fin, hollow pin fin, solid pin fin with four equal perforations, solid pin fin with one large perforation, knurled fins, hollow fin.

3. Experimental Set-Up

To study the heat transfer parameters, an experimental set-up has been fabricated for the purpose. This set-up primarily consists of a Rectangular Duct, a Heating Unit, a blower, a Data Unit and an Anemometer. Fig. 1 shows a line diagram of the set-up. This experimental set up was fabricated based on an experimental studies made by Amol B et al. (2013).

A Rectangular Duct is made of galvanized iron with a thickness of 0.5 mm. It is made up of 130×150 mm internal cross-section and the length of the channel was taken as 890 mm.

A 2.4 HP capacity Blower is used to allow the air to flow with a required velocity. It will be operated from 0 to 2800 rpm, 130W, 180/230V, 50 Hz, Single Phase. It is operated from a convergent channel made of Galvanized Iron. It has a convergent and divergent section at both ends having the inclination of 30°.

An Anemometer is used to measure the mean inlet velocity of the air flow entering and leaving the test section. The specification of anemometer used is: Range: 4 to 30 m/s or 1.4 to 108 KMPH, Vane Probe, Model No. AM 4201, LT – Lutron, Made in Thaiwan.

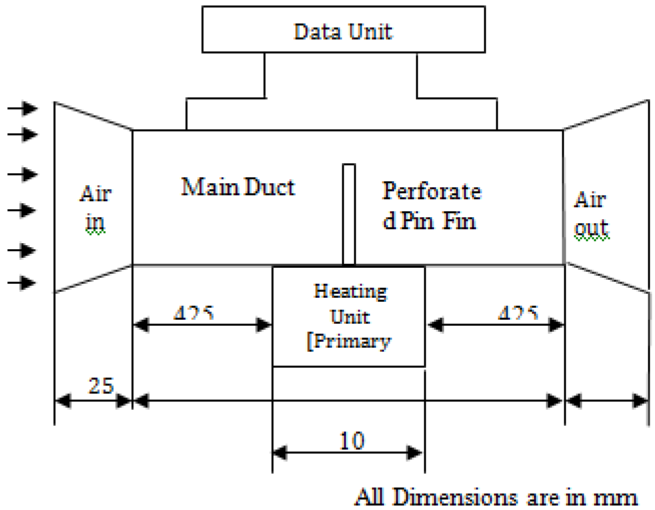

Figure 1: Experimental setup used for the Study

The range of the Reynolds number used for the experimentation is 4,000 – 10,000, which is based on the hydraulic diameter of the channel over the test section (D_h = 139.286 mm) and the average velocity (U). The heating unit for the test section mainly consisted of an electrical heater. The heater output has a power of 180 W at 220V and a current of 10 A. The whole assembly was mounted on a Flat Table made up of wood. The temperature measurement of the base plate is done by RTD Sensors which can sense the temperature from 0°C to 600°C. The RTD 's are screwed into the heater and temperature is obtained from on the data unit as shown in Fig.1.

4. Solution Methodology

The net rate of heat transfer is obtained from the energy balance which is given as follows:

$$q_{\text{heat generated due to electric power}} = q_{\text{net, conduction}} + q_{\text{net, convection}} + q_{\text{net radiation}} \quad [1]$$

Rearranging the above equation we get,

$$q_{\text{net, convection}} = q_{\text{heat generated due to electric power}} - q_{\text{net, conduction}} - q_{\text{net radiation}} \quad [2]$$

The heat generated in terms of voltage and current is given by:

$$q_{\text{heat generated due to electric power}} = VI \quad [3]$$

Where I is the current in amperes and V is a voltage in Volts supplied to the heating unit.

$q_{\text{heat generated due to electric power}}$, represents is electrical heat generated in the primary surface

$q_{\text{net, conduction}}$ is the net rate of heat transfer due to conduction,

$q_{\text{net, convection}}$ net rate of heat transfer due to convection,

$q_{\text{net radiation}}$ net rate of heat transfer due to radiation.

