Evaluation of the Effect of Different Shapes of Perforation Given in Heat Sink Fins on the Performance of Heat Sink

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Abstract – Heat sink is a device, which extract heat from the heat source and dissipate in to the environment. Many of the complex and compact electronic devices generate heat, which degrades its performance. So to improve the performance of device, it is necessary to maintain device at room temperature. For maintaining the temperature heat sink is used, which extract heat continuously from the heat source and maintain temperature in the permissible range. The performance of heat sink depends on the different process parameters. So to improve the performance of heat sink, here in this work effect of different shapes of perforated fins was analysed. For analysing the effect of different shapes of perforation on heat sink fins, it considered four shapes of perforation. Through analysis it is found that heat sink fins having circular perforation shows maximum heat transfer and lower thermal resistance as compared to other shape. After analysing the effect of different shapes of perforation, it also analysed the effect of arrangement of perforation that is in-line and staggered. After CFD analysis of heat sink, it is concluded that heat sink having circular staggered arrangement perforation have maximum heat transfer with lowest thermal resistance.

Keywords – Heat Sink, Perforation, Shapes, Thermal Resistance, Fins

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1. INTRODUCTION

Heat sink is an electronic digital component or simply a device of an electronic circuit which usually disperses heat via other parts (primarily coming from the power transistors) of a circuit into the neighbouring medium and so cools them for enhancing their very own effectiveness, consistency and also eliminates the early failure of the elements. For the cooling intention, it comes with a fan or chilling device. It is a passive heat exchanger which usually exchanges the heat provided by an electronic or a mechanical device to actually a fluid medium, quite often air or a liquid coolant, just where it is dissipated aside from the gadget, therefore permitting control of the device's temperature at best variants. In largely computer systems, heat sinks are applied to cool central processing units as well as graphics processors Heat sinks are employed with the high-power semiconductor devices just like power transistors and optoelectronics for example, lasers and light emitting diodes (LEDs), in which the heat dissipation potential of the component alone is deficient to limited its temperature.

Heat transfer from heat sink can be increase through different modification in the design of heat sink and fins. So in order to increase the heat transfer rate by increasing the turbulence in air while moving across the channel of fins. To increase the heat transfer from heat sink, here in these work perforations were given on fins of heat sink to increase the turbulence. And also analysed the effect of inline and staggered arrangement of perforations on the fins. For analysing the effect of different shapes of perforation on turbulence inside the channel of heat sink, here it considered four different shapes of perforation. For analysis of different shapes of perforation it considered circular, elliptical, rectangular and square shape having same cross section. For analysing the effect of change in velocity of air with change in shape of perforation, for each case of perforation three different air velocity cases were analysed.

2. DEVELOPMENT OF CFD MODEL OF HEAT SINK

For analysing the effect of different parameters on which the performance of heat sink depends, first it has to develop the CFD model of heat sink. For developing the CFD model first it has to develop the solid model of heat sink and then perform different processes.

2.1 Development of solid model

For performing CFD analysis it has to first develop the solid model of heat sink on the basis of geometrical parameters considered during experimental analysis performed by Yoon et.al[1]. Based on that parameters it develop the solid model, the geometric parameters of heat sink is Length of complete channel, Base thickness (t_b), Heat sink fin thickness, Total height of heat sink, Length and width of heat sink and Width of heat source is 450 mm, 8 mm, 3 mm, 50 mm, 150 mm and 60 mm. Based on the above geometric parameter solid model of heat sink developed. The solid model of heat sink is shown in the below fig.

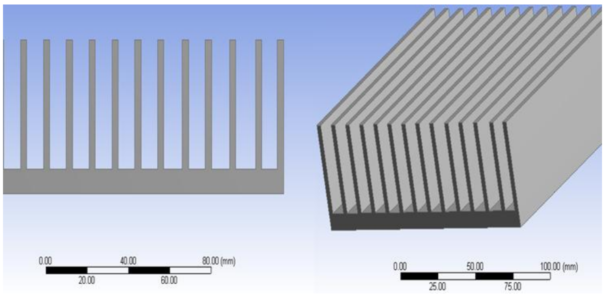

Fig.1 front view of heat sink

2.2 Meshing

For performing Numerical analysis, first complete body is discretized in to number of elements and node. Simulation work on the number of nodes and elements, mesh of the solid model of heat sink is shown in the below fig.

