Increasing Efficiency of Heat Sink by the Using of Different Shapes of Perforation Given in Heat Sink Fins

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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*

INTRODUCTION:

This thesis intends to understand the phenomena of heat transfer enhancement in plate-fin heat sinks and its effects on fluid flow and heat transfer characteristics on various configurations of Pin Fin Heat Sinks. Heat transfer from micro channel heat sink is a relatively new development that has attracted the interest of engineers involved in the design of electronic systems. In this chapter, the role of heat sinks and jet impingement techniques to tackle today's electronic cooling problem are described briefly.

1.1 Thermal Management of Microelectronic Devices

In the present scenario of many advanced technologies, use of electronic equipment has become almost inevitable. These electronic equipment's play a vital role in many critical areas of technology and resulted in high density of components in small volume. Therefore, there has been a steady increase in heat dissipation rate from electronic components for the last few decades. As these devices consume electric power, this power needs to be dissipated or otherwise heat will be accumulated and temperature of device may exceed to dangerous levels. Figure 1.1 shows that major cause of electronic failures is temperature [Sivasankaran et al. (2010)]. The continuing increase of power densities in microelectronics and the simultaneous drive to reduce the size and weight of electronic products have led to the increased importance of thermal management issues in these applications. Over the time, the size and cost of typical electronic device has drastically decreased while the required functionality, reliability and operating temperatures have significantly increased. In addition, day by day the rate of automation is increasing significantly in all the fields, for example, today's average new automobile content is about 40% of electronics [Nielsen et al. (2012)]. The temperature at the junction of an electronics package (chip temperature) has become the limiting factor determining the lifetime of the package. The most common method for cooling packages is the use of passive heat sinks (Fig.1.2a) or active heat sinks (Fig.1.2b). Passive heat sinks used in natural convection applications where normal heat dissipation load is about 5 – 30 W, which are relatively simple, and their usage does not require external power.

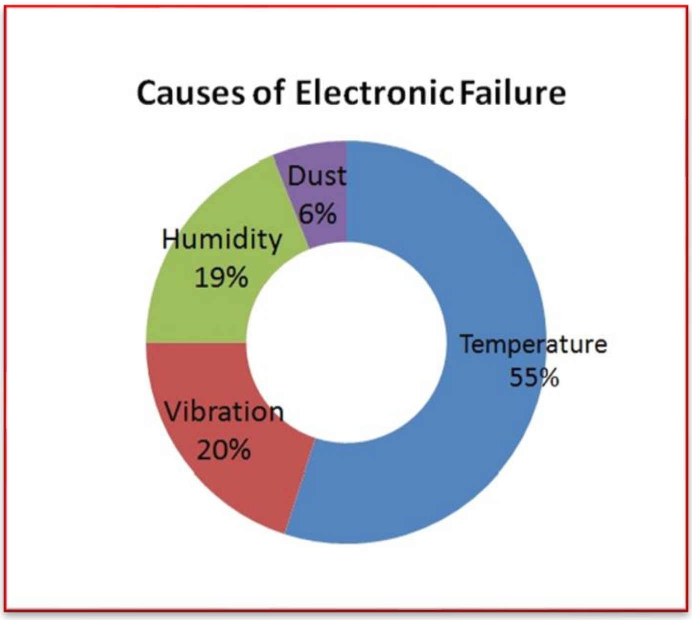

Fig.1.1: Major Causes of Electronic Failures (Ndao et al., 2009)

(a) Passive

(b) Active

Fig. 1.2: (a) Passive mode (b) Active mode

1.1.1 Need for Cooling of Integrated Circuits

Electronic equipment relies on the flow and control of electrical current to perform a fantastic variety of functions, in virtually every major industry throughout the world. Whenever electrical current flows through a resistive element, heat is generated in that element. An increase in the current or resistance produces an increase in the amount of heat that is generated in the element. The heat continues to be generated as long as the current continues to flow. As the heat builds up, the temperature of the resistive element starts to rise, unless the heat can find a flow path that carries it away from the element. If the heat flow path is poor, the temperature may continue to rise until the resistive element is destroyed and the current stops flowing. If the heat flow path is good, the temperature may rise until it stabilizes at a point where the heat flowing away from the element is equal to the heat generated by the electrical current flowing in the element.

