Natural convection around radial heat sink and application in electronics cooling system

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Abstract— Radial or annular fins are one of the most popular choices for exchanging the heat transfer rate from the primary surface of cylindrical or any shape. In electronic systems, a heat sink is passive component that cools a device by dissipating heat into the surrounding air. Heat sinks are used to cool electronic components such as high-power semiconductor devices, and optoelectronic devices such as higher-power lasers and light emitting diodes (LED).

Light emitting diode lights have recently attracted the attention of the illumination industry, due to their lower power consumption, longer life, and smaller, more durable structure compared to other light sources However, their use presents a thermal problem, since about 70% of their total energy consumption emitted as heat.

Index Terms— Natural convection, radial heat sink, electronics cooling, annular fins.

I. INTRODUCTION

In electronic systems, a heat sink is a passive component that cools a device by dissipating heat into the surrounding air. Heat sinks are used to cool electronic components such as high-power semiconductor devices, and optoelectronic devices such as higher-power lasers and light emitting diodes (LEDs).

Light-emitting diode (LED) lights have recently attracted the attention of the illumination industry, due to their lower power consumption, longer life, and smaller, more durable structure compared to other light sources. However, their use presents a thermal problem, since about 70% of their total energy consumption is emitted as heat. An efficient heat sink design is essential to solve this problem. Natural convection heat sinks are appropriate for LED lights, considering their overall advantages. However, natural convection heat sinks commonly have rectangular bases, whereas LED lights are generally circular. It is therefore desirable to investigate natural convection heat transfer via a heat sink with a circular base. (1)

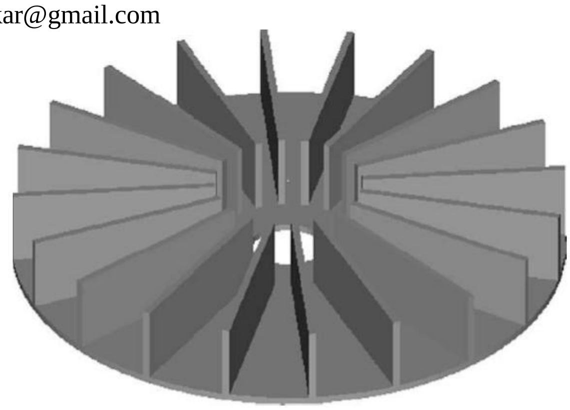

Figure 1 Radial heat sink with a circular base and rectangular fins.

II. EXPERIMENTAL INVESTIGATION

The numerical model is verified with experimental data, by comparing the differences between ambient and heat sink temperatures. The heat sink is made of aluminum (Al2014), with no additional surface treatment. As Fig. 1 shows, the experimental setup consisted of a film heater a heat sink, an insulator, type-k thermocouples a power supply, a wattmeter, and a personal computer. The film heater is attached to the bottom surface of the heat sink. Thermal grease is used to minimize the thermal contact resistance between the film heater and the heat sink. To reduce heat loss, the film heater

Section is surrounded by an insulator, heat sink temperatures are measured with eight thermocouples (located at four points of the central region and four points of the outer region of the upper heat sink base), and the ambient temperature is measured with two thermocouples. For the numerical simulation, radiation heat transfer is neglected. In the experiments, however, natural Convection and radiation heat transfer occurs simultaneously

A.Methodology

Experiments are performed and steady-state observations are recorded. Fin spacing, heater input, and percentage of area removed are the parameters of experimental study. Table 2 summarizes the parameters included in the experimentation. Radiation loss is accounted suitably by the predetermined values of emissivity, which are 0.5 for no blackened and 1 for black array. [11]

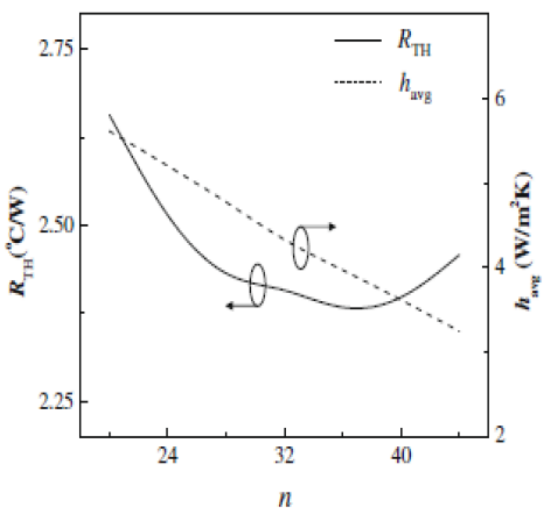

Fig. (a) The effect of number fins.