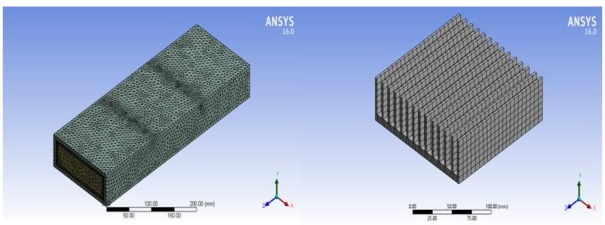

Fig.2 mesh of the solid model of heat sink

2.3 Boundary condition

During the analysis the velocity of air moving inside the domain vary from 2, 4 and 6 m/s, whereas the temperature of air at the inlet of domain is 25^0 C. heat sink inside the domain remain constant at a particular position. Whereas outer surface of domain act as a thermal insulator, and inside the domain no slip condition were applied. During the analysis the interface between heat sink and air were also considered as no slip condition. Heat generation at the chip were transfer to the heat sink at the base. Here in this work 100 W of heat is given to heat sink at a particular position.

3. VALIDATION OF CFD MODEL OF HEAT SINK

In order to validate the CFD model of heat sink, here in this work it considered aluminium alloy AA-6063 for the manufacturing of heat sink as considered during experimental analysis performed in the base paper. Other boundary conditions that are velocity of air, heat flux were considered same as considered in base paper. For analysing the effect of different velocity of air here in this work it considered three different velocity of air that is 2, 4 and 6 m/s.

3.1 For 2 m/s velocity

Here in this section air flowing inside the domain at the rate of 2 m/s, where as other boundary conditions were same as mention in the above section.

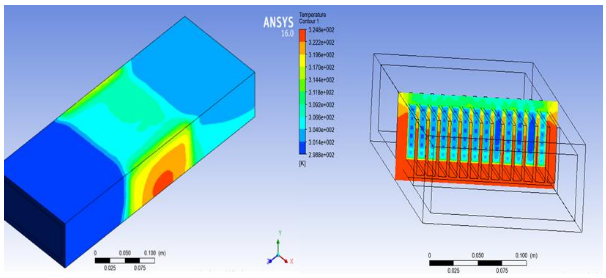

Fig.3 temperature contours for complete domain

Through above graph it is found that the value of temperature is higher at the base of heat sink and it is varying from base to top of the heat sink. The maximum temperature is achieved at the base of the heat sink which is measure numerically. After measuring the base temperature, with the help of equation 1 and 2, it calculates the value of thermal resistance and Nusselt number of heat sink at 2 m/s velocity of air.

$$R_{th} = \frac{T_b - T_\infty}{Q_h}$$

Where

T_b = Average base temperature of heat sink (°C)

T_∞ = Ambient (air) temperature (°C)

Q_h = Heat transfer rate (W)

R_{th}= Thermal resistance (°C/W)

$$R_{th} = \frac{(324.4347 - 273.16) - 25}{100}$$

R_{th} = 0.2628 ($°C/W$)

$$Nu = \frac{h_{avg} D_h}{k_a}$$

Where

Nu = Nusselt number

h_{avg} = average convective heat transfer coefficient (W/$m^2 k$)

k_a = thermal conductivity of air (W/m-k)

D_h = hydraulic diameter (m)

$$Re = \frac{\rho_a V_a D_H}{\mu_a}$$

$$3094 = \frac{1.1839 \times 2 \times D_H}{1.84 \times 10^{-5}}$$

D_H = 0.02404 m

$$Nu = \frac{14.55 \times 0.02404}{0.02624}$$

Nu = 13.33

Where

ρ_a = density of air (kg/m^3)

V_a = velocity of air (m/s)

D_H = hydraulic diameter of heat sink (m)

μ_a = viscosity coefficient of air (Pa-sec)

After calculating the value of thermal resistance numerically, it is then compare with the value of thermal resistance obtained from the base paper. The comparison of thermal resistance value is shown in the below table.