As per the literature review the net rate of heat transfer due to radiation is 0.5 % of the total heat supplied in the form of power and hence can be neglected. The heat losses due to side, bottom and top walls of the test section were assumed to be neglected since the side walls are insulated. Thus the heat transfer due to convection is equal to net rate of electrical heat generated in the primary surface.

$$q_{net\ convection} = \bar{h} A_s \left[T_s - \left[\frac{T_{out} + T_{in}}{2} \right] \right] \quad where\ \bar{h} = average\ heat\ tr \quad [4]$$

A_s = Surface area of the fin, T_s = Surface temperature of the fin, T_{out} and T_{in} represents the duct inlet and outlet temperatures of the ambient air.

Rearranging the above equation, we get the average heat transfer coefficient as follows:

$$\bar{h} = \frac{q_{net\ convectio}}{A_s \left[T_s - \left[\frac{T_{out} + T_i}{2} \right] \right]} \quad [5]$$

From the above the Nusselt number is found by using the following equation:

$$Nu = \frac{\bar{h}}{i} \quad [6]$$

The correlation used for Nusselt Number without fin is given by following equation:

$$Nu_s = 0.077 Re^{0.716} Pr^{0.3} \quad [7]$$

5. Results and Discussion

The effect of heat transfer parameters are discussed here in detail.

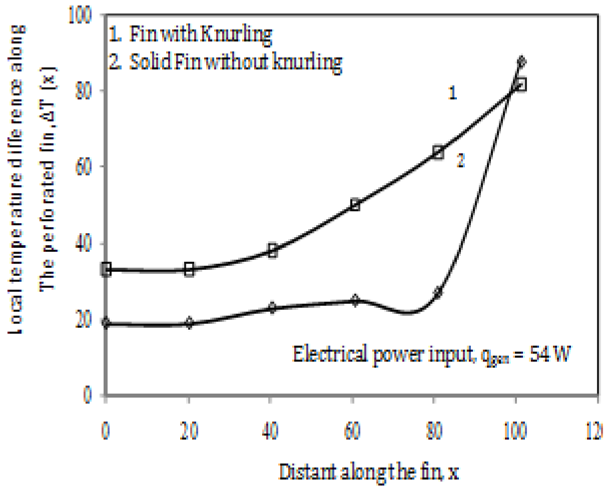

Figure 2: Variation of local temperature difference along the pin fin in forced convection mode of heat transfer

Figure 2 the comparative studies on variation of temperature difference along the fine for two different fin configurations viz., fin with knurling and fin without knurling is presented. This study was performed in forced convection mode of heat transfer. A fixed electrical input power of 54W is maintained throughout the study. A uniform velocity of air at 20 m/s is maintained. Curve 1 shows the variation in knurled fin and curve 2 shows the variation of temperature difference in solid fin. It can be seen from that the heat transfer rate is more in knurled fin than that of a solid fin. Further it can be seen that the temperature difference increases as we move from primary surface to the fin tip.

An attempt is done to study temperature difference variation temperature along the pin fin for two modes of heat transfer viz., the free convection and forced convection. Figure 3 shows the local temperature difference [ΔT(x)] profiles along the vertical hollow cylindrical perforated pin fin and vertical solid cylindrical perforated pin fin with same cross sectional area and of same length. The experiment was performed in free convection mode. The fixed electrical power input of 54 W is used at the primary surface of the pin fin. It can be seen that at a given location along the perforated fins the local temperature difference is more for hollow-cylindrical perforated pin fin than that of the solid perforated pin fin. This is so because more surface area of hollow-cylindrical perforated pin fin was exposed to air which increases the convective heat transfer rate both from inside as well as outside surface of the pin fin. Also, as we move from primary surface to the tip of the fin, the temperature difference decreases and reaches to the minimum for both the cases. Here, we can see that the drop in fin temperature is found to be decreasing by 3.21 % and 4.86 % at the tip and primary surface respectively. Also the drop in temperature for hollow and solid perforated pin fins as we move from primary surface to tip of the fin are given by 8.33 % and 5.11 % respectively.

