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Heat Transfer Enhancement by using perforation: A Review

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Abstract - *Pin fins heat sink are used to increase heat transfer in variety of applications such as cooling of electronic component, (Integrated CPUs, chipset and hard disk drives), heat exchanger etc. Perforated pin fin heat sink gives higher heat transfer rate compared to solid pin fin heat sink by varying the different parameter like shape of pin fin, diameter of Perforations and number of Perforations different heat transfer rate can be achieved. The present paper reviews the literature which deals with heat transfer enhancement by using perforation.*

***Key Words*: Natural convection, forced convection, pin fins; Perforation, Heat transfer coefficient, pressure drop.**

1. INTRODUCTION

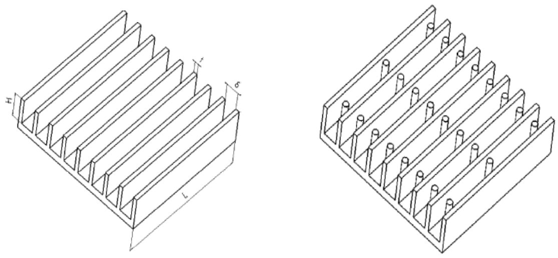
Heat sink is a device which absorbs the heat from heated component and dissipates heat to surrounding air. Air cooling is the most widely used technique for heat rejection. Heat sink dissipates heat to surrounding air by convection. In forced convection heat dissipated by means of some external sources such as fans. In natural convection, the extended surfaces are used which increases surface area by adding fins to the surface in order to achieve required rate of heat transfer. Heat transfer from a pin fin heat sink depends on many parameters; shape and size of the fins, spacing between the pin fins, number of pin fins, number of perforation, diameter of perforation ,thermal conductivity, the type of flow and the fluid, temperature difference between the heat sink and the fluid.

1.1 Need of Perforation

The electronic systems during their operation generate heat which continuously increases the temperature of electronic component and causes their failure at high temperature. This generated heat need to be dissipated quickly to surround atmosphere to keep working temperature of electronic device at protected and portable level. A heat sink is a passive device that dissipates heat to surroundings air using extended surfaces such as fins. Perforation means circular hole is provided on pin fin. Perforation on pin dissipates the heat rapidly to surrounding fluid because it disturbs fluid flow. Perforation on pin also helps to reduce the overall size, weight and cost of heat sink.

2. LITERATURE REVIEW

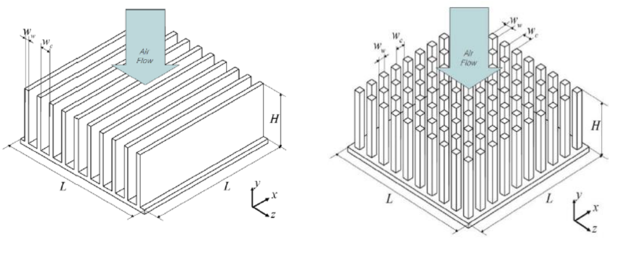
Xiaoling Yu et al. [1] compared thermal performance two types heat sink such as plate fin heat sink and plate-pin fin heat sink. The plate pin fin heat sink was constructed by providing columnar pin fin in between plate fins. The material used for heat sinks is aluminum having thermal conductivity of 202 W/(mK). The base heat sink was heated uniformly with a heat load of 10 W and varied wind velocities through passages of the heat sink such as 6.5, 8.0, 10.0 and12.2 m/s respectively. They have observed that plate pin fin heat sink gives lower thermal resistance and more pressure drop than plate fin heat sinks.



(a) (b)

Fig-1: (a) Plate fin heat sink (b) Plate-pin fin heat sink. [1]

Dong-Kwon Kim et al. [2] compared plate and pin-fin heat sinks subjected to an impinging flow. They performed experiment for different flow rates and channel widths. They used volume averaging method to predict pressure drop and the thermal resistance. The material of heat sinks was aluminum alloy 6061 with thermal conductivity of 170 W/(mK).The result indicate that optimized pin-fin heat sinks shows lower thermal resistances when dimensionless pumping power is small and the dimensionless length of heat sinks is large.