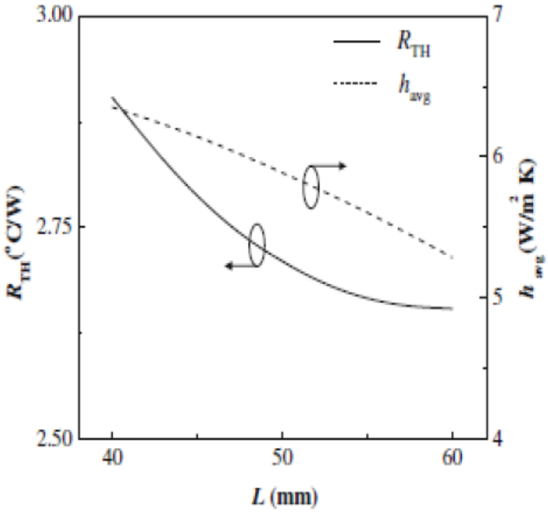

Fig. (2) The effect of fin length.

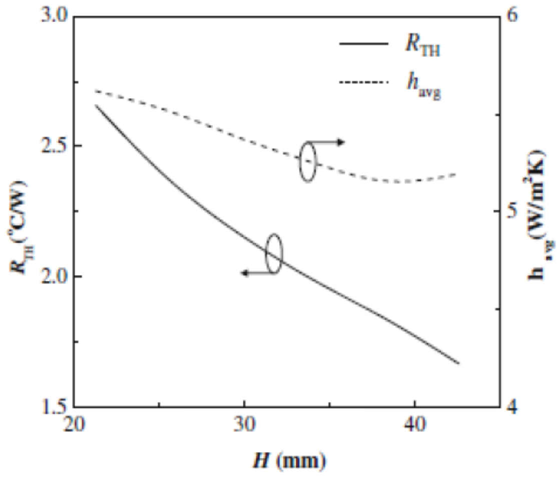

Fig. (c) The effect of fin height.

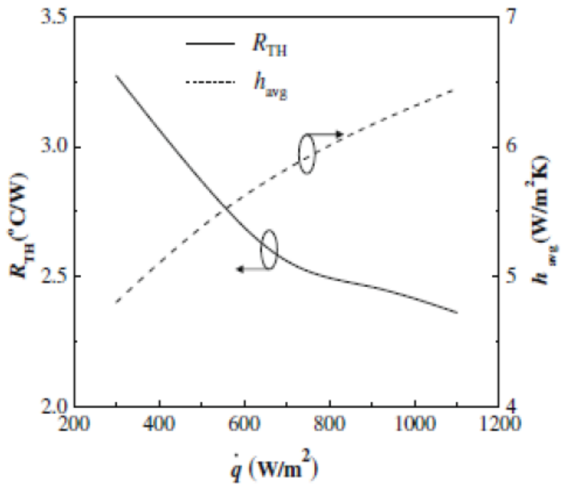

Fig. (d) The effect of fin heat flux.

Figure 2 Comparison of the temperature differences between the experimental and numerical

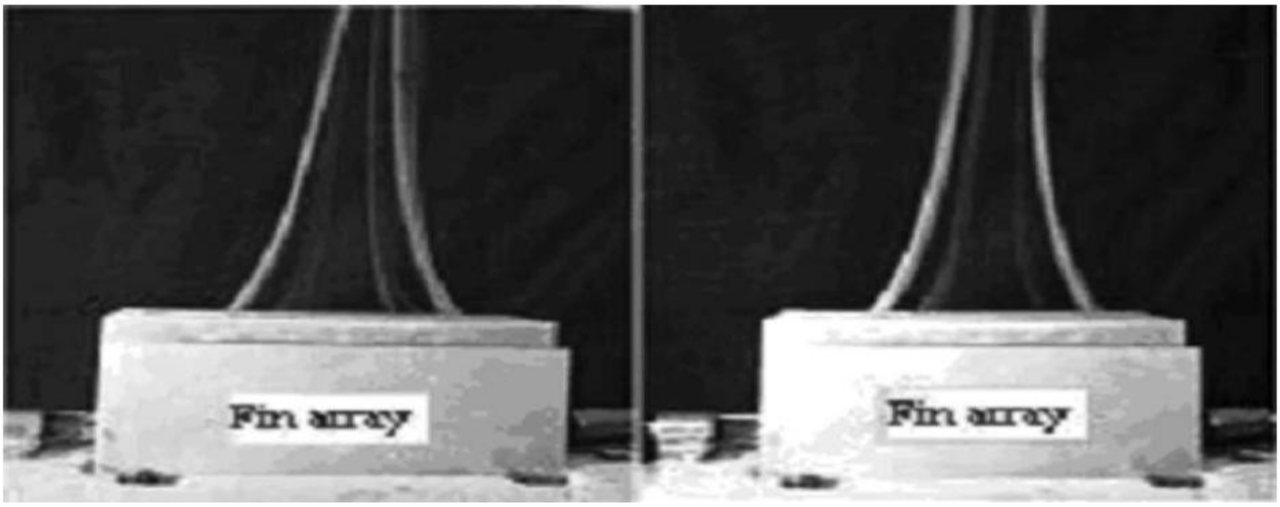

Figure 3 Photograph showing simple visualization by simple smoke technique.

