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Experimental Investigation of Heat Transfer by Forced and Natural Convection in a Pin Fin for Different Materials

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***Abstract:** In the modern generation heat exchange equipment has become of great importance in many industrial processes and internal combustion engines because it increases the use of energy resources as well as conversion and reuse of thermal energy. In recycling thermal energy, the minimization of temperature differences is more important. High-specific output engines can be developed by developing finned surfaces. Thus fins play an important role in energy. Our investigation deals with the problem of finding the optimum configuration of the fin with the maximum heat dissipation rate. This experimental study focuses on the analysis of the effectof forced convection and natural convection on the characteristics of heat transfer within the pin fin.*
***Keywords:** Heat transfer, forced convection, natural convection, pin-fin, Aluminium, Brass*

I. INTRODUCTION

The study of thermodynamics manages energy and its different forms with its change starting with one structure then onto thenext. For the purpose when it is desired to accentuating the heat evacuation between constructions and encompassing surroundingfluid, it's a typical practice to use an all-inclusive surface connected to the bottom surface. The positioning of an extended surface to an object is termed as fin [1]. Fins or extended surfaces are normally used in heat exchangers to enhance heat transfer between the main surface and ambient fluid. The heat transfer rate is enhanced by increasing the temperature difference between the object and the environment or by enhancing the co-efficient of convective heat transfer or by maximizing the surface area of the body [2]. At the point when it is important to enhance the heat transmission rate between construction and encompassing fluid, it is normal practice to use fin. The selection of appropriate fin relies upon various boundaries like geometrical shape, fin spacing, fin height,base thickness, types of materials, surface finish, and so on. During this experiment, we've utilized a set-up named – Pin Fin apparatus, which is employed to acknowledge the study of heat transfer in a pin fin. Pin fin arrays are a commonly used cooling structure in the trailing edge of gas turbine blades. The pin fins increase not only the internal wetted (cooled) surface area but also the structural integrity and stiffness [3]. Fins are likewise utilized in the electrical device in which produced heat should be effectively dispersed, examples are engine, generator, transformer, etc. In this experiment, we have used the convection mode ofheat transfer i.e. forced convection and natural convection. Murali et al. [4] found that there is an optimum angle of grooves and the number of threads per inch for which the heat loss per unit mass is maximum. Gawai et al. [5] shows that heat transfer enhancement using dimples is based on the principle of scrubbing action of cooling fluid taking place inside the dimple and the phenomenon of intensifying the delay of flow separation over the surface. Ghasemi et al. [6] used a simple and highly accurate semi-analytical method called the Differential Transformation Method (DTM) issued for solving the non-linear temperature distribution equation in a longitudinal fin with temperature-dependent internal heat generation and thermal conductivity. Naidu etal. [7] studied the effect of the inclination of the base of the fin array on heat transfer rate. Peles et al. [8] investigates heat transfer and pressure drop phenomena over a bank of micro pin fins. Saedodin et al. [9] shows a simple method studying the performance of porous and solid fins in a natural convection environment. Bhanja et al. [10] studied the finite-length fin with an insulated tip.Schnurr, N. M [11] shows the optimization of the design of longitudinal and triangular radiating fins concerning its weight. Yang et al. [12] shows that, with proper selection of physical parameters, significant heat transfer enhancements and pressure drop reductions can be achieved simultaneously with porous pin fins. Muniyandi, V. [13] studied heat transfer characteristics of a pin fin with perforation. The pin fin fabrication and experimentation are done under forced convection conditions. Singh et al. [14] performed an experimental investigation of square micro-pin fins heat sink for identifying the most suitable pin fin geometry forheat removal applications under forced convection. Panse et al. [15] studied the combination of additive manufacturing and microchannel cooling where microchannels are fabricated using Direct Metal Laser Sintering (DMLS).

Aldoori, W. H. [16] in this experiment studied the coefficient of the heat transfer which has been conducted for a set of rectangular fins with different fin height and resulted in the temperature difference between the surface of the block and flowing air increasing with increasing Reynolds number for all heat flow states. Jubear et al. [17] performed an experimental study of free convective heat transfer from a vertically rectangular fin array. The outcome of convection heat transfer coefficient, convection heat transfer rate, Nusselt number (Nu), and the Rayleigh Number (Ra) from fin arrays depends on fin height. Khetib et al. [18] in this experimental study found that electronic component is cooled by installing cylindrical pin-fins and by changing the diameter of the pin-fins, the variations in pressure drop along with heat transfer were examined. Mohammed et al. [19] in this study tried to predict the effectiveness of closely spaced parallel rectangular fin array arrangement. The resultant of temperature contour lines depicted a heat range from the hot base through the extended surfaces to the fin tips. Kaldgi et al. [20] studied the dimpled specimen's transient properties and determine their influence on heat transfer. Lee et al. [21] proposed that varying fin density not only improves the thermal performance but also reduces the weight of the pin-fin heat sink cooled by natural convection.

