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Natural Convection Heat Transfer Augmentation from Heat Sinks using Perforated Fins: A Review

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Abstract: *Heat Sinks with fins are generally used to augment the heat transfer rate in many industrial applications such as cooling of Automotive, Telecommunication, Electronic, Power electronic components. In many situations where heat transfer is by natural convection, fins are best solution because of their less cost and trouble free operation. The weight and size of equipment are the most important parameters of design. In these days the general trend is to use compact systems especially in electronic devices, which leads to higher packing density of systems causing higher heat production. It affects the performance of electronic devices and may cause its failure. The most preferred method for cooling these system is passive cooling because it is cost effective and reliable. This leads to focus on development of effective fin heat sink. Fins of different shapes and size are generally used in industry. In solid fin array stagnant layer is formed around the solid fin which slow down the heat dissipation rate. Increasing the fluid flow movement around the fin results in increasing heat removal rate. It can be achieved by making perforations in the fin. Here in this work focus is on perforated fins. The main objective of this paper is to study various researches done in past to augment heat transfer rate by providing proper perforations.*

Keywords: *Perforated fins, Natural convection, Heat sink, Nusselt number.*

1. INTRODUCTION

Many Engineering devices produce heat during their operation. If this heat is not removed rapidly to its surrounding atmosphere, this may cause rise in temperature of system components. This heat cause serious overheating problems in device and leads to failure of components so the produced heat within the device must be rejected to its surrounding to maintain the device at recommended temperature for its efficient working. The methods used in the cooling of high power density electronic devices vary widely depending on the applications and the required cooling capacity. The heat produced by electronic devices has to pass through a complex network of thermal resistances to the environment.

Fins are extensively used in cooling of computer processors, air craft engines, air cooled automobile engines, cooling of generators, motors, transformers, refrigerators and other electronic devices etc. They are very important aspect in geometry of heat sinks. A fin is generally a flat surface extended from heat sink surface. It is used for augmentation in heat transfer to and from environment by increasing the convection heat transfer surface area. The provision of perforations on continuous rectangular fins increases the heat transfer rate from heat sink. It is due to fact that perforations provided on fins disrupt the thermal boundary layer growth and this maintains thermally developing flow regime along the fins which leads to higher heat transfer coefficient. In addition provision of perforations reduces the weight and can lead to lower production cost. Introduction of shape modifications by cutting some fin material to make slots, holes, cavities, grooves or channels through the fin body increase the heat transfer area and/or the heat transfer coefficient. A great number of experimental and numerical works has been carried out to study the effect of perforated fin parameters like perforation shape, perforation size etc. on heat transfer rate from fin array by the investigators.

1.1 Cooling Methods

1.1.1 Active method

In this method external power is required for heat transfer enhancement. The active heat transfer augmentation techniques have not found commercial interest because of operating and capital cost of augmentation devices. Augmentation of heat transfer is of vital importance in many industrial applications. There are various specimens of active methods are that which produces effect pulsating by cams, reciprocating pump-piston etc.

1.1.2 Passive method

In these systems external power is not needed. Passive cooling methods are widely used for power electronic and electronic devices because they provide noiseless, low-price and trouble free solutions. Some passive cooling methods include natural convection air cooling, heat pipes and thermal storage using phase change materials. using fins is one of the best inexpensive and common ways to remove unwanted heat and it has been successfully used for many engineering applications. Fins are of various shapes, such as circular, rectangular, pin fin rectangular etc., see fig.1, depending on the application. In natural convection, it is necessary to optimize the parameters of the heat sink geometry in an application independent manner.

1.1.3 Compound method

Compound method is a hybrid method in which both active and passive methods are used in combination. This method need composite design.

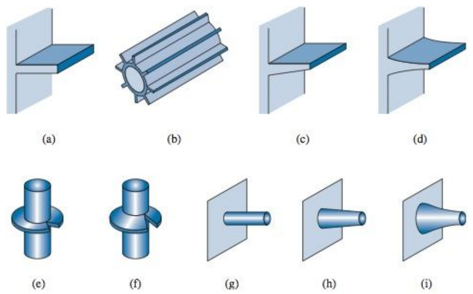

Figure 1. Different types of fins

2. REVIEW OF PREVIOUS WORK

Harahap and McManus [1] carried out experiment on horizontal rectangular fin arrays with different geometry and find out that array with shorter fin length showed higher average convection coefficient when compared with two series of rectangular fin arrays having same spacing and height because single chimney flow pattern is obtained in small length fin array.

