HEAT TRANSFER ANALYSIS ON BASE OF HEAT SINK WITH UNIFORM HEAT GENERATION

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Abstract - The present work describes the important results of problem of combined conduction, convection and radiation from a rectangular heat sink base subjected to uniform internal heat generation in its base. The governing equations for temperature distribution within the base are obtained by a relevant energy balance between rate of heat generation, heat conducted, convected and radiated. The derived non-linear partial differential equations are converted into algebraic form using finite difference method with 2nd order accuracy. The obtained algebraic equations have been solved simultaneously by Gauss-siedel iterative method with stringent convergence criteria and a C code has been written for above purpose. The computational domain has been discretized uniformly in all directions. A grid convergence test has been carried out to optimize the size of element. A complete parametric study has been carried out to study the effect of material of heat sink, regime of convection and role of radiation on local temperature distribution and maximum heat sink base temperature. It has been observed that material with high conductivity decreases the local temperature gradient and thus the maximum temperature. The regime of convection has a great influence on maximum temperature of heat sink with 15K of drop in $T_{max.}$ for a change in flow regime from free convection to forced convection. A special study on exclusive role of convection on maximum temperature reveals that one should not ignore the role forced convection in heat dissipation.

Key Words: Heat generation, Multimode heat transfer, Radiation

1. INTRODUCTION

Seyed et al. [1] conducted experimental analysis on cooling performance of mini channel heat sink with four different circular channels by using Nano fluid with replacing the pure water, for the parameters of Nusselt number, heat transfer coefficient, friction factor, and thermal resistance with the volume flow rate $(0.3\ to\ 1.5\ l/\min)$. Due to the presence of Nano particles the Nusselt number and heat transfer coefficients found to be increased and thermal resistance decreased with increase in volume flow rate. An experimental and numerical analysis on heat transfer characteristics of liquid cooling heat sink with micro pin fins was carried out by **Wang et al. [2]** with the geometric parameters diameter of micro pin fin and porosity of fin array with the heat flux 300kW/m^2 to estimate the flow patterns, effective thermal resistance. Due to increasing porosity of micro pin fin array and pin diameter, it was observed that flow rate is increased and more surface area occurs due to small pin diameter. **Ranjbar et al. [3]** performed Experimental and numerical investigation of circular mini channel heat sink with the length and width of 60 mm, height of 16 mm fabricated from aluminum material designed with four circular mini channels with volume flow rate(0.3to1.5 L/min) and numerical simulation is performed using Finite Volume Method. Due to high flow rate and increase in channel diameter, the pressure drop decreased and heat transfer coefficient increased. **Rajput et al. [4]** performed experimental, numerical and analytical studies with the purpose of optimization of geometrical fin parameters for heat sink of North Bridge based on natural convective heat transfer. In this Heat sink of the Northbridge used in IBM mother board has been optimized for more heat transfer and less weight using finite element analysis. The heat sink is mounted on the motherboard of IBM PC to dissipate heat. **Pawar et al. [5]** performed experimental analysis for high heat flux condition. The heat sink mounted on the hot component for cooling the component under forced convection. The CFD simulations are performed for optimization of heat sink parameters with objective of maximization of heat transfer coefficient. It is concluded that better configuration of a heat sink which can work smoothly even after the temperature inside the component exceeds the IGBT permissible temperature is found i.e. best optimised configuration of heat sink is found.

2. PROBLEM DESCRIPTION

In the present analysis heat sink study is performed for the conjugate convection and taking internal heat generation uniformly by taking two finned heat sink array into account for finding the local and maximum temperature distribution which hadn't implemented for the previous works. Figure shows the problem geometry consists of a rectangular base of size L×B with straight fins. Base of the heat sink is subjected to uniform volumetric heat generation (q_v). Thermal conductivity of the sink material is k. Air, at an ambient temperature(T_∞), is the cooling medium that offers the convection heat transfer coefficient h W/m^{2}K.

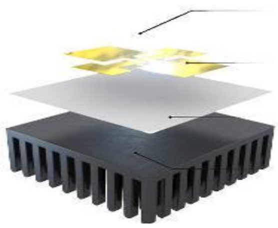

Fig.:1 Base of heat sink

The heat generated at the base of the sink is first conducted overall the base. The geometry is considered as two-dimensional object with x and y directions respectively. A computational domain is discretized uniformly in x and y directions. Governing equations are obtained by appropriate energy balance and are converted into algebraic form by finite difference method. Gauss-Siedel iterative technique has been adopted to solve the above equations. A computer code in C++ has been written to find the maximum temperature of the board and local temperature profiles.

3. METHODOLOGY

In order to establish temperature field within the heat sink, the governing equations are obtained by adopting an energy balance between internal conduction, convection. There exist nine different kinds of governing equations for heat sink base and for fins namely, interior nodes, Semi element on left, right, top, bottom, boundaries and all 4-corner quarter elements. The governing equations for temperature distribution of entire computational field are obtained by making energy balance of heat generation, conduction, convection and radiation.