(a) (b)

Fig-2: (a) Plate fin heat sink (b) Pin fin heat sink. [2]

Abdullah H. et al. [3] compared solid and perforated horizontal rectangular fin in natural convection by using finite element technique. They keep the same dimensions, thermal conductivity, base temperature and ambient temperature for both fins and studied the effect of the perforation on heat transfer rate.

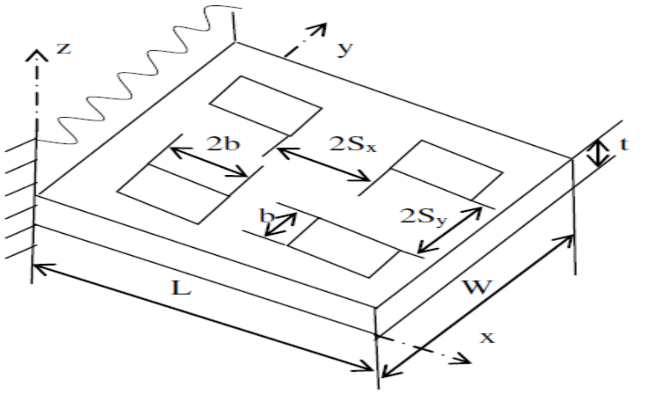


Fig-3: The fin with rectangular perforations. [3]

They found that, perforated horizontal rectangular fin has more heat transfer and less weight compared to equivalent solid fins. The heat transfer enhancement of the perforated fins are depends on fin thickness and thermal conductivity of material.

E.A.M.Elshafei [4] studied the natural convection heat transfer from circular pin fin heat sinks. In this study, they compared solid circular pin fins with perforated circular pin fins in staggered arrangement. The base plate and the pin-fins were made of aluminum with a thermal conductivity of 237 W/(mK). The range of Rayleigh number was taken from $3.8x\ 10^6 \leq Ra \leq 1.65\ x10^7$. They also tested performance of heat sink for two different orientations such as upward and sideward orientations and observed that, the perforated pin fins gives better heat transfer in sideward arrangement than upward arrangement. For the same heat supplied, the temperature difference between the base plate and surrounding air was less for perforated pin fin heat sink than that of solid pin.

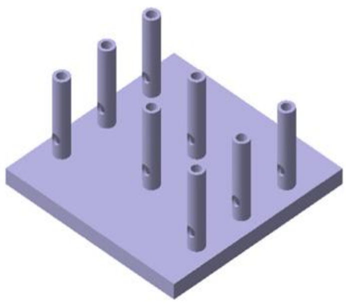


Fig-4: Single hollow perforated pin fin heat sink. [4]

Monoj Baruah et al. [5] investigated the performance of elliptical pin fins which arranged in a staggered manner. Two types of elliptical pin fins have been taken for the study, namely, solid elliptical and perforated elliptical pin fins. The pin fins were made of Aluminum with thermal conductivity 202.4 W/m-k. The height of the both pin fins was kept the same as 23.0 mm. Three perforations were provided on elliptical pin fins and its performance compared with corresponding solid elliptical pin fin. They have observed that, the perforated elliptical pin fins gives more heat transfer and less pressure drop than solid elliptical pin fin.

Anupam Dewan et al. [6] investigated forced convective heat transfer from an array of circular pin fins. The arrays of solid and perforated pin fins are mounted on a flat plate in staggered manner along the flow direction. Aluminum material was selected as fin material. The air inlet velocities varied from 1.5 m/s to 6.0 m/s. The height and diameter of the pin fins was taken 23.0 mm and 2.3 mm respectively. The perforation diameter 1.15 mm was provided on pin fin at the heights of 11.5 mm from the base. They found that perforated fin enhanced the heat transfer and reduced the pressure drop. The circular perforation on pin fin reduces the weight and the cost of pin fin.