1.2 Heat Sink

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.

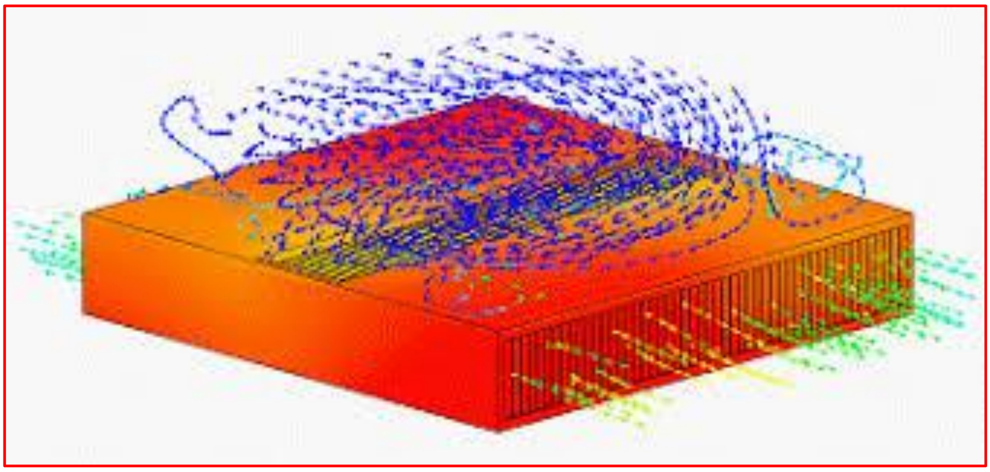

Fig. 1.3: Heat Sink

A heat sink is manufactured to improve its surface in touch with the cooling medium encircling it, like the fresh air. Air velocity, selection of material, protrusion style and surface area treatment are elements that affect the functionality of a heat sink. Heat sink add-on strategies and thermal user interface components also impact the die temperature of the integrated circuit. Thermal adhesive or thermal grease improve the performance of heat sink by stuffing air interruptions among the heat sink and the heat spreader on the device. A heat sink is commonly manufactured by copper or aluminium. Copper is employed since it has various suitable properties for thermally reliable and long lasting heat exchangers. Initially and primarily, copper is a superb conductor of heat. This represents that copper's great thermal conductivity permits heat to pass throughout it promptly. Aluminium heat sinks are employed as a cheap, light in weight replacement to copper heat sinks, and have a reduced thermal conductivity when compared to copper.

LITERATURE REVIEW

In later past years, the usage of various heat sinks has expanded the interest of engineers and researchers to simulate their issues with computational, experimental and numerical methods.

[1] Yoon et.al (2018) In his experimental paper, they have tested and analysed the radiative heat efficiency, depending on the position of the partial hot area. Numerical modelling simulations for forced convection were used to analyse the heat transfer between heatsink and the surrounding air. The best location of partial heat, which is discussed in terms of the impact of the total rate of heat transfer, air velocity, the ratio of total length of heat sink to the hot width surface of the heat sink, the thermal conductivity of the heat sink and the thickness of the base of heatsink. Based on this analysis, it is suggested that a relation would be developed by experiments to determine the best location for the heat. Therefore, it is possible to reduce the heat resistance of heat by 30% by finding the best position of the partial heating. The thermal efficiency is expected to be improved by changing the mounting position of the heating element on the radiation to make the electronics efficient.

[2] Hussain et.al (2019) In his paper, the investigation develops a computational fluid dynamics (CFD) model, validated through comparison with an experimental data from the literature, which demonstrates the effect of flow direction and fillet profile on the thermal performance of plate-fin heat sinks. In particular, a plate-fin heat sink with fillet profile subject to parallel flow has been compared with the conventional design (plate-fin heat sink without fillet profile subject to an impinging flow) and satisfactory results have been perceived. The results of this study show that the base temperature along with the thermal resistance of the heat sink is lower for the proposed design. Therefore, the developed approach has strong potential to be used to improve the thermal performance of heat sinks and hence to develop more advanced effective cooling technologies.