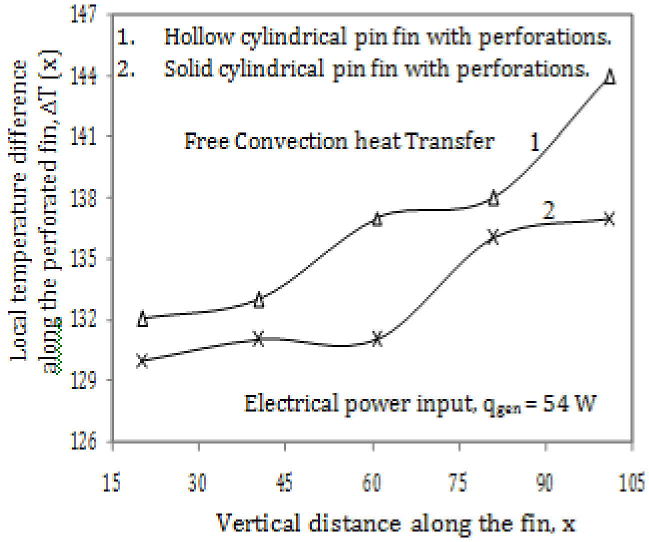

Figure 3: Variation of local temperature difference along the pin fin in free convection mode of heat transfer

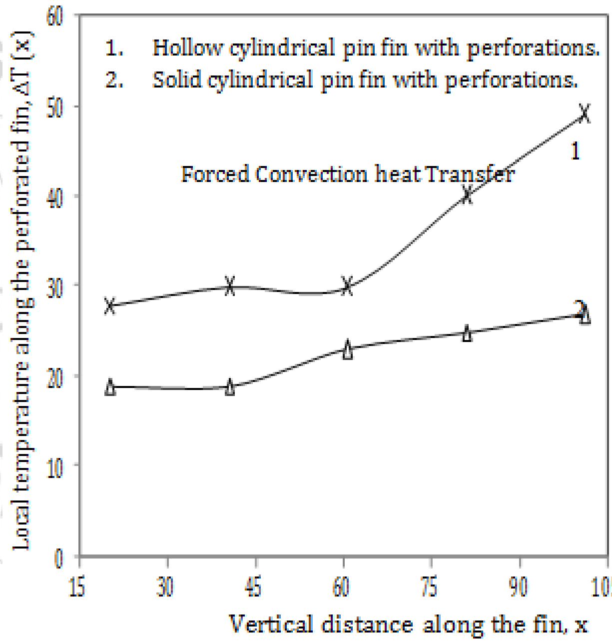

Figure 4: Variation of local temperature difference along the pin fin in forced convection mode of heat transfer

A similar study was also performed by using the same set up under forced convection mode of heat transfer. As shown in Fig. 4.The air was pumped at the velocity of 20 m/s at inlet of the duct and as it reached the outlet it is reaching approximately 5 m/s. This study is also performed for a constant input power of 54 W. As in Fig. 2 here also the temperature difference drops down as we move from the primary surface to the tip of the pin fin. But the drop in temperature at the tip is decreasing by 44.89 % and that of at primary surface is 34.14 %. This show that there is a large increase in the heat transfer from the surface by using forced convection instead of free convection mode of heat transfer. Also here too the temperature difference is decreasing as we move from primary surface to the tip of the pin fin. The tip and surface temperature is decreasing by temperature is decreasing by 29.63 % and 42.85 % respectively.

Figure 5: Solid Pin fin used for the purpose

Figure 6: Perforated Pin Fin used for the purpose

Figure 7: Fin with four perforations used for the purpose

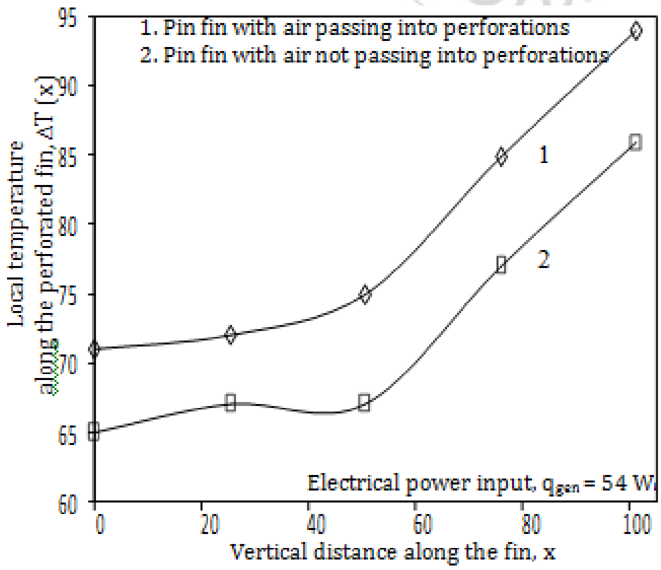

Figure 8: Temperature difference profiles along the pin fin with change in orientation

