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Experimental Investigation of Enhancement of Convective Heat Transfer Coefficient in Circular Tube with Pin Fin Element

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Abstract - *Heat transfer enhancement is an active and important field of engineering research since increases in the effectiveness of system through suitable heat transfer augmentation techniques can result in considerable technical advantages and savings of costs. This work presents an experimental study on the Nusselt number, friction factor, Reynolds number, and different rates of velocities enhancement factor characteristics in a circular tube with internally placed pin fin element. In the experimentation, measured data are taken at different rate of velocity number with air as the test fluid. The experiments were conducted on a circular tube with 36 number of pin fins of 10mm length and 4mm dia are inserted in the entire length of the tube in the orthogonal direction. Theoretical and experimental heat transfer coefficient are calculated, The heat transfer coefficient and friction factor data obtained is compared with the data obtained from a plain circular tube under similar geometric and flow conditions. The variations of heat transfer coefficient, Nusselt number (Nu), friction factor (f) and Reynolds number (Re) respectively is determined and depicted graphically. It is observed that at all Reynolds number, Nusselt number and heat transfer coefficient increases for a circular tube with pin fin element*.

Key Words: ***Heat transfer enhancement, pin fins, friction factor, Nusselt number.***

1. INTRODUCTION

The technology of cooling gas turbine components through internal convective flows of single-phase gases has developed over the years from simple smooth cooling passages to very complex geometries involving many differing surfaces. To achieve high heat transfer rate in an existing circular pipe it is important to taking care of the increased pumping power, several techniques have been proposed in recent years.

Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. Convection is the mechanism of heat transfer through a fluid in the presence of bulk fluid motion. Convection is classified as natural (or free) and forced convection depending on how the fluid motion is initiated. In natural convection, any fluid motion is caused by natural means such as the buoyancy effect, i.e. the rise of warmer fluid and fall the cooler fluid. Whereas in forced convection, the fluid is forced to flow over a surface or in a tube by external means such as a pump or fan. In the present experiment forced

Convection is used to find the heat transfer coefficient using passive technique.

The detailed study of active and passive techniques in heat transfer augmentation is studied by many authors and there study presents. [1] Ronald S. Bunker, Et al presented study on, turbulent internal flows in circular tubes with six different concavities (dimple) surface array geometries to enhance the heat transfer rate. [2] **S.** Eiamsa-ard., and P.Promvonge, have studied that experimentally the transfer and turbulent flow friction characteristics in a circular wavy-surfaced and constant heat-flux tube with a helical-tape insert to enhance the heat transfer rate. [3**]** Betu lAyhan Sarac- investigated heat transfer and pressure drop characteristics of a decaying swirl flow in a horizontal pipe. The decaying swirl flow is produced by the insertion of vortex generators with propeller-type geometry Three different positions of the vortex generator in the axial direction are examined. [4] Naga Sarada S,Etal, investigated the augmentation of turbulent flow heat transfer in a horizontal tube by means of mesh inserts with air as the working fluid. Sixteen types of mesh inserts with varying size of screen diameters they have observed heat transfer rate. [5] P.K.Nagarajan and P.Sivashanmugam- have experimentally investigated heat transfer and friction factor characteristics of circular tube fitted with 300 right-left helical screw inserts with 100 mm spacer of different twist ratio has been presented for laminar and turbulent flow to increase heat transfer coefficient. The main objective of the study is to investigate the effect of pin fins inside the circular pipe to release more heat from the surface of the test specimen to the working fluid to enhance the heat transfer coefficient. Here both theoretical and experimental approaches are used to find the heat transfer rate and data obtained are compared with the plain circular pipe data.

2. TECHNICAL DETAILS OF PIN FIN ELEMENT

The geometrical configuration of pin fin element inserted internally in circular pipe with dia of the pin is 4mm and length of the fin is 10mm inserted orthogonally in the pipe.

There are total 36 number of pin fins are used. The dia of the test section is (OD=40mm) and (ID=38mm), length of the test section 400mm.