Ji-Jinn Foo et al. [7] studied the forced convective heat transfer with perforated pin fin array subjected to a vertical impinging flow. They investigated rate of heat transfer and pressure drop by varying the number of horizontal perforation and the diameters horizontal and vertical perforation on pin fin. Further their performance compared with the solid pins. All pin fin array were made of aluminum material which contains 14 pins of 8 mm diameter and 50 mm height. All cases studied for four different inlet velocities such as 5, 10, 15 and 20 m/s respectively. They observer that, the perforated pin fin array gives more heat transfer than the corresponding solid pins. The pressure drop decreases with increase in number of perforation and diameter of perforation; therefore perforated fins consume less pumping power than solid.

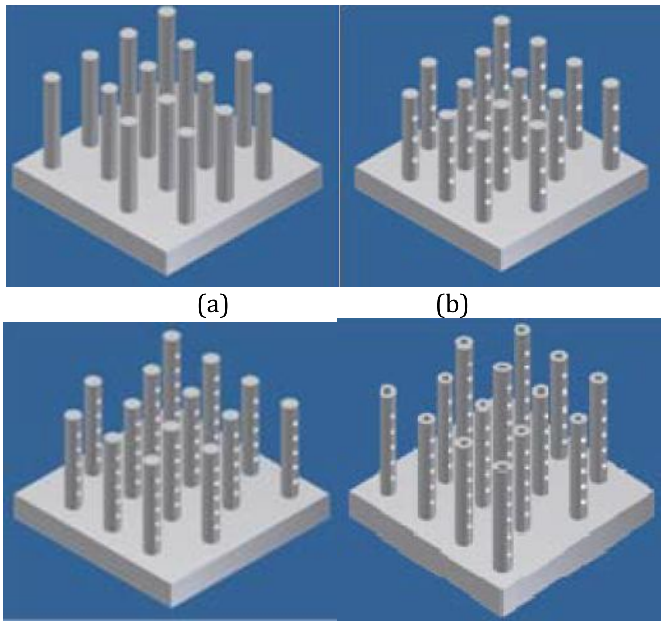


Fig-5: (a) Solid pin fin heat sinks. (b) Pin with three horizontal perforation (c) Pin with five horizontal perforations (d) Pin with horizontal and vertical perforation. [7]

G. Ganesh Kumar [8] studied combined conduction-mixed convection of pin-fins with uniform internal heat generation. They were compared four different cases such as solid pin with and without knurling, pin fin with four perforations and pin with single large perforation. It was observed that, knurled fin gives more heat transfer rate than that of a solid fin. They also found that, the variation of local temperature difference is more in free convection for hollow perforated pin fin compared to that the solid perforated pin fin.

Fig-6: Solid Pin fin [8]

Fig-7: Perforated Pin Fin [8]

R. Sam Sukumar et al. [9] studied heat transfer characteristics of heat sink with continuous and interrupted rectangular fins. Further they provide through holes on both rectangular fins and observed that interrupted fin with through holes gives better performance than interrupted rectangular fins of heat sinks.

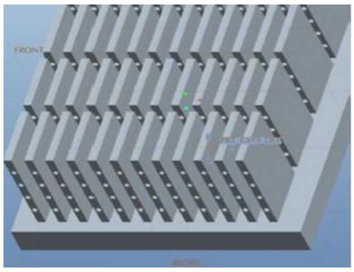


Fig-8: Interrupted rectangular fins with through holes.[9]

Amol B. Dhumne et al. [10] carried out heat transfer analysis of cylindrical perforated pin fins in a rectangular channel. The Reynolds number varied from 13,500–42,000, the clearance ratio 0, 0.33 and 1, the inter-fin spacing ratio as 1.208, 1.524, 1.944 and 3.417. They observed that the cylindrical perforated pin fins gives higher heat transfer than the solid cylindrical fins. The heat transfer enhancement depends on the clearance ratio and inter-fin spacing ratio of pin fin.

Raaid R. Jassem [11] studied effect of perforation on heat transfer rate. They have taken five fins and provide different shape of perforation on fins such as circle, square, triangle, and hexagon. They found that the temperature drop is higher for perforated fins than that of solid fins and fins with triangular perforation gives higher heat transfer.