B. Objectives

A) Design and manufacture the various fin structure by changing the parameter like number of fin, fin length, fin height.

B) Parametric studies were carried out by numerically investigating the effects of the number of fins, fin length, fin height, and heat flux on the thermal resistance and the heat transfer coefficient.

C) Find out one optimum design from various fin structure (heat sink)

D) Compare of the temperature difference between the experimental and numerical results. [1]

THERMO-FLOW CHARACTERISTICS

There are two flows, i.e., vertical and horizontal flows, around the radial heat sink. The vertical flow is in the upward direction, since air is heated by the heat sink (which is maintained at a higher temperature) and becomes lighter than the surrounding air. The horizontal

Flow is created by air entering from outside the heat sink to make up for the vertical flow in the inner region. Therefore, the overall flow pattern is chimney-like. The temperature of heat sink maintains almost uniformly high because of high conductivity of aluminum. The heat transfer rate in the outer region of the heat sink was higher than in the inner region. This was because the temperature difference between the air and the heat sink decreased as the cool air proceeded towards the inner region of the heat sink.

III. PARAMETRIC STUDY

The effects of the number of fins, fin length, fin height, and heat flux on the thermal resistance and the heat transfer coefficient were investigated.. The effect of the number of fins on the thermal resistance and heat transfer coefficient is shown in Fig. 2(a). The average heat transfer coefficient decreased as the number of fins increased, since the flow rate of the cooler air entering the spaces between the fins decreased and the air was heated more quickly on account of the reduced space between fins. However, when the number of fins was less than 36, the thermal resistance of the heat sink decreased with increasing n, since the effect of the increased heat transfer surface area was larger than the effect of the decreased heat transfer coefficient. When the number of fins was greater than 36, the thermal resistance of the heat sink increased with increasing n, since the heat transfer coefficient was very small. Consequently, there exists optimum number of fins that gives the minimum thermal resistance.[3]

Fig. 2(b) shows the effect of the fin length. As the fin length increased, the thermal resistance and average heat transfer coefficient decreased. The thermal resistance leveled off and reached a steady value when the fin was longer than 55 mm. This was because the air temperature in the inner region was almost the same as the heat sink temperature, and hence any additional fin length beyond 55 mm did not contribute to the heat transfer rate.[3]

Fig. 2(c) indicates the effect of the fin height. A lower thermal resistance resulted from the increased heat transfer surface area created by the incremented fin height. However, the change in the heat transfer coefficient was relatively small, since the velocity of the air entering from outside increased very little with increasing fin height.[3]

Fig. 2(d) illustrates the effect of the heat flux applied to the heat sink base. The decrease in thermal resistance due to increasing heat flux resulted in a greater rising air velocity, which in turn increased the flow rate of the cooler air entering from outside. Accordingly, the average heat transfer coefficient increased almost linearly, thanks to the enhanced effect of natural convection.(3)

IV. FLOW VISUALIZATION

Figure 3 shows the photographs of flow visualization by simple smoke technique using for normal and 30% INFAs. From photographs, it is concluded that coalescing of two streams at less height from fin bottom in normal fin array whereas it is at more height in INFAs, giving wider chimney and enhancing the heat transfer rat

Single chimney flow pattern is retained in INFAs also with a wider chimney zone, which is the possible reason for heat transfer enhancement. When single chimney flow pattern is present, in mid channel stagnant bottom portion becomes ineffective. The modified array is designed in inverted notched form and that has proved to be successful retaining single chimney together with the removal of ineffective fin flat portion. This is the main contribution of present paper. Limited CFD solutions obtained are in good agreement with experimental work. Radiation contribution is also important and needs further investigation. (11)

V. CORRELATION

A correlation for predicting the Nusselt number for a heat sink with a horizontal circular base and rectangular fins was derived as a function of the parameters investigated in the previous section, as well as other geometric parameters, and was obtained from numerical data. This formula is based on the correlations for rectangular heat sinks obtained in previous studies, using average fin spacing and the modified channel Rayleigh number and the properties are based on the film temperature. The predicted correlation was consistent with the numerical data, with an error of less than 10%, when $t = 2$ mm, $20 \leq n \leq 36$, 21.3 mm$\leq H \leq$ 63.9 mm, 75 mm $\leq r0 \leq$ 102 mm, 40 mm $\leq L \leq$ 80 mm, and 300W/m2 $\leq q \leq$ 1100W/m2.(3)

VI. RESULTS AND DISCUSSION

Parametric studies were carried out by numerically investigating the effects of the number of fins, fin length, fin height, and heat flux on the thermal resistance and the heat transfer coefficient. Based on these results, a correlation was proposed to predict the Nusselt number for a heat sink with a horizontal circular base and rectangular fins.