Baskaya Senol, et.al. [2] carried out parametric study to find out effect of fin height, fin length, fin spacing and concluded that overall heat transfer is enhanced with increasing in H, height of fin and decrease in L, length of fin, hence increase in H/L.

Al-Essa and Al-Hussien [3] numerically investigated Natural convection heat transfer from a horizontal rectangular fin with square perforation with two orientations. It is found that square perforations increases surface area and heat removal rate. increase in heat transfer is obtained at certain value of perforation dimensions. Square perforations of inclined type is best for low fin thickness and parallel type for high fin thickness.

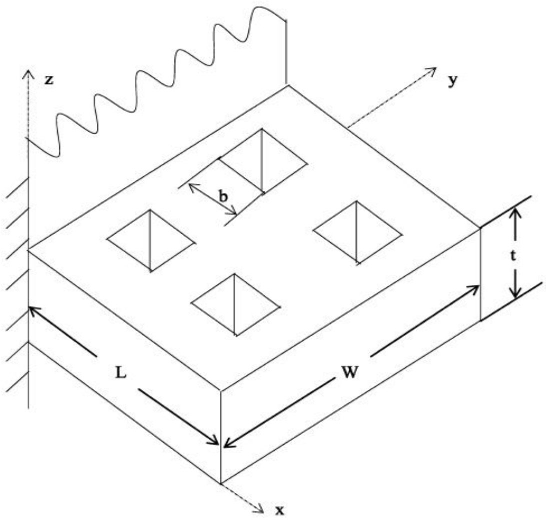

Figure 2. Fin with parallel square perforation

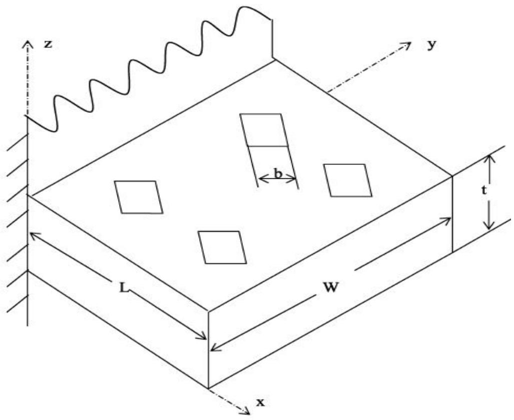

Figure 3. Fin with inclined square perforation

Al-Essa and Al-Widyan [4] Studied the Natural convection heat transfer augmentation from horizontal rectangular fin embedded with triangular perforations. It was found that temperature drop along the perforated fin length is consistently larger than that on equivalent solid fin. for a certain values of triangular dimensions, perforated fin can augment heat transfer.

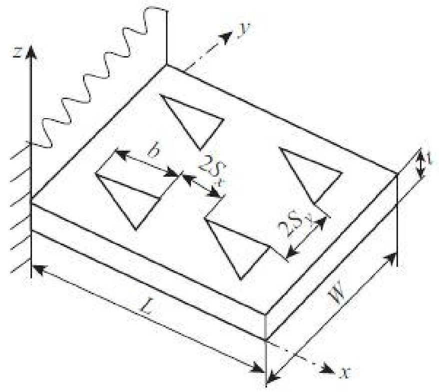

Figure 4. Fin with equilateral triangular perforations

R.K. Ali [5] experimentally investigated the heat transfer augmentation by perforation in air cooling of two in-line rectangular heat sources. Distance between seperations of two heat sources investigated at S/L=0.5 and 1. His results show dimensionless temperature of heat sources decreases gradually with hole open area ratio(β) and the decrease in the average dimensionless temperature for heat source is upto 21% at β=0.2944. for the first heat source, maximum increase in average nusselt number compared with flow over single heat source is 27% corresponding β=0.2944 and Re_L = 10798.

Shaeri and Yaghoubi [6] carried out numerical study of heat transfer from fin array with rectangular perforation. Rectangular perforations along the length of bluff plate varies in number from 1 to 8. They found that average nusselt number, friction coefficient and average pressure drop decreases with increase in perforation.

