ (h_w without internal threads) - (Equation XII)

III .RESULTS AND DISCUSSIONS

The experimentation is carried out with the Circular duct with and without using heat transfer enhancement methods. Heat transfer coefficient and friction factors are calculated for all conditions. Parameters were plotted for different values of Reynolds number.

For the arrangement without internal threads and with internal threads of different pitches.

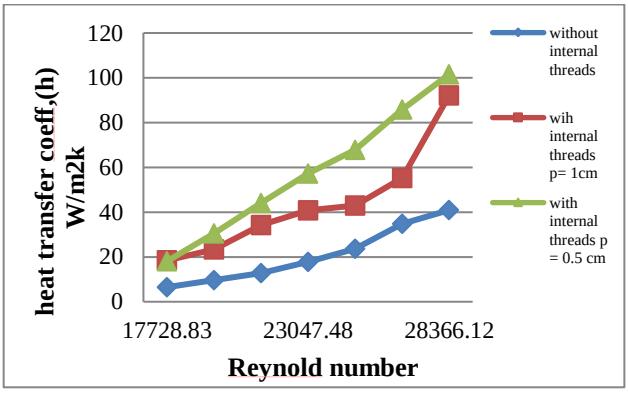

Figure 4: Heat transfer coefficient Vs Reynolds Number

From the Fig.4, it is observed that the heat transfer coefficient increases with increase in Reynolds no. As Reynolds no. increases, the air flow will cause more turbulence so due to which the heat transfer rate will increase. From the Fig.4 it is observed that the circular duct without using any internal threads gives the less heat transfer coefficient with the use of internal threads of pitch 1cm create more turbulence in duct which increases the heat transfer coefficient. Internal threads of pitch 0.5cm gives gives maximum value of heat transfer coefficient as compared to internal threads of pitch 1cm.

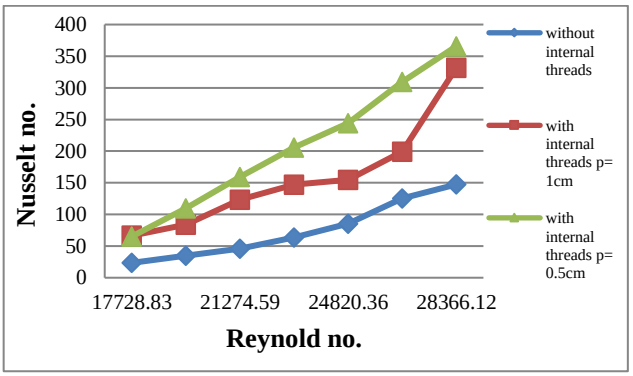

Fig. 5. Nusselt Number V/s Reynolds Number

From the Fig. 5. it is observed that there is increase in Nusselt number as increase in Reynolds number .As Reynolds number increases the air flow will cause more turbulence due to which heat transfer rate will increase in heat transfer coefficient (h) and $Nu = hD_h/k$ i.e increase in heat transfer coefficient increases the Nusselt number. From fig 5. it is observed that maximum Nusselt number is obtained for internal thread of pitch p= 0.5 cm as compared to p= 1cm and without internal threads.

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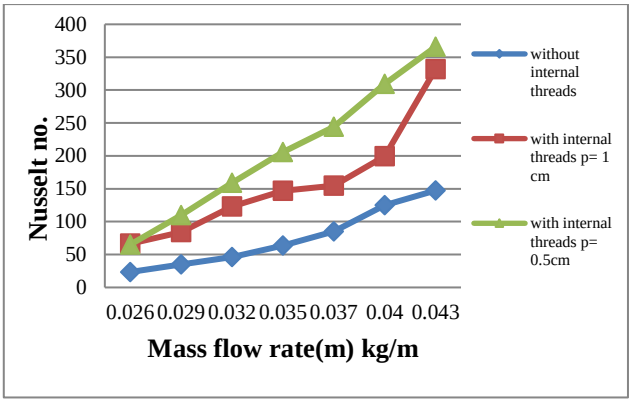

Fig.6 Nusselt Number Vs Mass flow rate

From the fig.6, it is observed that as the mass flow rate increases the Nusselt number increase. There is increase in Nu number with internal threads of pitch p= 0.5cm as compared to when there is internal threads. This is because in the presence of internal threads in circular channel the turbulence created by air is more which enhance the heat transfer rate. Also if we compared internal threads of different pitches the Nusselt number is more in pitch p=0.5cm for same mass flow rate.

