International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.6, Nov-Dec. 2012 pp-4572-4576 ISSN: 2249-6645

Experimental Investigation of Flow Pattern on Rectangular Fin Arrays under Natural Convection

Vinod M. Wankar, [1] S.G. Taji[2]

[1](Student in Department of Mechanical, PES Modern College of Engineering, Pune, India)
[2](Professor in Department of Mechanical PES Modern College of Engineering, Pune, India)

Abstract: *In Natural convection heat transfer with the help of fin arrays, parameter are fin length to height ratio, spacing and orientation of geometry. In the longitudinally short fin array, where single chimney flow pattern is present hence heat transfer coefficient is high. In long rectangular fin arrays, air is stagnant at central zone hence it is not so much contributed in heat dissipation. In present study experimental setup is developed to studying the effect of natural convection over rectangular fin array. Fin spacing, height and heater input are the parameter study during experimentation. Lampblack coating is used to black fin surface. Flow patterns of various spacing's are investigated using smoke flow visualization techniques.*

Keyword: *Fin Arrays, Flow Visualization, Flow Pattern, Heat Transfer Coefficient, Natural convection.*

NOMENCLATURE:

a = correlation constants
A_b = area of base
g =acceleration due to gravity
Gr = Grashoff's number
H = heat transfer coefficient
H =fin height
K = thermal conductivity
L =fin length
Nu_S =Nusselt number based on S
Nu_b =Nusselt number based on base
Ra =Rayleigh number
Q = heat transfer rate
S =fin spacing
T = temperature

Subscripts
a =Ambient
b = base
S =Fin spacing

I. INTRODUCTION

Natural convection cooling with the help of finned surfaces often offers an economical and trouble free solution in many situation. Fin arrays on horizontal and vertical surface are used in variety of engineering application to dissipate heat to surrounding. The main controlling variables generally available to the designer are the orientation and the geometry of the fin arrays. For effective dissipation of heat, plain horizontal surfaces facing upward are preferred since they provide relatively higher surface heat transfer coefficients than other orientations. Since the heat transfer coefficient strongly depends upon the mechanism of fluid flow, a thorough understanding of the resulting flow patterns from the fin array is also of much use to the designer. The problem of natural convection heat transfer from a rectangular fin array on a horizontal base surface has been studied experimentally by some investigators. In some of these investigations, flow visualization studies have been conducted aiming at the study of associated flow patterns.

II. LITERATURE REVIEW

Experimental work on horizontal fin arrays was studied by various authors. Starner and McManus [1] was the first one on the topic of natural convection heat transfer from rectangular fin arrays on horizontal surfaces. The purposed of investigation was to experimentally determined average heat transfer coefficients for rectangular fin arrays of various dimension. Harahap and McManus [2] extended the work of Starner and McManus with object of more fully investigating the other objectives of their study were to investigate flow field. The other objectives of their study were to investigate flow field. Jones and Smith [5] undertook their investigation with prime objective of establishing the optimum spacing of fins for maximum transfer from given base surface. They experimentally determined averaged heat transfer coefficient for horizontal arrays over a wide range of spacing. Mannan [4] studied the effect all pertinent geometrical parameter of fin array on its performance. His work covered wide range of length: 127mm to 508mm, height: 254mm to 1016mm and spacing: 4.8mm to 28.6mm with temperature difference varying from 39^{o}C to 156^{o}C. Sane and Sukhatme [6] considered the situation of an isothermal rectangular fin array on a horizontal surface.

III. EXPERIMENTAL SETUP

Experimental setup is constructed on the basis of simplicity and practicability. Fin flats are manufactured using 2 mm thick commercially available aluminum sheet cut to the size of 200 X 75 mm. Spacers are cut from same aluminum sheet. Some spacer of 2mm and 3mm thickness are also cut of required size and quantity. Basic dimension of fin array used for experimentation are L=200 mm, W=100 mm, H=40 mm. These dimensions are decided by taking into account the convenience of measurement of surface temperature, input wattage as well as location of thermocouples so as to observe flow pattern by using simple smoke technique. This experiment deals with the study of natural convection, proper care is taken to avoid any effect of turbulent air flow around the fin array. An enclosure is fabricated in the formed of cubical with a volume of approximately 1 m^3. Three wall of cubical are enclosed with plywood sheets and front wall with acrylic sheet.