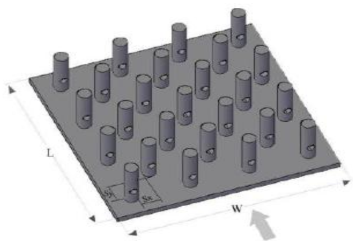


Fig-9: Base Plate with fins in staggered arrangement [10]

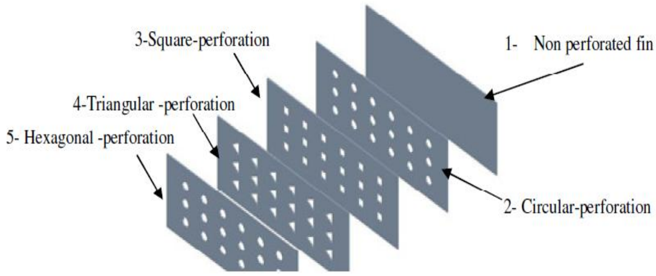


Fig-10: Plate fins with different shape of perforation. [11]

Bayram Sahin et al. [12] numerically investigated heat transfer and pressure drop performance of perforated fins with square cross section. They were kept clearance ratio constant(C/H=0) and varied the pin-fin spacing ratio in stream wise direction (Sy/D=1.208, 1.944 and 3.4) and the Reynolds number (Re=13.500, 27.500 and 42.000) .The height of fin was taken as 100 mm .All Square pin fins were perforated at a distance of 17 mm from the bottom of base plate with 8 mm diameter. They have observed that the lowest pin-fin spacing ratio of Sy/D=1.208 with clearance ratio of C/H=0 gives better cooling performance.

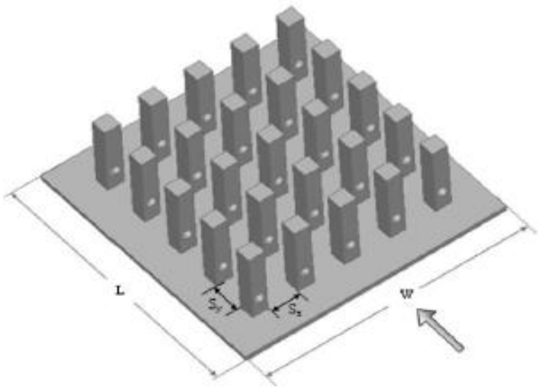


Fig-11: Square pin fin with single perforation. [12]

Ali Shakir Baqir et al. [13] studied staggered perforated pin fin array in a rectangular channel. They have compared HLV (horizontal, vertical, lateral) perforated pin fin with HV perforated and solid pin fin. They observed that the HLV perforated pin fin shows higher heat transfer and lower pressure drop than HV perforated and solid pin fin heat sink. The weight reduction for the HLV perforated pin fin is relatively higher than HV and solid pin fin.

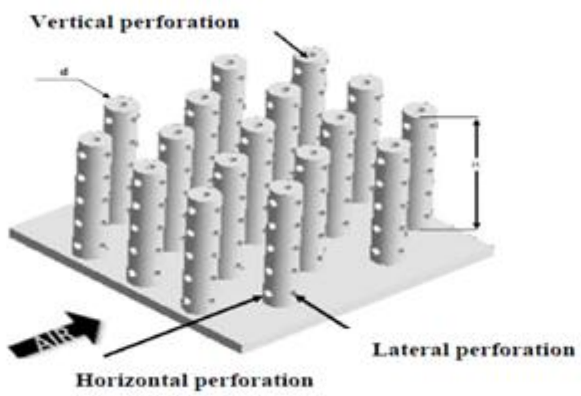


Fig-12: Pin fins with vertical, horizontal and lateral perforation. [13]

Kavita H. Dhanawade et al. [14] studied the square and circular perforated fin arrays in forced convection. They varied size of perforation as 6mm, 8mm and 10mm and range of Reynolds number from 21 x10^4 to 8.7 x10^4.They observed that square perforated fin array gives more heat transfer at low Reynolds number and the circular perforated fin array performs better at high Reynolds number.