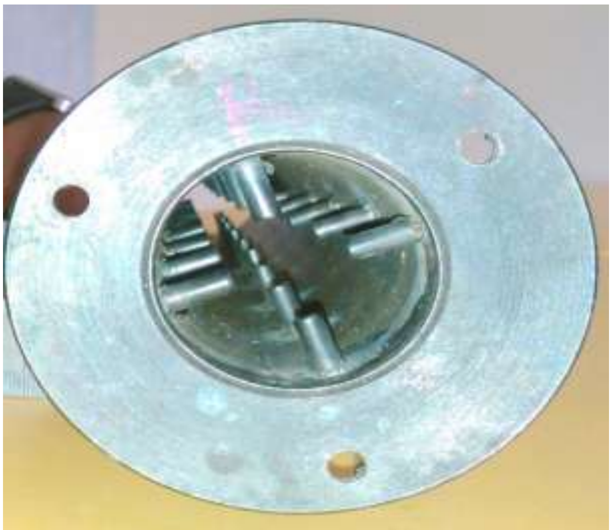

FIG .1 geometric details of test section with fins inside

FIG 2.Schematic representation of experimental setup

3. EXPERIMENTAL PROCEDURE

The method used for determining the heat transfer coefficient is to supply a known heat input to the heating coil and measure the temperature attained by the test section. Before undertaking the experiments an uncertainty analysis was performed to determine the effect of each of the parameters involved on the uncertainty in the heat transfer co-efficient values. The following procedure is followed in conducting experiments.

The experiment consists of an air blower to blow air through a pipe. A value is provided to control the air flow rate. A test section has been provided in the straight portion considerably away from the bend so that at test section the flow is fully developed. A flow straightener is provided. The test section has an electrical heater which is insulated to reduce the heat losses to the atmosphere. The test section is provided with 4 thermocouples at different axial locations (T_1, T_2, T_3, T4, and T5) to measure the variation of the pipe surface temperature along the test section. Inlet and outlet air temperature is measured by providing two more thermocouples at the inlet and the exit if the test section.

Voltmeter and ammeter is provided to measure the rate of heat input. Air flow rate through the test section is measured by means of orifice meter. **4. Calculation of heat transfer coefficient**

The heat transfer coefficient of the plain pipe and pipe with fins are calculated by using the fallowing equations.

For plain pipe friction factor is calculated by using

$f=0.184Re^{-0.2}$ ***equation* (1)**

To find nusselt number dittus –boelter eqn is used

$Nu=0.023Re^{0.8}Pr^{0.4}$ ***equation (2)***

Heat input $Q= m_{cp} (T_{out} - T_{in})$ ***equation (3)***

$h_{exp}=Q/A_s*(T_s - T_a)$ ***equation (4)***

h_{exp}= heat transfer coefficient

To calculate the friction factor for pipe with fin is

$\mathbf{f=0.316Re^{-0.25}}$ ***equation (5)***

$Nu=0.0224Re^{0.905}*Pr^{0.8}$ ***equation (6)***

Above equation is used to calculate nusselt number for the pipe with fins.