Top of the enclosure is kept open for undisturbed natural convection. The base plate of fin array was heated using cartridge type heater, which were given stabilized power input using dimmerstat. For realistic temperature measurement of the fin surface and ambient temperature, thirteen calibrated Cu-Constantan 36 gauge thermocouples, mounted at appropriate location are used. In order to account for heat dissipated by radiation black coating (using the black soot by burning camphor) is used. Syporex block placed at bottom and side of assembled array make provision four thermocouple to account the conduction loss through bottom and sides of the arrays. Two thermocouples are attached to the Bakelite plate to measure temperature. Schematic diagram of experimental setup showing electrical connection is shown in Fig 1. The fin array assembly is mounted inside the cavity of syporex block is as shown in Fig. 2.

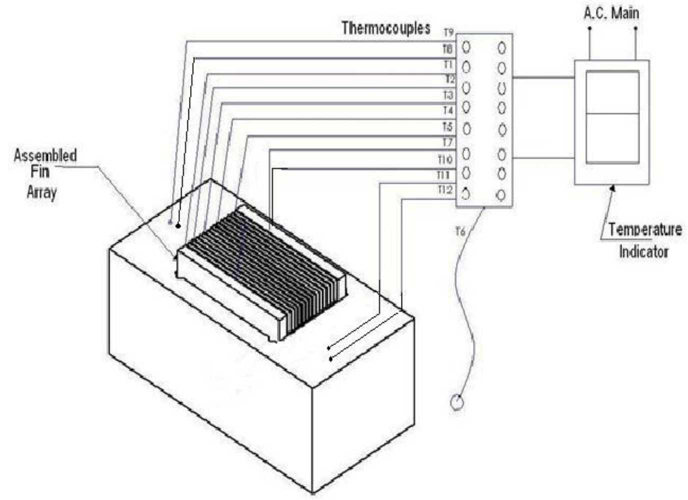


Fig. 1 Schematic diagram of experimental setup showing
Electrical connection

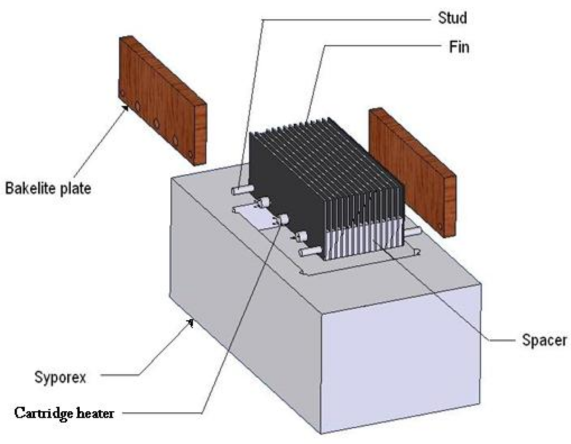


Fig. 2 Fin array assembly is mounted inside the cavity
Of syporex block

IV. RESULT AND DISCUSSION

Fig. 3 shows the effect of fin spacing on h_a with heater input as the parameter. As the fin spacing increases the h_a increases for fin array, as expected. For 2-4 mm spacing h_a is very small i.e. in the range of 0.88 to 1.81W/m^2 K. The highest value of h_a is 5.7929 W/m^2 K at the spacing of 12 mm. The increasing trend is steep up to spacing about 9 mm after which there is a gradual rise. The percentage increase of h_a from 2mm to optimum value is approximate 27%. Fig. 4 shows the effect of fin spacing on h_b with heater input as the parameter. From the Figure 4.2 it is clear that the values of h_b increases as fin spacing increases. It reaches to its maximum value (h_b=40 W/m2 K) at fin spacing about 10 mm and again decreases (h_b=18 W/m2 K). This trend can be attributed to restriction of entry of air in the channel at smaller fin spacing. The trend of increase in base heat transfer coefficient is observed from S= 4 to 10mm and it is maximum at fin spacing 10 mm. At the optimum spacing, h_b is nearly 40 W/m^2 K for the fin array. Fig. 5 shows variation of base Nusselt number with fin spacing to height ratio. It is observed that as the value of Nu_b increases as fin spacing increases from 4 to 8 mm. It reaches to its maximum value and again decreases. The reason for decrement in Nub may be due to the chocking of fluid flow at smaller spacing for spacing 2 to 4 mm. Optimum fin spacing is decided by the highest value of base Nusselt number i.e. Nu_b is 53.35 at S=10mm. Nu_b is increased by 45% from spacing 2mm to 10mm. It is observed that the optimum fin spacing for the two arrays is in a band of 8 to 10 mm. Fig. 6 shows variation of ha with ΔT. It is observed that as the value of ΔT increases with the value of ha also increases. For spacing is 2 mm, ha value is less than 0.884 W/m2 K as spacing increases then it increases upto 5.7 W/m^2 K for spacing equal to 12 mm.