Table.1 Comparison of value of thermal resistance at different velocity of air

S. No.	Velocity (m/s)	From base paper thermal resistance (R_{th}) (°C/W)	For numerical analysis thermal resistance (R_{th}) (°C/W)	Error (%)
1	2	0.2615	0.2628	0.49
2	4	0.1665	0.1693	1.65
3	6	0.1280	0.1295	1.15

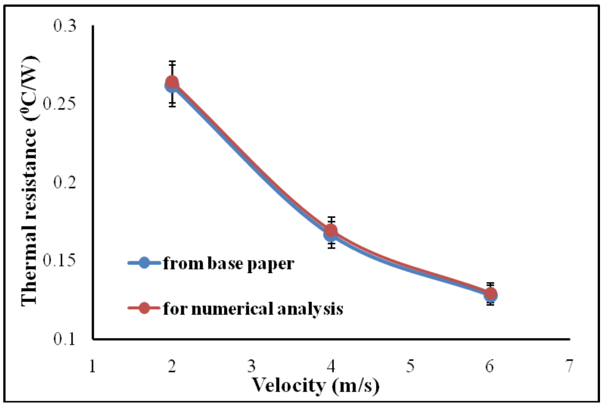

Fig.4 comparison of value of thermal resistance at different velocity of air for AA-6063 material

After calculating the value of thermal resistance, it also calculates the value of Nusselt number to measure heat transfer rate. For calculating the Nusselt number first it calculates the value of average heat transfer coefficient numerically and using this heat transfer coefficient and eq. 2, it calculates the value of Nusselt number for different velocity of air. Comparison of value of Nusselt number obtained numerically and from base paper.

Table 2. Comparison of value of Nusselt number

S. No.	Velocity (m/s)	From base paper Nusselt number (Nu)	For numerical analysis Nusselt number (Nu)	Error (%)
1	2	14	13.33	4.78
2	4	23.5	22.38	4.76
3	6	28.6	27.27	4.65

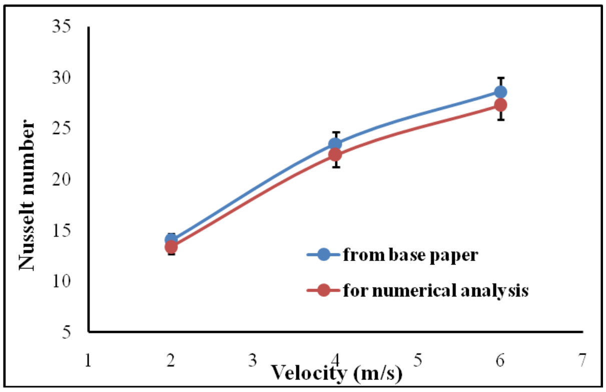

Fig.5 comparison of value of Nusselt number at different velocity of air

Through analysis it is found that the value of thermal resistance and Nusselt number measured through CFD analysis were near to the values obtained from the base paper. There is very less percentage of error were found at all velocity of air, which shows that the perform numerical analysis of heat sink is correct. Variation of Nusselt number and thermal resistance with respect to velocity of air measured numerically follows same trend as followed in base paper.

4. RESULT AND DISCUSSION

4.1 Effect of different perforation shapes

For analysing the effect of different shapes of perforation, here in this work inline perforation were make throughout the heat sink fins which is place inside the heat sink channel. Different shapes of perforation on heat sink fins were analysed in the below section.

4.1.1 For Rectangular shapes of perforation

Here in this case rectangular shape of perforations was created throughout the fins of heat sink. During analysis of heat sink having rectangular perforation, boundary conditions were remaining same as considered during the analysis of non-perforated heat sink. The solid model of heat sink having rectangular perforation is shown in the below fig.

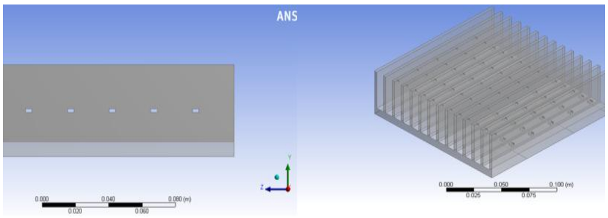

Fig.6 heat sink having rectangular perforation

After calculating the value of thermal resistance for each case of different shapes of perforation, it compares the value of thermal resistance for different shapes of perforation with respect to change in velocity of air at the inlet of channel.

5. COMPARISON OF THERMAL RESISTANCE AND NUSSELT NUMBER FOR DIFFERENT SHAPES OF PERFORATION

For finding the optimum shape of perforation given on heat sink fins, here it compares the value of thermal resistance and Nusselt number for different shapes of perforation at different velocity of air.