II. EXPERIMENTAL SETUP AND MATERIALS USED

For this study, we have used an experimental setup named “Pin fin apparatus” present in the Heat Transfer laboratory atTechno International Newtown. We have used pin fin with and without dimple channels for brass and aluminium in this case.

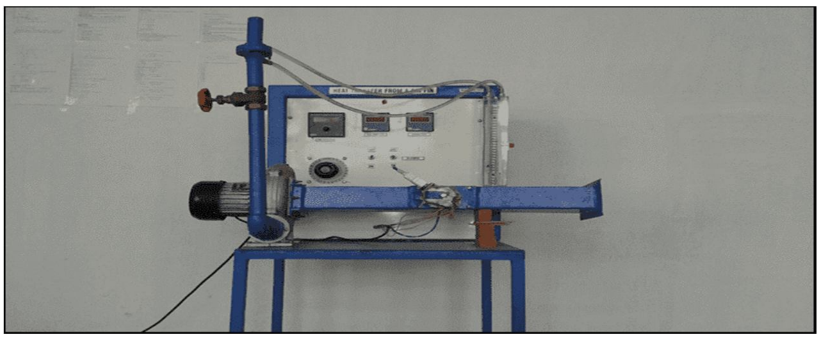

Fig.1. Pin Fin Apparatus

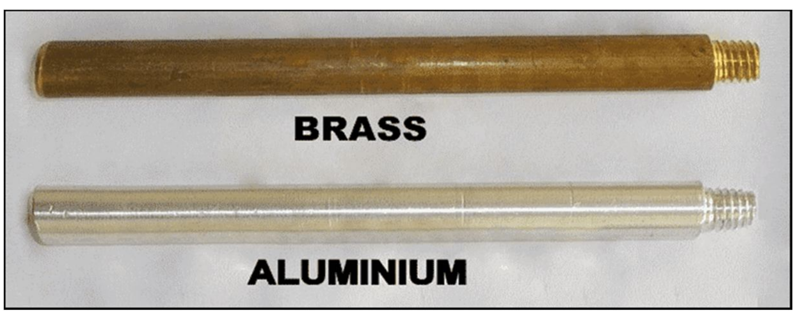

Fig.2. Pin fin without dimple channels

Fig.3. Pin fin with dimple channels

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III.RESULTS AND DISCUSSIONS

Table I. Data recorded for brass and aluminium pin fin with and without dimple channels

		Without Dimple Channels				With Dimple Channels			
	Sl. No.	Brass		Aluminium		Brass		Aluminium	
		Natural Convection	Forced Convection	Natural Convection	Forced Convection	Natural Convection	Forced Convection	Natural convection	Forced convection
Heat Transfer Rate (Watt)	1	0.02838	0.532019	0.05269	0.537951	0.06255	0.754544	0.06235	0.469319
	2	0.06096	1.1310653	0.11964	1.251317	0.13611	1.747408	0.14213	1.133956
	3	0.12891	2.468212	0.23501	2.215098	0.23877	3.05905	0.26503	2.06338
	4	0.19263	3.865256	0.36122	3.501533	0.37598	4.756635	0.39718	3.064912
	5	0.27081	6.311998	0.48591	4.761437	0.55137	6.689312	0.54732	4.92285
Heat transfer coefficient (W/m^2 °C)	1	8.32273	22.2533268	9.24317	22.42113005	9.11262	21.86227793	9.24108	21.75302047
	2	9.33161	22.46327667	10.1917	22.62603002	10.2197	22.07035783	10.4416	21.93452883
	3	10.4929	22.73167338	11.7719	22.88826123	11.196	22.29156527	11.5528	22.13546317
	4	11.129	23.04642518	12.469	23.21141315	12.012	22.57512096	12.3083	22.34304972
	5	11.6644	26.89533296	12.9104	23.61016086	12.7428	22.91832736	12.9024	22.73405685
Effectiveness	1	0.99999	0.993161	0.99999	0.996719	0.99999	0.995199	0.99999	0.997728
	2	0.99999	0.993097	0.99999	0.996689	0.99999	0.995154	0.99999	0.997709
	3	0.99999	0.993016	0.99999	0.996651	0.99999	0.995106	0.99999	0.997688
	4	0.99999	0.99292	0.99999	0.996604	0.99998	0.995044	0.99999	0.997667
	5	0.99999	0.991749	0.99999	0.996546	0.99998	0.994969	0.99999	0.997626