Fig. 7 shows a comprehensive plot of Nu_s vs Ra_s with previous investigators. On the same plot the present experimental data is superimposed. It is observed that the present data is confirming the trends obtained by previous investigators. Mannan shows a diversion from other investigator because of he has wide range of short fin arrays.

V. FLOW VISUALIZATION

In the present work flow visualization study is conducted by simple smoke technique using dhoop stick. Fig. 8 shows photographs of flow visualization by means of simple smoke studies using dhoop stick for heater input of 100W for the fin array under study. It is clear from the photographs that the single chimney flow pattern is obtained in higher spacing whereas fluctuating flow pattern found in 2mm to 4mm spacing. This confirms better performance of higher spacing fin array in terms of increase in the heat transfer coefficient.

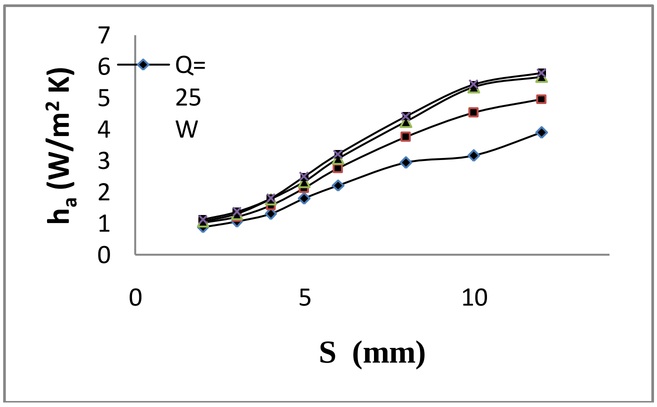


Fig 3: Variation of fin spacing 'S' with h_a

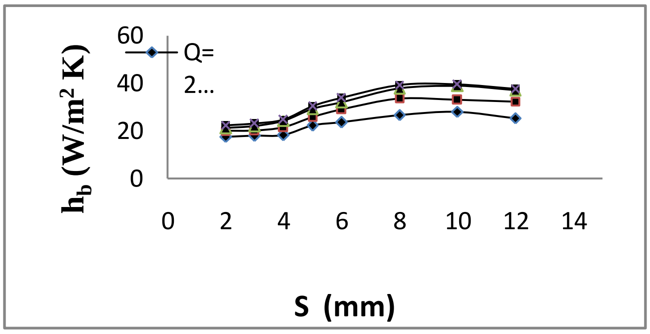


Fig 4: Variation of fin spacing 'S' with h_b

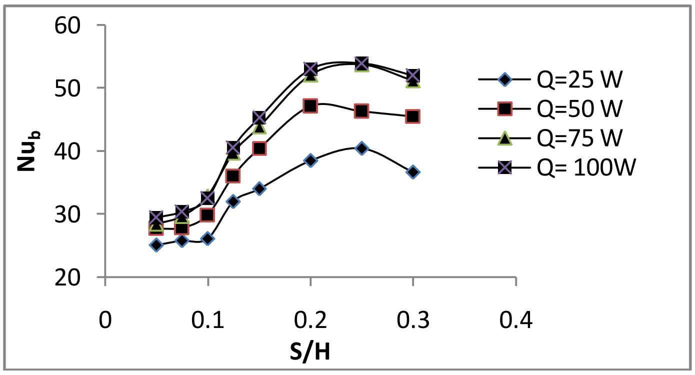


Fig. 5: Variation of 'S/H' with Nu_b

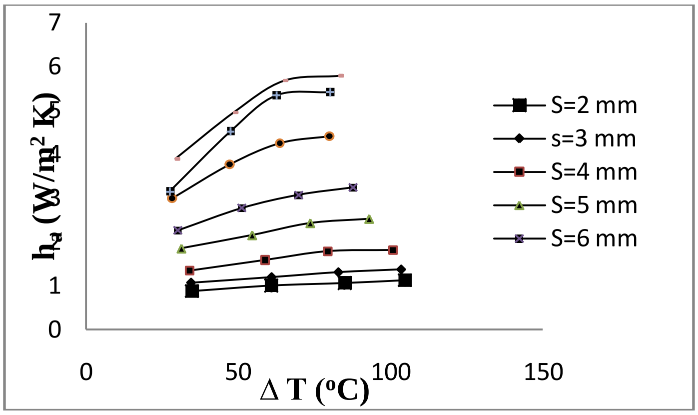


Fig. 6: Variation of Δ T with h_a

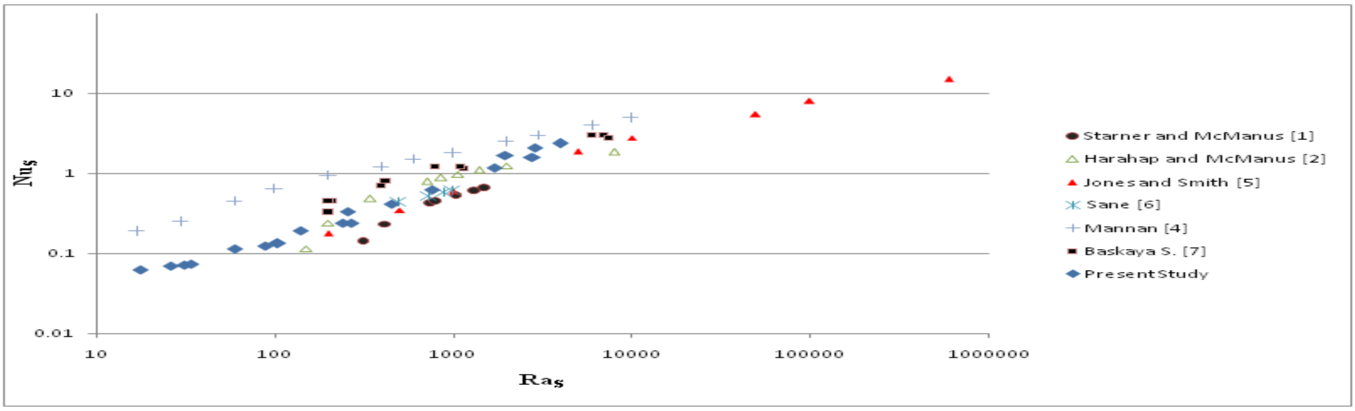
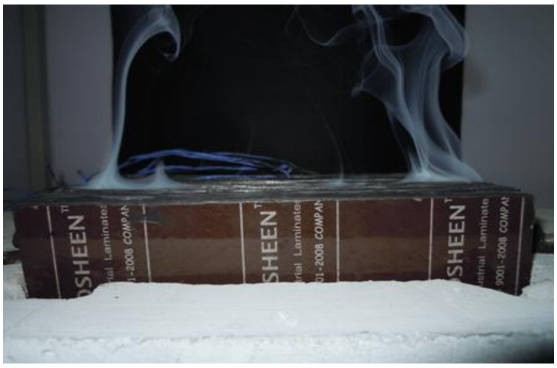
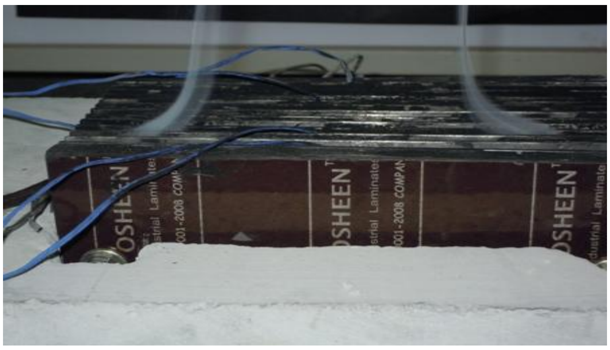