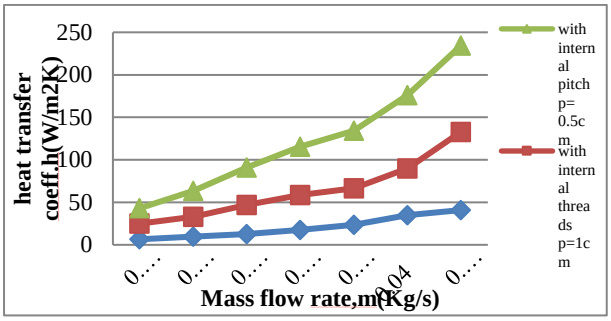

Fig.7 Heat transfer coefficient Vs Mass flow rate

From the Fig.7, it is observed that the heat transfer coefficient increases with increase in mass flow rate. As mass flow rate increases, the air flow will cause more turbulence so definitely the heat transfer rate will increase. From the Fig.7 it is observed that the Circular channel without internal threads gives least heat transfer coefficient.With internal threads of pitch p= 1cm increases the heat transfer coefficient. With internal threads of pitch p= 0.5 cm gives maximum value of heat transfer coefficient as compared with other channels.

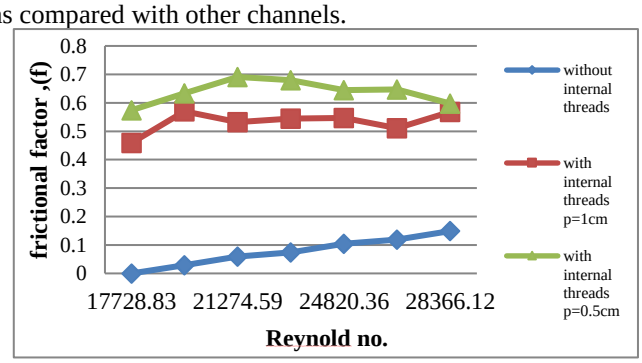

Fig.8 Friction factor Vs Reynolds Number

From the Fig.8 it is observed that as the Reynolds increases there is decrease in friction factor is observed this as the velocity goes on increasing with Reynolds number and friction factor is inversely proportional to the velocity .From fig. it is observed that least friction factor is obtained in duct without internal threads and maximum friction factor is observed in with internal threads of pitch(p=0.5cm).

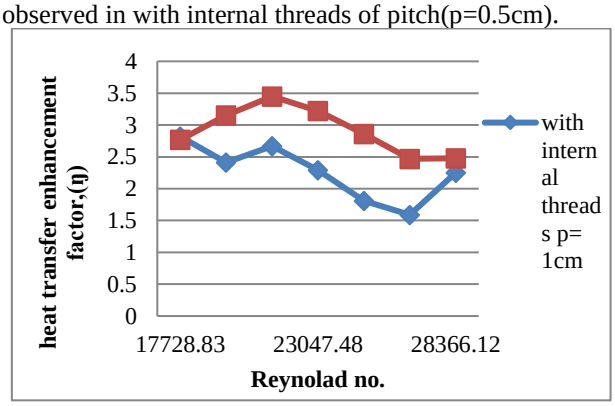

Fig.9 heat transfer enhancement factor Vs Reynolds No.