VII. CONCLUSION

Natural convection from a radial heat sink was experimentally and numerically investigated. The general flow pattern was like that of a chimney; i.e., the cooling air entering from outside was heated as it passed between the fins, and then rose from the inner region of heat sink. Parametric studies were performed to compare the effects of the number of fins, fin length, fin height, and heat flux on the thermal resistance and the heat transfer coefficient. As the number of fins, fin length, and fin height increased, the thermal resistance and heat transfer coefficient generally decreased. However, there existed optimal values of the number of fins and fin length to obtain an effective low heat sink temperature. The thermal resistance decreased and the heat transfer coefficient increased in proportion to the heat flux applied to the heat sink base. A correlation was proposed to predict the average Nusselt number for a radial heat sink.

NOMENCLATURE

b	spacing between fins, mm
c_p	coefficient of heat capacity, J/(kg °C)
F	view factor
h	heat transfer coefficient, W/m^2 K
H	fin height, mm
k	thermal conductivity, W/m °C
L	fin length, mm
M_w	gas molecular weight, kg/kmol
Nu	Nusselt number, hL/k
n	number of fins in the normal direction
Pr	Prandtl number
p	pressure, N/m^2
$\dot{q}$	heat flux, W/m^2
R_c	universal gas constant
R_{TH}	thermal resistance, °C/W
Ra*	modified Rayleigh number, $\frac{\rho^2 g\beta c_p \pi (r_o^2 - r_i^2)\dot{q}L^3}{\mu l k^2}$
r	radius, mm
T	temperature, K or °C

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REFERENCES

[1] Seung-hwan Yu,Kwan-soo Lee,Se-Jin Yook, “natural convection around radial heat sink”,International journals of Heat and Mass Transfer 53(2010) 2935-2938.

[2] Seung-Hwan Yu, Daeseok Jang, Kwan-Soo Lee , “Effect of radiation in a radial heat sink under natural convection”, International Journal of Heat and Mass Transfer 55 (2012) 505–509.

[3] S.A. Nada, “Natural convection heat transfer in horizontal and vertical closed narrow enclosure with heated rectangular finned base plate”, International journals of Heat and Mass Transfer 50 (2007) 667-679.

[4] M Dogan, M. Sivrioglu, “Experimental investigation of mixed convection heat transfer from longitudinal fins in a horizontal rectangular channel”, International journals of Heat and Mass Transfer 53(2010) 2149-2158.

[5] Abdullaatif Ben-Nakhi,Ali J. Chamkha, “Conjugate natural convection in a square enclosure with inclined thin fin of arbitrary lengh, International journals of thermal science 46 (2007) 467-478.

[6] B. Kundu, D Bhanja, “performance and optimization analysis of a constructal T-shaped fin subject to variable thermal conductivity and convetive heat transfer coefficient”, International journals of Heat and Mass Transfer 53 (2010) 254-267.

[7] Yongping Chen , chengbin zhang , Mingheng Shi, Jiafeng Wu, “Three dimasional numerical simulation of heat and fluid flow in noncircular microchannel heat sinks”, International Communications in Heat and Mass Transfer 36 (2009) 917-920.

[8] Reng-Tsung Huang, Wen-Junn Sheu,Chi-Chuan Wang, “Orientation effect on natural convective performance of square fin heat sinks”, International journals of Heat and Mass Transfer 51 (2008) 2368-2376.

[9] Copiello, Giampietro Fabbri, “Multi-objective genetic optimization of the heat transfer from longitudinal Wavy fins”, International journals of Heat and Mass Transfer 52 (2009) 1167-1176.

[10] Yang WH, Tarng YS, Design optimization of cutting parameters for turning operations based on the Taguchi method, Journal of Material Processing Technology, 84, 1998, 122–129.

[11] Sanjeev D. Suryawanshi1, Narayan K. Sane, “Natural Convection Heat Transfer From Horizontal Rectangular Inverted Notched Fin Arrays”, Journal of Heat Transfer AUGUST 2009, Vol. 131 / 082501-5.