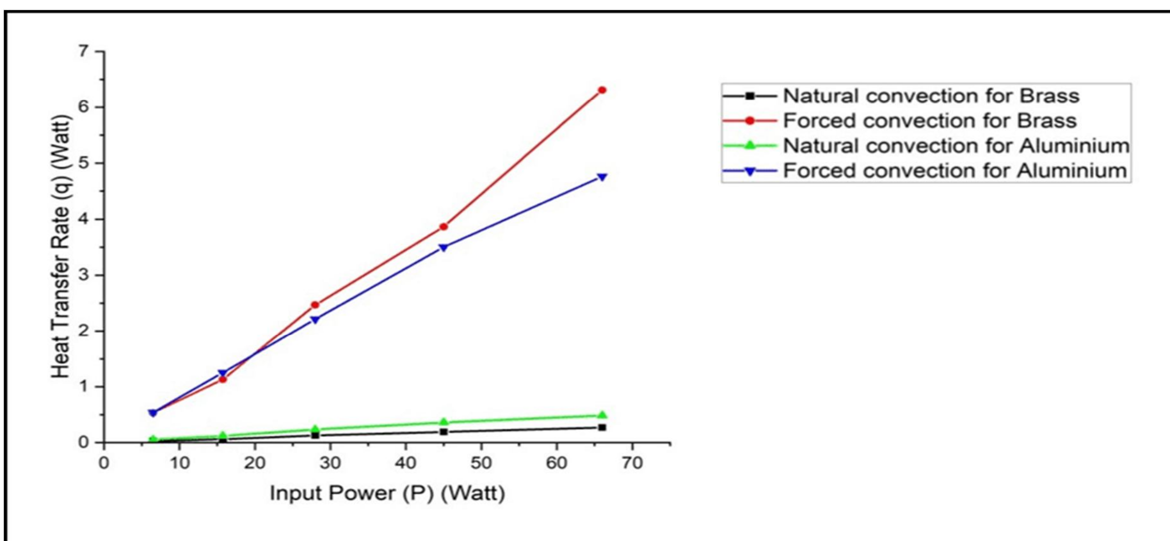

Fig.4. Plotting of Input Power (P) vs. Heat transfer rate (q) without dimple

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A. Comparison between heat transfer rate for both natural and forced convection with the increase in input power for different pin-fin (without dimple channels)

From fig.4. we can see that the heat transfer rate for different pin fins is increasing in both cases i.e. natural and forced convection. In the case of natural convection, the curve for different metal fin increases in the same manner, and the curve for an aluminium pin fin goes at a higher level than the curve of brass fin. In the case of forced convection, the curves overlap on one another at low input power, but as the input power is increased the rate of heat transfer increases. In the case of forced convection, the rate of heat transfer is high for brass pin fin at high input power. For high input power, the rate of heat transfer for the brass pin fin increases more rapidly than the aluminium metal fin.