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{q_v}{k}-\frac{h}{k}\left(T_{i,j}-T_\infty\right)-\frac{\sigma\varepsilon}{k}\left(T_{i,j}^4-T_\infty^4\right)=0 \qquad 1$$

$$\frac{\partial^2 T}{\partial x^2}-\frac{2}{\Delta y}\frac{\partial T}{\partial y}+\frac{q_v}{k}-\left(\frac{h}{k}+\frac{2h}{k\Delta y}\right)\left(T_{i,j}-T_\infty\right)-\left(\frac{\sigma\varepsilon}{k}+\frac{2\sigma\varepsilon}{k\Delta y}\right)\left(T_{i,j}^4-T_\infty^4\right)=0 \qquad 2$$

$$\frac{2}{\Delta x}\frac{\partial T}{\partial x}+\frac{2}{\Delta y}\frac{\partial T}{\partial y}+\frac{q_v}{k}-\left(\frac{h}{k}+\frac{2h}{k\Delta x}+\frac{2h}{k\Delta y}\right)\left(T_{i,j}-T_\infty\right)-\left(\frac{\sigma\varepsilon}{k}+\frac{2\sigma\varepsilon}{k\Delta x}+\frac{2\sigma\varepsilon}{k\Delta y}\right)\left(T_{i,j}^4-T_\infty^4\right)=0 \qquad 3$$

Table -1: Summary of grid convergence test with different nodes

S.No	Nodes		No. of elements M×N	Δx m	Δy m	T_m K
	M	N				
1	11	11	121	0.0065	0.005	395.5819
2	31	21	651	0.0022	0.0016	370.9855
3	51	31	1581	0.0013	0.0012	362.7686
4	81	41	3321	0.0008	0.0007	362.2577

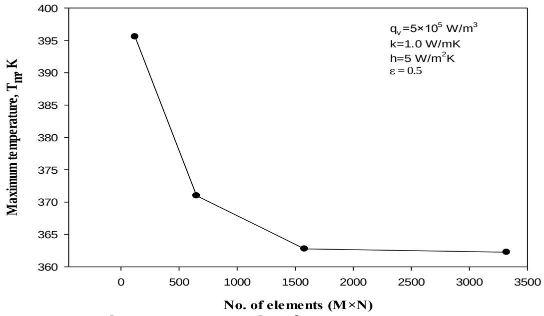

Fig.:2 A grid convergence with reference to maximum temperature

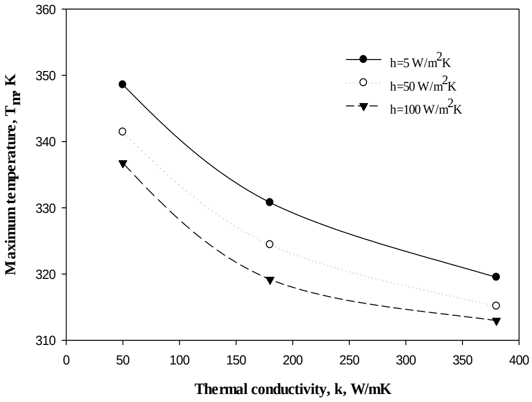

Fig.:3 Variation of maximum temperature of heat sink base with thermal conductivity for different values of convection heat transfer coefficient

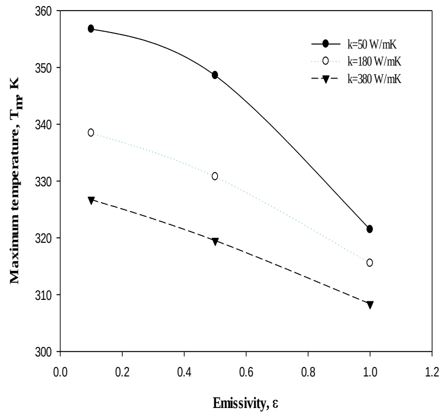

Fig.:4 Maximum temperature of heat sink base of emissivity for different heat sink materials.

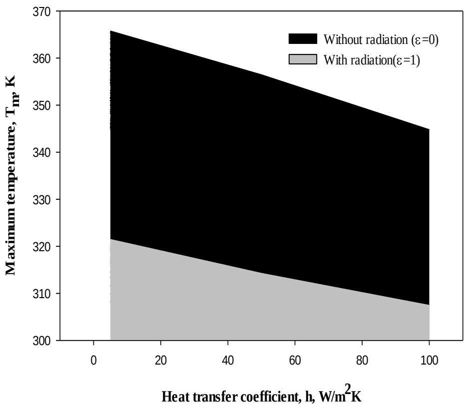

Fig.:4 Role of a radiation in entire regime of convection

4. CONCLUSIONS

1. The study of maximum temperature variation in different regimes of convection describes that there is a marginal drop in maximum sink temperature by transmitting the flow regime from free convection to forced convection. It has been observed a 15K drop in Tmax in the convection regime with a change in heat sink materials.
2. A study of exclusive role of radiation in keeping mind, the maximum base of heat sink temperature under control has been performed for two special cases namely with and without radiation. It concludes that in black body radiation, the maximum temperature is dropped by taking radiation into account. In a free convection regime to quantify, the Tmax.is dropped from 365K to 321K by considering the radiation. So, one should not neglect the role of radiation

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