From the Fig.9 it is observed that as the Reynolds no. increases there is decrease in heat transfer enhancement factor is observed as well as there is increase in enhancement factor is observed for some Reynolds number but if we observe the overall enhancement it goes on decreasing with increase in Reynolds number.

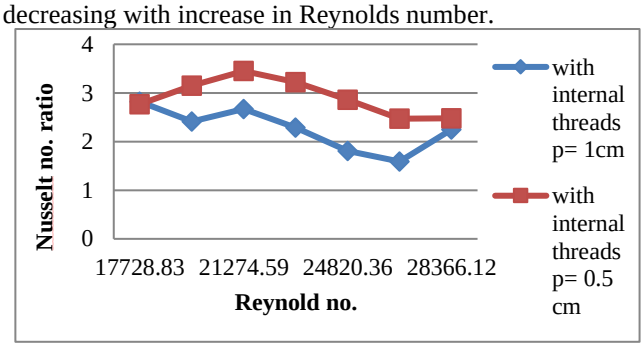

Fig.10 Nusselt Number ratio Vs Reynolds Number

From the Fig.10 it is observed that as the Nusselt number ratio decreases there is increase in Reynold number is observed as well as there is increase in Nusselt number ratio is observed for some Reynolds number but if we observe the Nusselt number ratio it goes on decreasing with increase in Reynolds number.

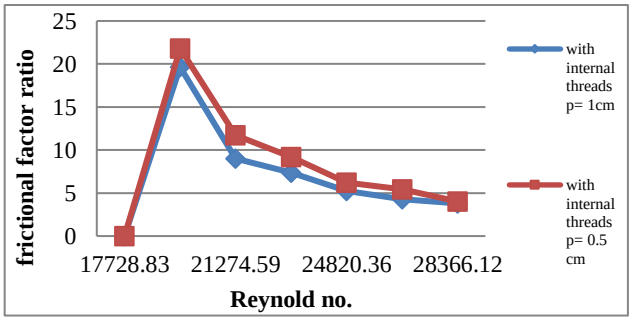

Fig.11 Friction factor ratio Vs Reynolds Number

From Fig11 it is observed that as the Reynolds number increases, there is decrease in friction factor ratio. As friction factor is inversely proportional to velocity i.e. nothing but Reynolds number hence increasing with Reynolds number there is decrease in friction factor and also decrease in friction factor ratio.

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As it is the ratio of friction factor with internal threads to without internal threads, the friction factor without internal threads is less and friction factor with internal threads decreases with Reynolds number hence friction factor ratio decreases.

IV. CONCLUSIONS

Experimental investigations have been carried out to study the effects of the internal threads of different pitches (p= 1cm & 0.5 cm) on the performance Circular duct. Heat transfer coefficient and friction factor are analyzed with using passive heat transfer enhancement methods. From the graph plotted above following conclusions are made**.**

- The heat transfer rate increases in duct with the internal threads as compared to without internal threads. The result shows that the heat transfer rate is increases as the Reynolds number increases.
- The internal threads of pitch p= 0.5 cm causes the maximum turbulence in the duct due to which maximum heat transfer to occur
- As the pitch of internal threads decreases it is found that there is increase in heat transfer rate but increases in friction factor is observed. So it can be concluded that minimum the pitch of internal threads maximum the heat transfer rate but more frictional losses will occur.

NOMENCLATURE

As	Heat Transfer Area, m^2
Cp	Specific heat of air, J/Kg.K
Dh	Hydralicdiameter, m
f	frictional factor, Dimensionless
g	Acceleration due to gravity ,m/s^2
h	Heat transfer coefficient, $W/m^{20}c$
p	Pitch of threads, m
L_t	Length of test pipe, m
m	Mass flow rate, kg/s
Nu	Nusselt Number, Dimensionless
Re	Reynold Number, Dimensionless
Q	Heat transfer rate, W
V	Velocity of flow , m/s
ΔP	Drop in pressure , N/m^2
μ	Viscosity of Air , N s/ m^2
ρ	Density of air, kg/m^3

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