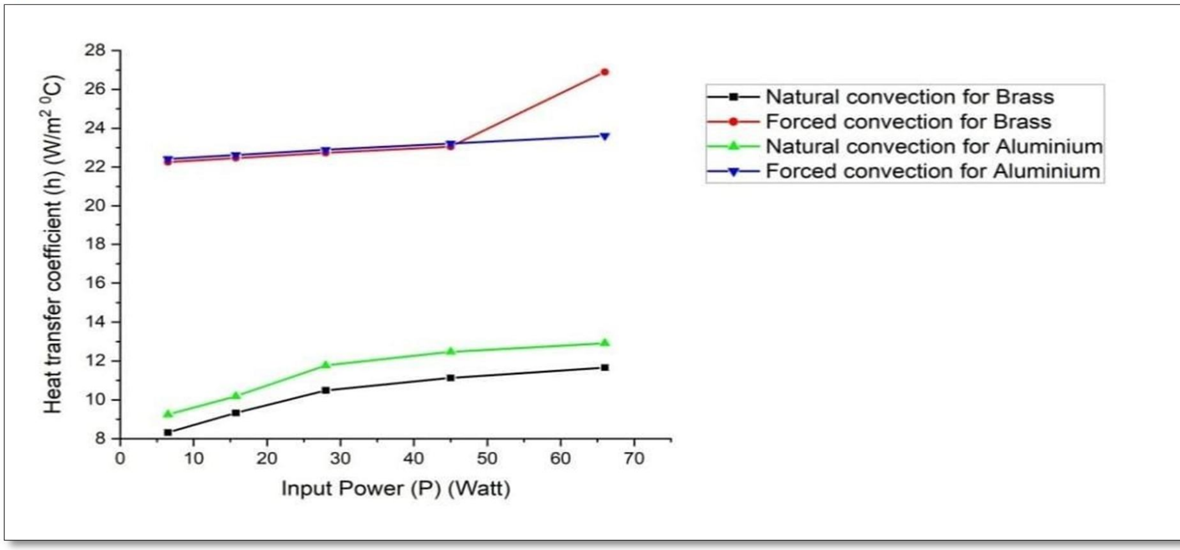

Fig.5. Plotting of Input power (P) vs. Heat transfer coefficient (h) without dimple

B. Comparison between heat transfer co-efficient for both natural and forced convection with increase in input power for different pin-fin (without dimple channels)

From fig.5. we can see that the heat transfer coefficient for different pin fins is increasing in both cases i.e. natural and forced convection. In the case of natural convection, the curve of different metals for heat transfer coefficient follows the same manner and the value of heat transfer coefficient for an aluminium pin fin is high compared to brass curve. In the case of forced convection, the curve of heat transfer coefficient for different metal fins follows the same manner at low input power. At high input power, the curve for brass pin fin for forced convection deviates from the other curve line. The value of heat transfer coefficient is high for brass pin fin in case of forced convection.

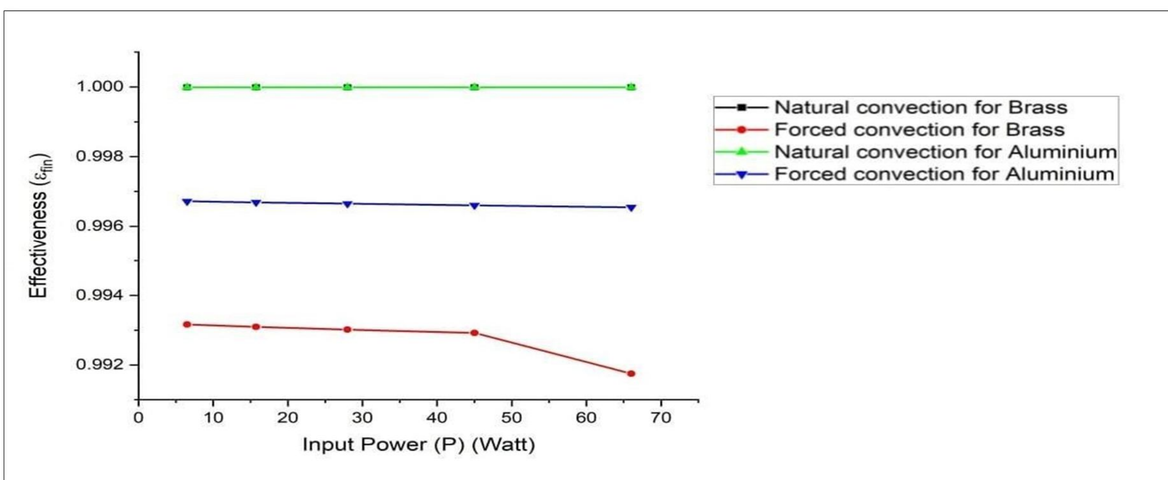

Fig. 6. Plotting of Input Power (P) vs. Effectiveness (Є) without dimple channels

C. Comparison Between Effectiveness for both Natural and Forced Convection with the Increase of Input power for Different pin-fin (without Dimple Channels)

From fig.6. We can see that the effectiveness is decreasing in the case of forced convection, but in the case of natural convection, there is no change in effectiveness with the increase of the input power. In the case of forced convection, effectiveness is decreasing in with the increase of input power. In the case of forced convection, curves for different metal fins decrease in the same manner at low input power but at high input power, the effectiveness for brass pin fin starts decreasing rapidly. The effectiveness of natural convection gets a higher value concerning forced convection.