4. RESULTS AND DISCUSSION

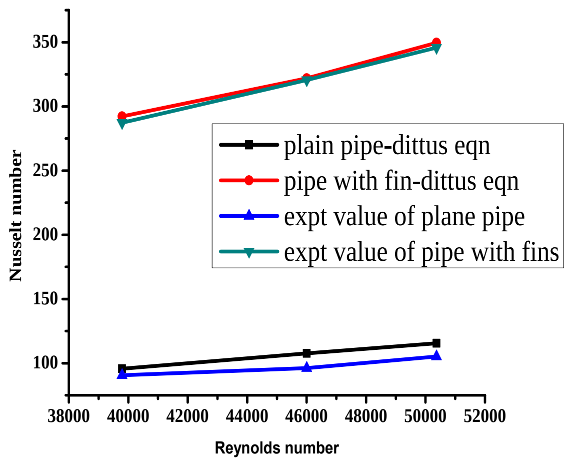

Fig -3(a) Reynolds number Vs Nusselt number

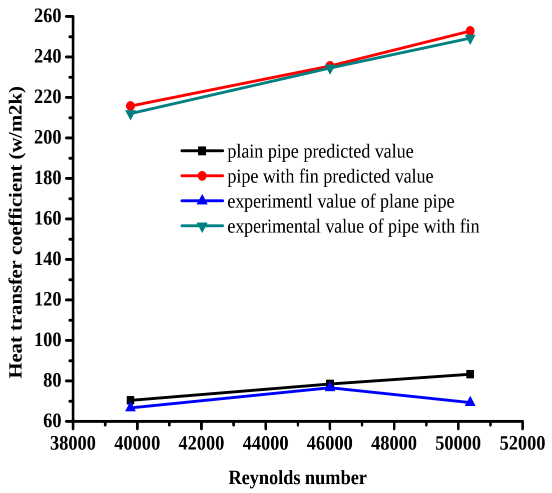

Fig-3(b) Reynolds number Vs Heat transfer coefficient

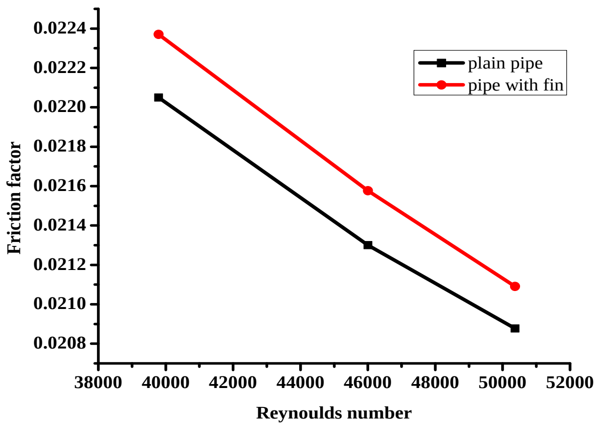

Fig-3(c) Reynolds number Vs friction factor

Fig3 (a), 3(b) and 3(c) shows the data's of the plain pipe and pipe with fins are taken at the 400w heat input. During variation of the Reynolds number there is variation in the heat transfer coefficient, friction factor, and nusselt number is shown .Fig 3(a) and 3(b) shows that by increasing the Reynolds number there is increase in the heat transfer coefficient, and nusselt number of the pipe having the fins inside, than the plain pipe. Due to increasing the surface area by inserting pin fins inside the pipe. Fig3(c) shows that friction is more in the plain pipe than the pipe having fins for the same Reynolds number due to flow restricted by the fins present in the pipe.

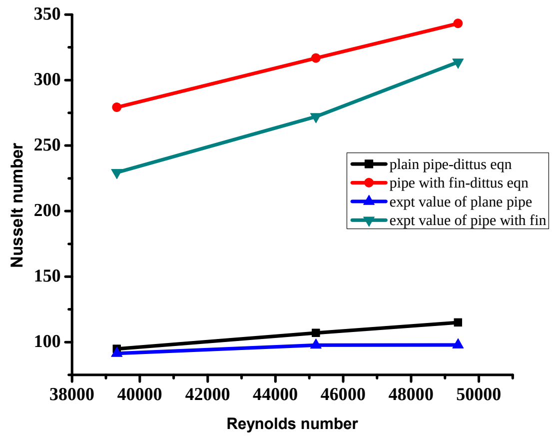

Fig-4(a) Reynolds number Vs Nusselt number

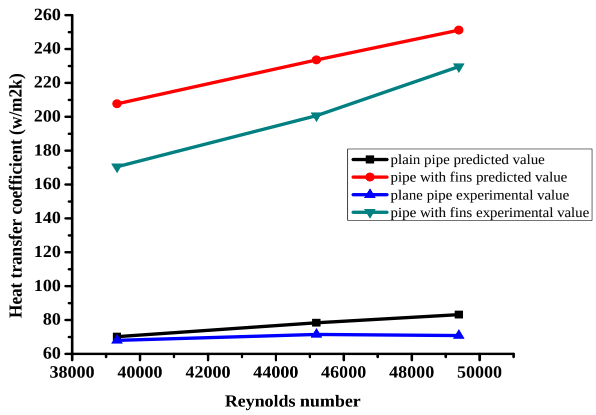

Fig-4(b) Reynolds number Vs Heat transfer coefficient

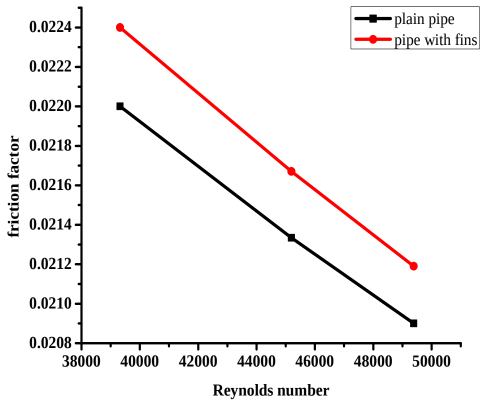

Fig-4(c) Reynolds number Vs friction factor

Similarly 4(a),4(b) and 4(c) shows the increasing the heat transfer, nusselt number and friction factor is high for the pipe with fins at 500w heat input due to increasing the surface area of the pipe.

5. CONCLUSIONS.

Experimental investigations of heat transfer coefficient, nusselt number and friction factor of a plain circular pipe and a circular pipe with pin fins inside are described in the present report. The conclusions can be drawn as follows:

1. The heat transfer coefficient increases for a test pipe with fins inside than those for plain pipe this is due to the fact that there is increase in the surface area of the pipe provided by the pin fin, which increases the turbulence of air.
2. The friction factor increases for a test pipe with fins than the plain pipe, because in the test pipe with fins swirl flow is generated.
3. The enhancement of nusselt number is higher in the case of pipe with fins, than plain pipe because of the extended surface and high turbulence

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