[3] Hasan et.al (2018) In his paper using of the phase change materials (PCMs) in a micro-channel heat sink (MCHS) is numerically investigated. The air is first used in heat sink and then four phase change materials (paraffin wax, neicosane, p116 and RT41) have been used as cooling mediums in different types and different configurations at different ambient temperatures. Constant heat flux is applied on the base of heat sink and mixed (convection and radiation) boundary condition is applied at the top surfaces of heat sink. The results showed that, using of the phase change materials in micro-channels heat sink with different configurations lead to enhance the cooling performance of micro heat sink. The phase change material should be selected according to its melting temperature according to the certain application as different phase change martials caused different values of reduction in heat sink temperature in range of ambient temperature due to difference in melting temperatures of PCMs. The cost of materials depends on the classification of the PCM (organic and inorganic) and quantity of PCMs used in a certain application

[4] Liao et.al (2017) In his paper, the thermal conductivity of the pin fin heat sink with the delta winglet vortex generators in the crossflow was tested numerically along with experimental setup. Impact of the Reynolds flow, the angle of attack of the vortex machine, the shortest distance between the vortex machine between the distance between each vortex generator and the heat sink of the vortex engine and the configuration of the vortex machine on the effect of radiation had been tested. The results suggest that the heat resistance decreases with increased Reynolds, but the size of the reduction decreases with Reynolds. The heat resistance produced at the shortest distance between the generators equal to the length of the radiation, is less than that obtained when the shortest distance between the vortex generators is greater than the length of the radiation. The heat transfer of this type of heat sink is high when the rotary generator is placed in the centre of sink on the both sides. Although increasing the height of the vortex engine can also increase the heat transfer, the pressure difference also increases. The thermal resistance of the heat sink with the vortex generators, which is arranged in the general stream, is lower than the sink in comparison with the heat generation of the vortex generators prepared in the overall stream.

[5] Jeon et.al (2016) numerous studies on heat transfer from natural convectors with radial heat sinks having perforated ring were applied here. Impact of the number of perforations (0-6), hole diameter (0-3 mm) and length of holes (1.5-6 mm) and directional angle (0-180) on the thermal efficiency were studied. The results revealed that radial heat sinks having a perforated ring undergone best thermal performance as compared with heat sink having imperforated rings. In case of the thermal resistance, the radial heat sink with reduced mass by 37% having optimized perforated ring had shown 17% decrement than that of imperforated ring. This can be set to unobstructed natural convective flow through the perforation.

RESULT AND ANALYSIS

During the analysis of heat sink, for calculating the value of thermal resistance occurs during heat transfer inside the heat sink some mathematical calculations were used on the basis of which the thermal resistance where calculated. The mathematical relation used for the calculation is given in below section [1]

Thermal Resistance

$$R_{th} = \frac{T_{b,avg} - T_\infty}{\dot{Q}_h} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where

$T_{b,avg}$= heat sink average base temperature

T_∞ = ambient temperature of air

$\dot{Q}_h$ = heat transfer rate

Here in this analysis, it calculates the value of heat transfer rate from numerical analysis and with the help of heat transfer rate it calculates the value of thermal resistance of heat sink.

Nusselt Number

For predicting the performance of different heat sink materials for better heat transfer, here it calculates the value of Nusselt number for different materials at different velocity of air. For calculating the value of Nusselt number following relation was used. The relation used for calculating the value of Nusselt number is

$$\mathrm{Nu} = \frac{h_{avg} D_h}{k_a} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where

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

D_h = hydraulic diameter of sink (m)

$D_h = \frac{2\,(s_f \times H_f)}{s_f + H_f}$……………….(3)

H_f = 42 mm

s_f = 16.84 mm

k_a = Thermal conductivity of air

Here the value of average heat transfer coefficient was calculated through numerical method.

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.

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 shown in the below table.

Table.4.1 Geometric parameters of heat sink

Parameters	values
Length of complete channel	450 mm
Base thickness (tb)	8 mm
Heat sink fin thickness	3 mm
Total height of heat sink	50 mm
Length and width of heat sink	150 mm
Width of heat source	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.