Table 3. Comparison of thermal resistance for different shapes of perforation

Velocity (m/s)	Thermal resistance for numerical analysis (°C/W)	Thermal resistance for rectangular perforation (°C/W)	Thermal resistance for square perforation (°C/W)	Thermal resistance for elliptical perforation (°C/W)	Thermal resistance for circular perforation (°C/W)
2	0.2638	0.3147	0.2670	0.2535	0.2451
4	0.1693	0.2596	0.2135	0.1621	0.1537
6	0.1295	0.2281	0.1847	0.1177	0.1082

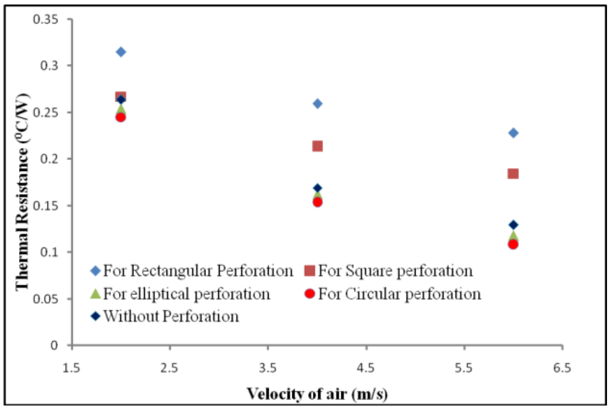

Fig.7 Comparison of thermal resistance for different shapes of perforation given on heat sink fins

From the above graph it is found that, for heat sink having circular perforation shows the lowest thermal resistance as compared to other shapes of perforations given on the heat sink fins. Whereas rectangular shapes of perforation on heat sink fins shows the highest value of thermal resistance as compared to other shapes of perforations.

Table.4 Value of Nusselt number for different shapes of perforation at different velocity of air

Velocity (m/s)	Nusselt number for numerical analysis	Nusselt number for rectangular perforation	Nusselt number for square perforation	Nusselt number for elliptical perforation	Nusselt number for circular perforation
2	13.83	12.43	13.34	14.10	14.48
4	22.50	14.22	18.71	23.11	24.31
6	27.51	24.62	25.49	29.82	32.90

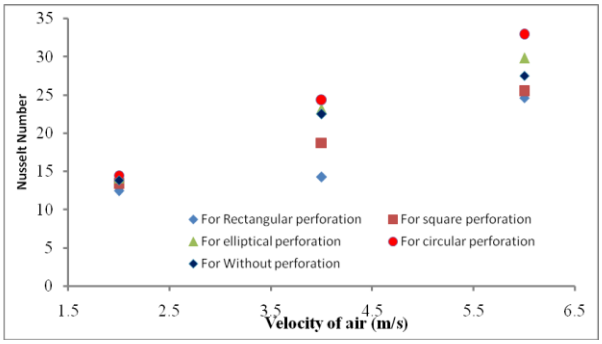

Fig.8 comparison of Nusselt number for different shapes of perforation

From the above graph it is found that for heat sink having circular perforation heat transfer is maximum as Nusselt number is higher for circular perforation as compare to other perforation and non-perforated heat sink. As lower velocity of air, there is very marginal variation in Nusselt number for different perforations. But as the velocity of air increases the variation in Nusselt number for different perforation varies significantly. So from the above results it is concluded that, heat sink having circular perforation shows the maximum heat transfer with lesser thermal resistance.

6. CONCLUSION

Through CFD analysis it is found that heat sink having perforation shows better heat transfer and lower thermal resistance as compared to non-perforated heat sink fins. Through analysis it is found that heat sink having circular perforation shows the highest Nusselt number as compared to other perforation shapes and non-perforated heat sink. Higher Nusselt number for circular shape perforation means, maximum heat transfer is taking place for heat sink having circular perforated fins and lowest thermal resistance. With change in velocity, it is found that change in variation of Nusselt number for different shapes of perforation at a particular velocity get varied. At lower velocity, variation in Nusselt number for different shapes of perforation is less as compared to change in variation at higher velocity. Through Numerical analysis it is found that, due to perforation on fins, turbulence in air gets increased with helps in increasing the performance of heat sink.So it is concluded that heat sink having circular perforated fins is the optimum heat sink for heat transfer application.

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