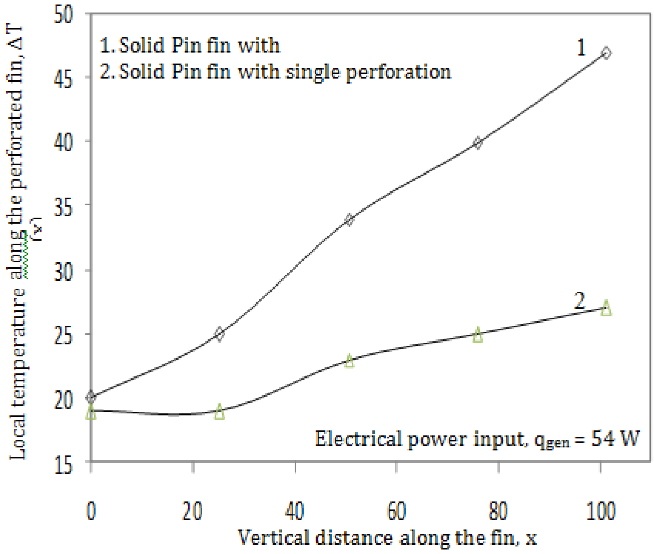

Figure 9: Temperature difference profiles along the solid pin fin and Single perforated solid pin fin

The variation of temperature difference along the pin fin with change in orientation of pin fin is shown in Fig. 8. This is study is performed for a forced convection heat transfer mode with the air being pumped through the duct by using blower at constant air flow rate of 15 m/s at inlet of the duct. The figure shows that the temperature difference is decreases from the primary surface to the tip. The temperature difference at a given location for a fin is more for the case where the air is restricted to flow through the perforations than that when we allow the air pumped into the perforations. The temperature difference is dropping by 8.51 % at primary surface, 10.67 % at center and 8.45 % at the tip. Also, it can be seen that the temperature difference drop is high at centre than that of at tip and primary surface as the air is flowing into the perforation there by increasing the interactive surface area at the center and thus increasing convective heat transfer rate.

Figure 9 shows the temperature difference profiles for two cases viz., Solid pin fin with no perforations and Solid pin fin with a single large perforation. The volume of the perforation is same as that of the sum of the small perforations made in perforated fin. From the figure it can be seen that the temperature difference is very less as for single perforated pin fin than that of non-perforated pin fin. The temperature difference is dropping as large as 40. 81 % for perforated fin as we move from primary surface to the tip of the fin. Thus it would be more suitable to use perforated pin than that of the solid fin to enhance the heat transfer rate.

6. Conclusions

An experimental study was made to comparison of solid with two different configurations knurled and fin without knurling, pin fin with four perforations and single large perforation was discussed. A brief comparison has been done to select an appropriate pin fin. Different temperature difference profiles are discussed for validation.

7. Nomenclature

A_s Surface are of the fin pin

D_h Hydraulic Diameter, m
h heat transfer coefficient, W/m^2 K
$\bar{h}$ mean heat transfer coefficient(W/m^2 K)
I Current, A
k_f thermal conductivity of air, (W/m K)
k thermal conductivity of pin fin, (W/m K)
Pr Prandtl number of air
Nu Nusselt Number
q heat transfer rate, (W)
Re Reynolds number
T_{in} Inlet temperature of the air from duct, K or °C
T_{out} Outlet temperature of the air from duct, K or °C
T_s average temperature of pin fin, K or °C
T_s (x) temperature at any location on pin fin, K or °C
T_w wall temperature of the pin fin, K or °C
T free stream temperature of air, K or °C
u velocity air along the pin fin, (m/s)
u free stream velocity of air, (m/s)
V Voltage, V
x Horizontal distance of the pin fin, m

GREEK SYMBOLS
υ_f Kinematic viscosity of air, (m2/s)
ρ Density of air, Kg/m^3

SUBSCRIPTS
conduction conduction heat transfer through pin fin
convection convective heat transfer through pin fin
radiationradiation heat transfer through pin fin

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