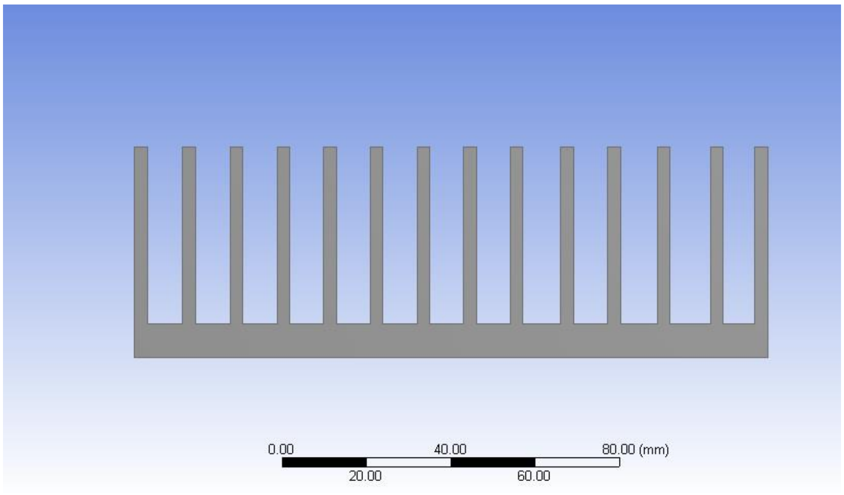

Fig. 3.1 front view of heat sink

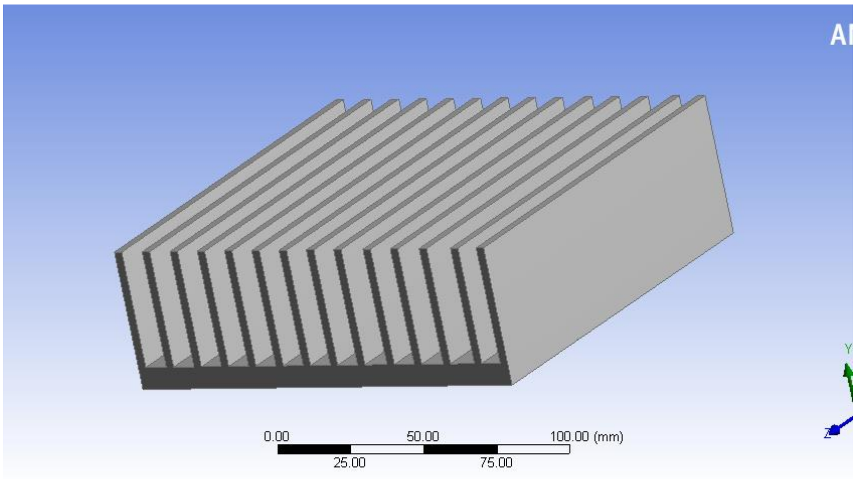

Fig.3.2 solid model of heat sink

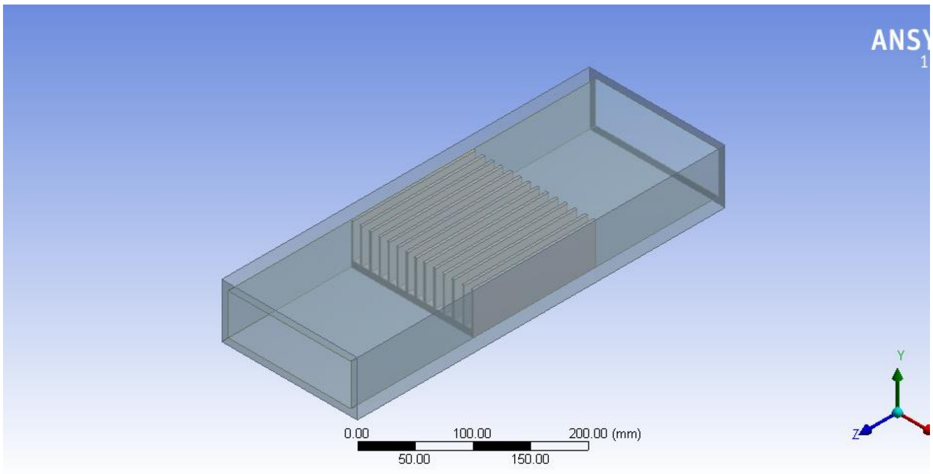

Fig.3.3 solid model of complete channel considered for the numerical analysis of heat sink

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.