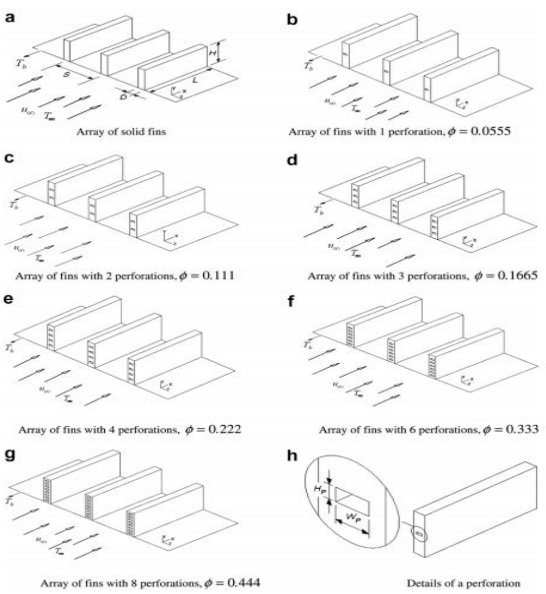

Figure 5. Arrays of solid and perforated fins

Shaeri and Yaghoubi, K Jafarpur [7] numerically studied the heat transfer from rectangular array of perforated fins with square window shape perforation, that are arranged in lateral surface of fins. Results showed that average friction coefficient, drag force and average nusselt number reduces with increase of perforation. fins having same porosity and smaller window sizes have lower nusselt number than fin with larger windows.

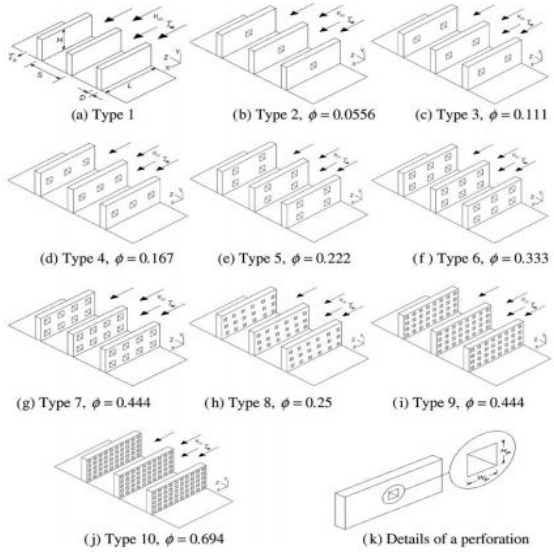

Figure 6. Lateral perforated fin arrays

E.A.M. Elshafei [8] experimentally studied the heat dissipation from heat sinks with solid and hollow/perforated circular pin fins in staggered combination, fitted into a heated base. Range of rayleigh number for test was $3.8*10^6 \leq Ra \leq 1.65*10^7$ .It was concluded that in case of hollow/perforated pin fin heat sinks, nusselt number of sideward arrangement was higher than upward arrangement. Temperature difference between base plate and atmosphere, ΔT at same heat input Q was found less for hollow/perforated pin fin heat sink than that for solid pin.

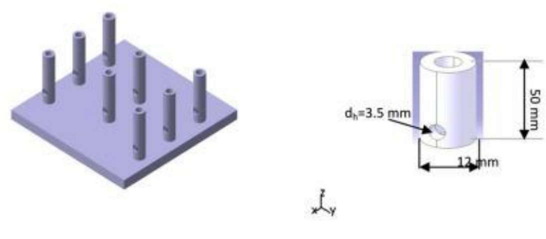

Figure 7. Perspective view of hollow/single perforated pin fin heat sink

Fengming Wang, et.al. [9] numerically and experimentally investigated the flow and heat transfer inside a rectangular channel embedded with pin fins. They compared several different shaped pin fins with same cross-sectional area in staggered arrangement. They concluded that heat transfer augmentation of drop-shaped pin fins is weaker than that of circular pin fins and average nusselt number reduction between drop-shaped and circular pins was about 23% for drop-A, 25% for drop-B, 26.5% for drop-C.