Fig. 7: variation of Ra_s with Nu_s

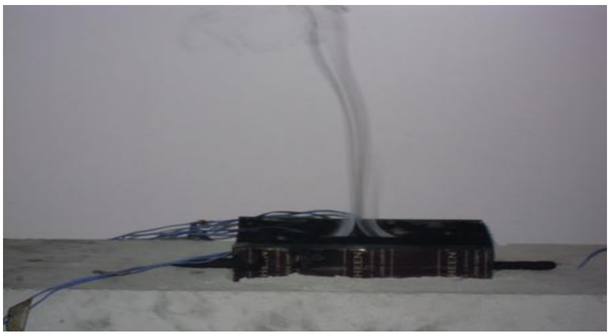


(a)

(b)



(c)



(d)

Fig.8: Flow pattern obtained with heater input of 100W

(a) 2mm (b) 4mm (c) 6mm (d) 12mm

VI. CONCLUSION

From the present study following conclusion are made:

1) Average heat transfer increase in optimum spacing 9-11 mm in Natural convection mode.
2) Fig. 7 shows experimental results also a good match with the previous experimental work reported on natural convection.
3) From experimental result it is observed that the heat transfer coefficient h_a is very small in case of spacing 2 mm to 4 mm (the range 0.88 W/m^2 K to 1.81 W/m^2 K) whereas h_a in case 6 to 12 mm (range of 1.9 W/m^2 K to 5.8 W/m^2 K). The percentages increased of h_a are 27% from 2mm to 12mm.
4) From experimental result it is observed that maximum value of Nu_a is 7.86 for 12mm spacing and maximum value of Nu_b is 58.35 for 10 mm spacing. Nu_a is increased by 81% from 2 to 12 mm spacing whereas Nu_b is increased by 27% from 2 to 10 mm spacing.
5) Base heat transfer coefficient values increase with optimum spacing and again decreases.
6) From flow visualization, it is observed that during spacing 2 mm to 4 mm the air entering from ends is not sufficient to cool the arrays and leaves before reaching central zone and single chimney flow pattern is not return.

REFERANCES

[1] Starner K.E. and McManus Jr. 1963. An experimental investigation of free convection heat transfer from rectangular fin arrays. Journal of Heat Transfer. 85: 273-278.
[2] F. Harahap, H.N. McManus Jr, Natural convection heat transfer from horizontal rectangular fin arrays, Journal of Heat Transfer 89 (1967) 32–38.
[3] Dayan A., Kushnir R., Mittelman G. and Ullmann A. 2004. Laminar free convection underneath a downward facing hot fin array. International Journal of Heat and Mass Transfer. 47: 2849-2860.
[4] Mannan K.D. 1970. An experimental investigation of rectangular fins on horizontal surfaces, Ph.D. Thesis, Ohio State University.
[5] Charles D. Jones. And Lester. F. Smith. 1970. Optimum arrangement of rectangular fins on horizontal surfaces for free convection heat transfer. ASME Journal of heat transfer. 92: 6-10.
[6] Sane N.K. and Sukhatme S.P. 1974. Natural convection heat transfer from rectangular fin arrays, 5th International heat Transfer conference, Tokyo, Japan, Vol. 3.
[7] Baskaya S., Sivrioglu M., and Ozek M. "Parametric study of natural convection heat transfer from horizontal rectangular fin arrays", International Journal of Thermal Science, 39, 797–805 (2000).
[8] Welling and Wooldridge.1965. Free convection heat transfer coefficient from rectangular vertical fins. Journal of Heat Transfer, Trans ASME series C pp 438-444.
[9] M. Mobedi and H. Yuncu 2003. A three dimensional numerical study on natural convection heat transfer from short horizontal rectangular fin arrays, Heat Mass Transf. 39 267–275.
[10] Yuncu H. and Anbar G. 1998. An experimental investigation on performance of fins on a horizontal base in free convection heat transfer. Sprigler-Verlag Heidelberg, Heat and Mass Transfer. 33: 507-514.
[11] Sobhan C.B., Venkateshan S.P and Seetharamu K.N. 1989. Experimental analysis of unsteady free convection heat transfer from horizontal fin arrays. Warme-and Stoffubertragung, Springer-Verlag. 24: 155-160.
[12] Dharma Rao V., Naidu S.V., Govinda Rao B. and Sharma K.V. 2006. Heat transfer from horizontal fin array by natural convection and radiation-A conjugate analysis. International Journal of Heat and Mass Transfer. 49: 3379-3391.