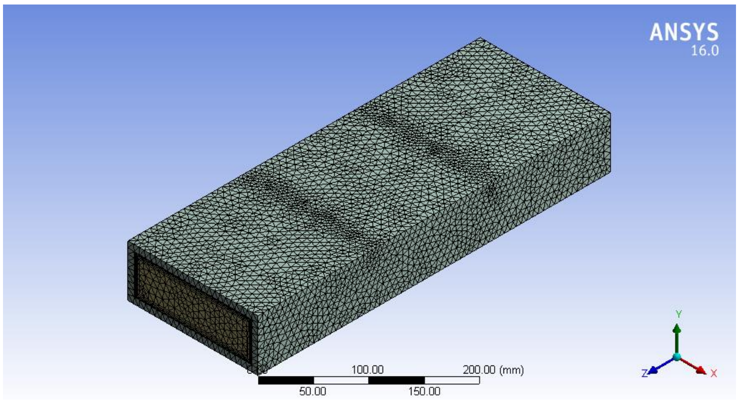

Fig.3.4 mesh of the solid model of heat sink

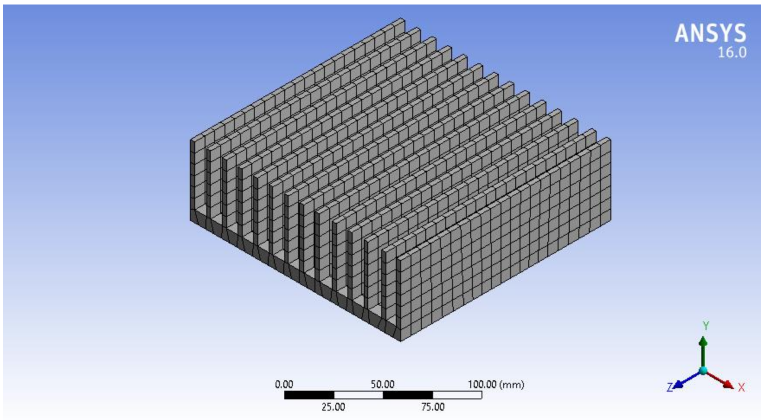

Fig.3.5 meshing of heat sink

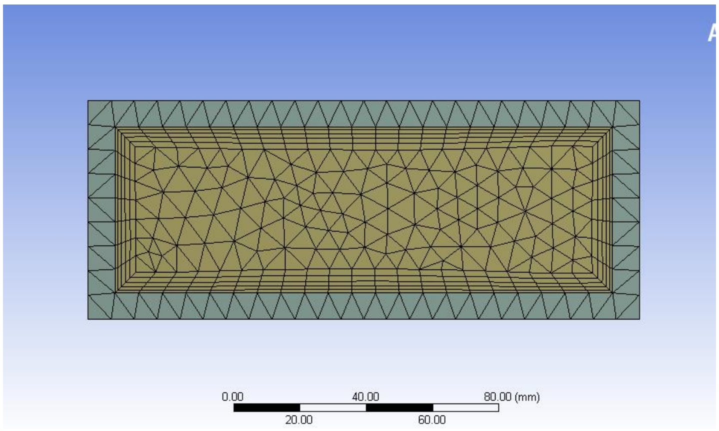

Fig. 3.6 shows the refinement of mesh used during numerical analysis

For getting good results it refines the mesh, in this work the solid model of heat sink is discretize in to 162699 number of element. The mesh having number of elements and nodes considered for analysis is shown in the below fig.

Statistics	
Nodes	58903
Elements	162699
Mesh Metric	None

Fig. 3.7 number of nodes and elements used for the numerical analysis

Name Selection

For applying different boundary conditions at different components and surfaces of channel, first name selection of different components and surfaces were performing. The name selection of different components of analysis channel is shown in the below fig.

4.3.3.1 Duct

For performing CFD analysis of heat sink, it consider duct in which heat sink is placed inside the duct. The cross sectional view of duct is shown in the below fig.