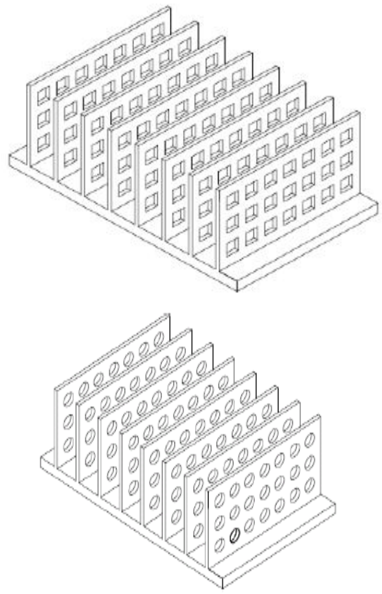


Fig-13: Square and circular perforated fin array respectively.[14]

Anusaya Salwe et al. [15] compared solid pin fin and perforated pin fin in forced convection. They varied the numbers of horizontal perforations and diameters of horizontal perforation on every pin-fin. They found that, Pressure drop for perforated pins was less compared to solid fins. The friction factor decreases with increasing number of perforation therefore perforated pin fins consume less pumping power than the solid pins for the same thermal performance.

Saurabh D. Bahadure, and G. D. Gosavi [16] carried out the thermal performance of a pin fin heat sink. In experiment, they varied the material of pin fin such as Aluminum, Copper and mild steel and number of perforation on pin fin from 1 to 3 respectively. The found that the material having higher thermal conductivity gives more heat transfer rate. The copper material shows higher heat transfer coefficient compared to aluminum and mild steel. The average heat transfer coefficient is higher for three perforations compared to solid, single, and two perforations respectively.

H. Saadat et al. [17] studied heat transfer from a perforated fin array with cross perforations. They have observed that cross perforation gives higher heat transfer than that of single direction perforation.

Murtadha Ahmed and Abdul Jabbar N. Khalifa [18] compared solid and perforated square pin fin heat sinks in natural convection. They found that the perforated pin fins gives better heat transfer than that of solid pins. The temperature drop across perforated pin fin was less than that of solid pin fins.

Umesh V. Awasarmol and Ashok T. Pise [19] studied the heat transfer characteristic of perforated fin array in natural convection by varying the diameter of perforation from 4-12 mm and angles of inclination form 0-90$^{0.}$ They observed that fins with 12 mm diameter of perforation shows greater heat transfer at an angle of 45$^{0.}$

Amer Al-Damook et al. [20] experimentally studied the effect of perforation on heat transfer and pressure drops characteristic. The five perforations were provided on pin fin. They found that, the Nusselt number increases with increase in number of pin perforations while at the same time reduced both the pressure drop across the heat sink and fan power needed to pump the air through them.

Vishvas S. Choure [21] studied heat transfer enhancement from perforated pin fin in staggered arrangement. The number of Perforation varied from one to five and diameter of perforation from 3 to 5 respectively. They have observed that pressure drop across the heat sink decreases with increasing number of perforation and diameter of perforation. The Nusselt number increases with increase in number of perforation and diameter of perforation.

M. S. Sundaram and M. Venkatesan [22] studied heat transfer of Perforated Fin in Forced Convection. They performed numerical analysis by varying different parameters such as diameter of perforation (2mm , 5mm, and 8mm), location of perforation (10mm, 20mm and 30mm)and number of perforations (1, 2 and 3). The heated pin fin was exposed to air at different velocities of 1.5, 3 and 5 (m/s). They observed that the temperature contour of perforated fin has lower base plate temperature than to a solid pin fin. The perforated pin fins with diameter 5 mm has maximum heat transfer and with further increase in diameter (d=8mm), there was a reduction in cross section area of pin fin heat sink

3. SUMMARY

1) Nusselt number increases with increasing number of perforations on pin fin heat sink.
2) The perforated pin fin having high heat transfer coefficient than solid pin fin.
3) The perforated pin fin is a light in weight compared to solid pin fin.
4) The perforated pin fin array is economical.
5) The heat transfer enhancement is depending on pin fin dimensions, the perforation geometry, and number of perforation and thermal conductivity of material.

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