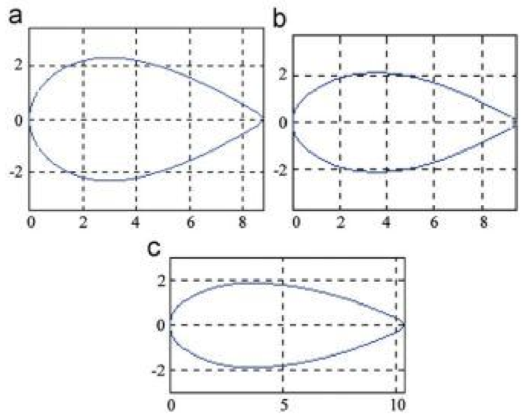

Figure 8. Cross-sectional geometries of drop-shaped pins. a) Drop-A, b) Drop-B & c) Drop-C

Zan Wu, et.al. [10] theoretically evaluated the performance of staggered pattern perforations in rectangular isothermal fins, vertical parallel isothermal plates, isolated isothermal plates under free convection. They considered the effect of ratios of open area, other geometric parameters and inclined angles. They found that staggered pattern perforations increase the total heat transfer rate for vertical parallel plates and isolated isothermal plates with low ratios of plate height to wall-to wall spacing by a factor of 1.06 to 1.20.

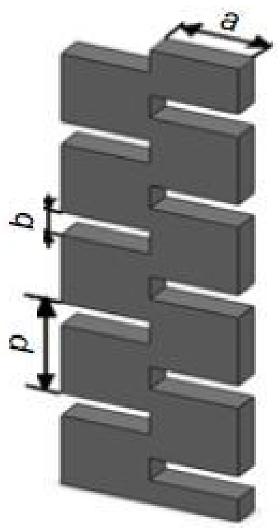

Figure 9. Isolated inclined plate

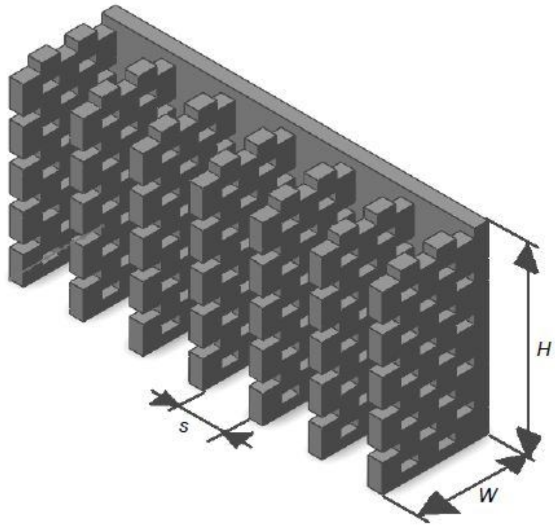

Figure 10. Vertical rectangular isothermal perforated fins on vertical surfaces

Dhanawade Hanamant S, et.al. [11] numerically and experimentally evaluated natural convection heat transfer and fluid flow characteristics of fin array with lateral circular perforation, equipped on horizontal flat surface. It was found that with increase in size of perforation heat dissipate increases. The flow pattern in case of solid fin array was sliding chimney in nature and in case of perforated fin it was single chimney in nature.

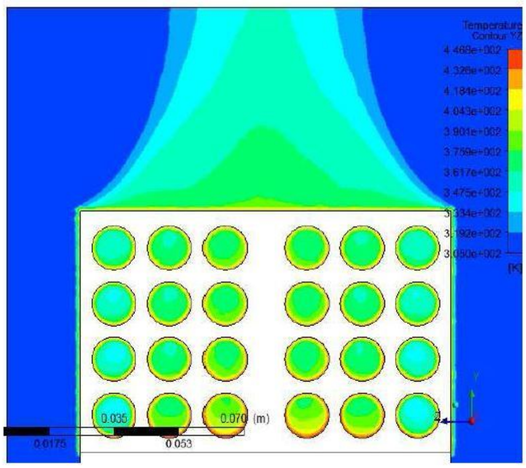

Figure 11. Single chimney flow pattern in case of perforated fin

3. CONCLUSIONS

1) Extended surfaces are the better method of augmenting heat transfer.
2) Perforated fin may dissipate about 48 to 58% more heat.

3) Perforated fins are light in weight, so decrease the manufacturing cost.
4) Fluid flow pattern is sliding chimney in case of perforated fins.
5) Material of perforated fin may have better strength.

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