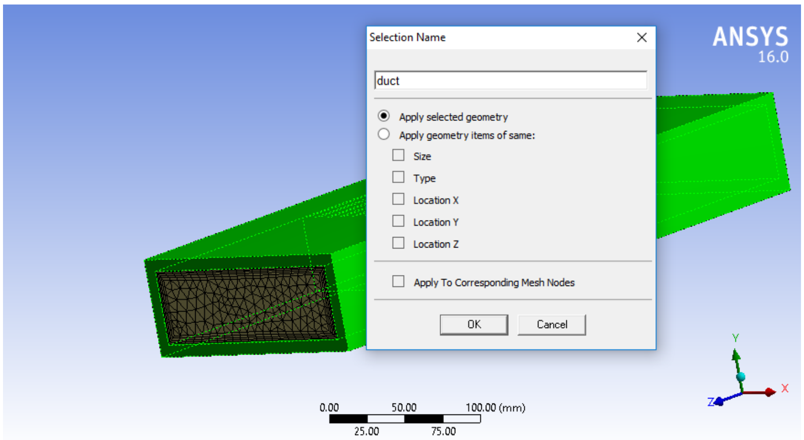

Fig.3.8 selection of duct during the analysis

Heat sink

Inside duct heat sink is placed wthrough which heat transfer is taking place. The name selection of heat sink is shwon in the below fig.

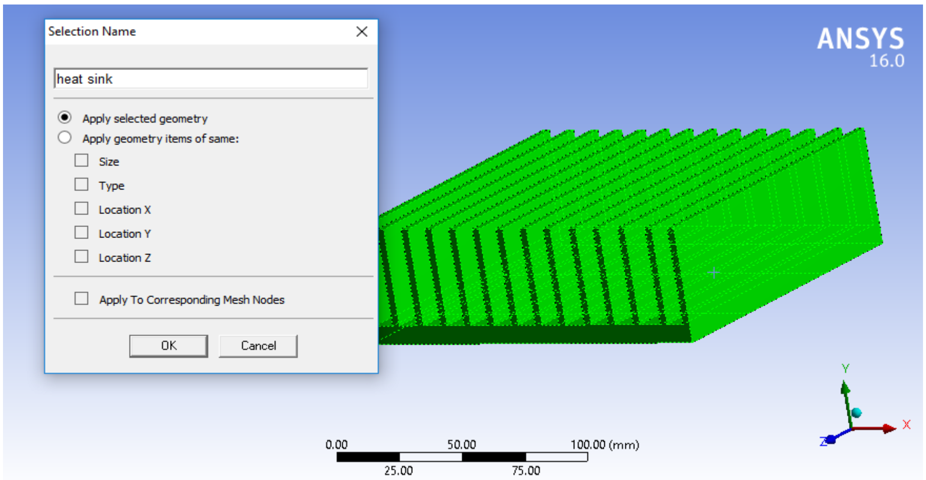

Fig.3.9 selection of heat sink

Air Inlet

Shows the selection of surface through which air is entering the channel

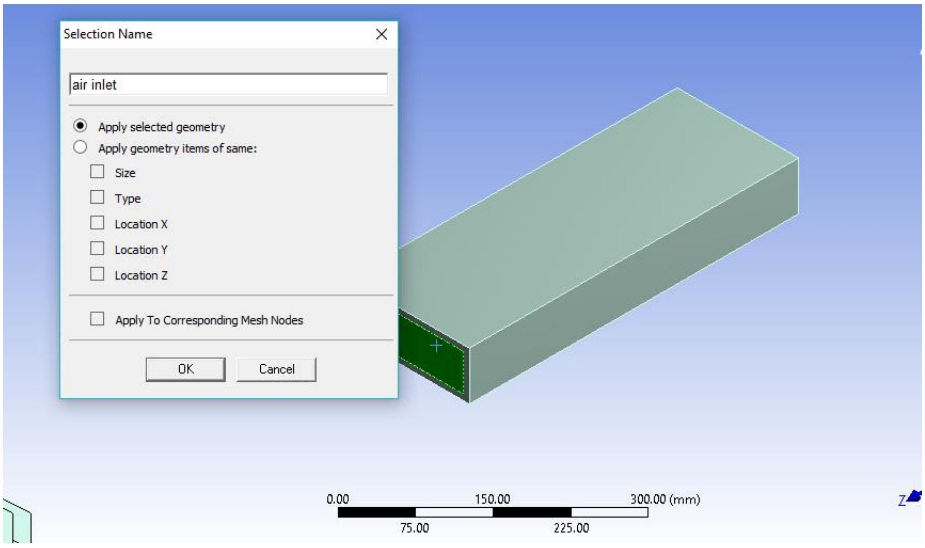

Fig.4.10 section of inlet of air

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