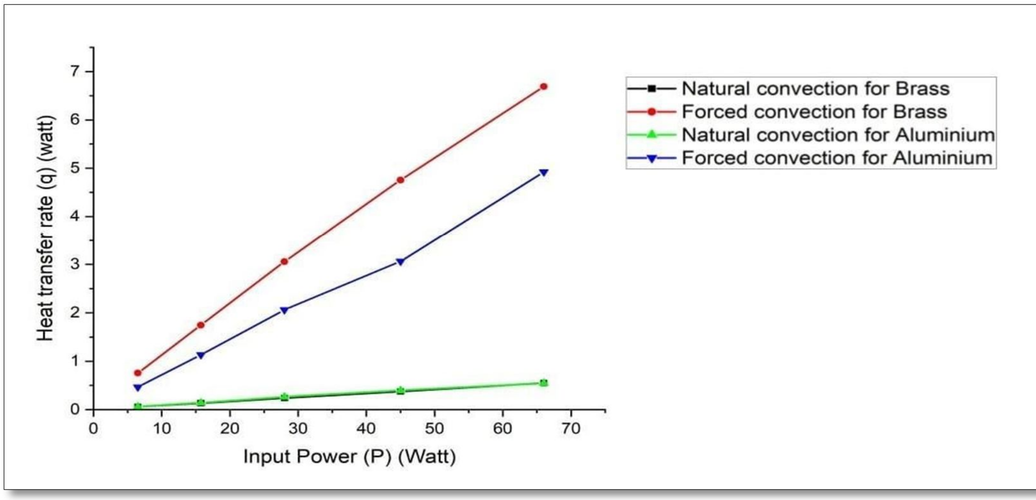

Fig.7. Plotting of Input Power (P) vs. Heat transfer rate (q) with dimple

D. Comparison between Heat Transfer rate for both natural and forced convection with the increase of input power for different pin- fin (with Dimple channels)

From the fig.7. We can see that the heat transfer rate is increasing in both the cases i.e. natural and forced convection for different metal fins with the increase of input power. In case of natural convection the curve of heat transfer rate for different metal fins overlap each other so we can choose any one of the material. In case of forced convection the rate of heat transfer for brass pin fin with dimple channels gets the higher value then the heat transfer rate for aluminium pin fin with dimple channels. From the graph we can see that the rate of heat transfer for brass pin fin with dimple channel is higher than other curves.

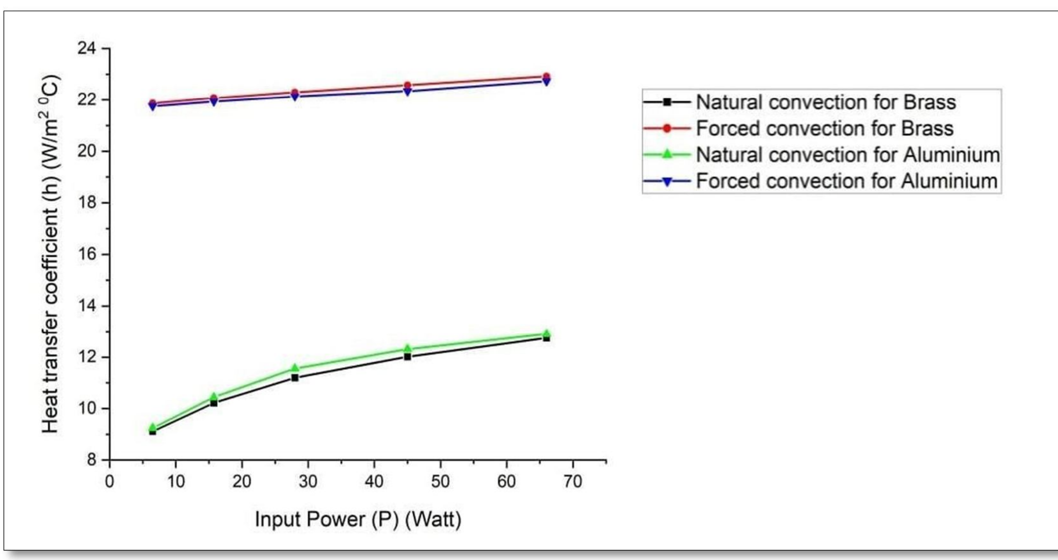

Fig.8. Plotting of Input power (P) vs. Heat transfer coefficient (h) with dimple

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E. Comparison between Heat Transfer Co-efficient for both natural and forced convection with the increase of input power for different pin- fin (with Dimple channels)

From the fig.8. We can see that the heat transfer co-efficient is increasing in both the cases i.e. natural and forced convection for fins made up of different metals. In case of natural convection, the curves for different metal fins (brass and aluminium) overlapson each other at low input power, and as the input power is increased the curve for aluminium pin fin with dimple channels increases more rapidly than the brass pin fin with dimple channels. In case of forced convection, the curves for different metal fins follows the same manner, but the value of heat transfer coefficient for brass fin with dimple channels gets the higher value then the value of heat transfer coefficient for aluminium fin.

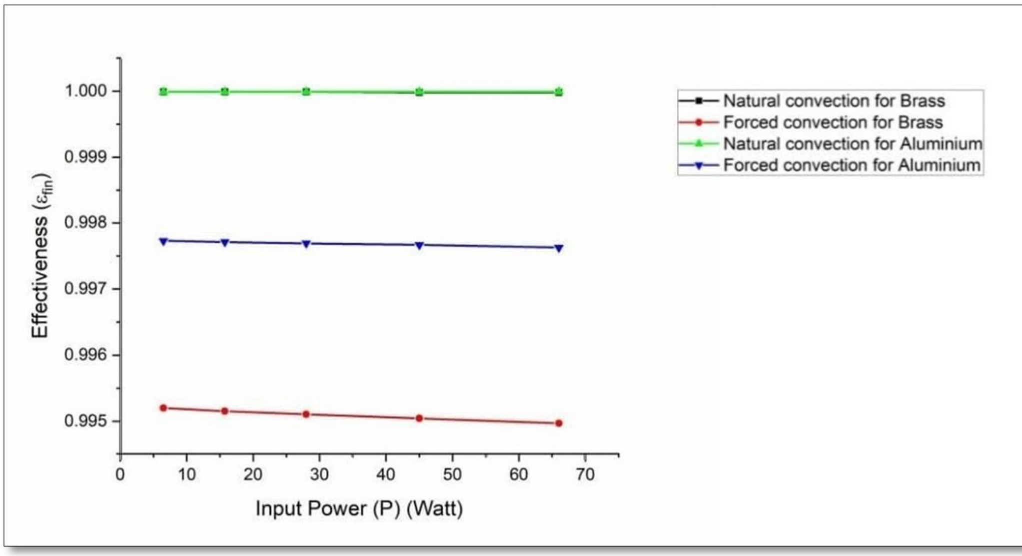

Fig.9. Plotting of Input Power (P) vs. Effectiveness (Є) with dimple channels

F. Comparison between Effectiveness for both natural and forced convection with the increase of input power for different pin-fin (with Dimple channels)

From the fig.9. We can see that the effectiveness is decreasing for forced convection and it remain constant for the natural convection. In case of natural convection both the curves overlaps each other so we can choose any material as a fin with dimple. In case of forced convection effectiveness is decreasing for both the materials but the value of decrement is higher in case of brass material then the aluminium material. At high input power, the value of effectiveness is higher in case of natural convection for both the material.

IV. CONCLUSION

Heat transfer rate depends on the method of setting fins in the plates, voltage applied across the pin fin and also depends on the positioning of fin etc. For time limitation and simplicity fins were held in horizontal position. The result that came from the experiment is discussed below:

1) By analysing all the figures that comes because of the experiment, we can say that effectiveness, heat transfer rate andheat transfer co-efficient is the function of the voltage applied across the base of the fin.
2) By analysing the figures comes from the result of experiment theoretically and analytically the relation between heattransfer co-efficient and effectiveness is established.
3) After performing the work and plotting the graphs it was noticed that heat transfer rate versus input power is best forforce convection. So for higher rate of heat transfer, forced convection equipment is to be installed.
4) Effectiveness vs. input power for pin fin in our experiment is suitable for force convection, low effectiveness of fin isrequired.
5) Convective heat transfer co-efficient vs. input power are best for force convection. So where high ‘h’ i.e. convective heattransfer co-efficient is required force convection equipment is to be installed.
6) It is seen easily that heat transfer rate, effectiveness and co-efficient of heat transfer for forced convection is much more compared to the natural convection. So it is preferred to have force convection where high rate of heat transfer is required.

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