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CFD ANALYSIS ON A HEAT SINK BY USING GRAPHENE

Vedulla Manoj Kumar[1], Sk.Farooq[2], P Hari Chandra Prasad[3]

[1,3]Pg Scholar, [2]Asst. Professor,Vignans University, Vadlamudi, Guntur, (India)

ABSTRACT

A heat sink is an electronic device made of good thermal conducting material and usually attached to an electronic device to dissipate the unwanted heat. The development of the digital computer and its usage day by day is rapidly increasing. But the reliability of electronic components is getting affected critically by the temperature at which the junction operates. As operating power and speed increases, and as the designers are forced to reduce overall systems dimensions, the problems of extracting heat and controlling temperature becomes crucial. In the last decade or so, CFD simulations have become more and more widely used in the studies of electronic cooling. In this paper the CFD simulation and Thermal analysis is carried out for heat sink with a commercial package provided by ANSYS-FLUENT. Here we are using graphene as a heat sink material because it has a number of properties which makes it interesting for several different applications. It is an ultimately thin, mechanically very strong, transparent and flexible conductor.

Keywords: Heat sink, CFD, Electronic cooling, ANSYS-Fluent, Graphene.

I. INTRODUCTION

Electronic equipment has made its way into practically every aspect of modern life, from toys and appliances to high-power computers. With this technology, these devices (electronic appliances and products) are capable of processing more data within a given period of time and the system performance is therefore regarded as higher. The larger the amount of data the system processes at a time, the greater the amount of heat it generates. The performance of these devices is directly related to the temperature; therefore it is a crucial issue to maintain the electronics at acceptable temperature levels. The rising demand for high performance and multiple functionality in electronic systems and devices continue to be the current great challenges in their thermal management.

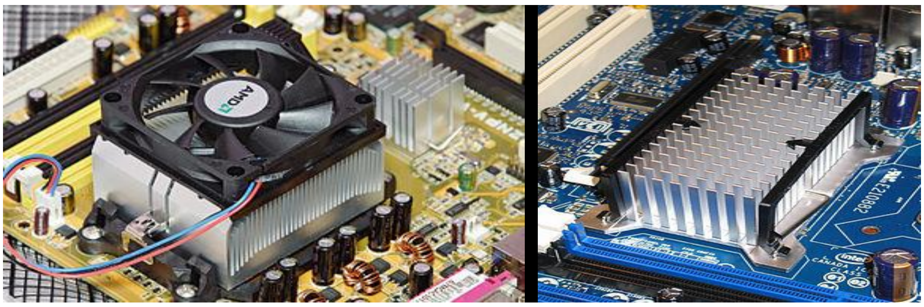

Fig (1). Active and Passive Heat Sinks

Most electronic devices operate for long periods of time, and thus their cooling mechanism is designed for steady operation. But electronic devices in some applications never run long enough to reach steady operation.

In such cases, it may be sufficient to use a limited cooling technique, such as thermal storage for a short period, or not to use one at all. Transient operation can also be caused by large swings in the environmental conditions. A common cooling technique for transient operation is to use a double-wall construction for the enclosure of the electronic equipment, with the space between the walls filled with a wax with a suitable melting temperature. As the wax melts, it absorbs a large amount of heat and thus delays overheating of the electronic components considerably.

The heat sink operation is based on Fourier's law of heat. Whenever a temperature gradient exists in a body, heat transfers from the high temperature sections to the lower temperature areas. The three different ways in which the heat can be transferred are through radiation, convention or by conduction. Thermal conduction occurs whenever two objects at different temperatures are in contact. This involves the collisions between the fast molecules of the hotter object with the slow moving molecules of the colder object. This leads to the energy transfer from the hot object to the cooler object. A heat sink thus transfers the heat from the high temperature component such as a transistor to the low-temperature medium such as air, oil, water or any other suitable medium through conduction and then convection.

II. LITERATURE REVIEW

R.Mohan et.al [1] has performed Experimental and theoretical investigations of the thermal performance of a variety of heat sinks have been made. The different kind of heat sinks were investigated. The parameters such as fin geometry, fin pitch and fin height are optimized primarily in this paper and a second task is carried out to optimize base plate thicknesses, base plate materials and modify design of heat sink for improving the thermal performance in the next generation. In this research work, the best heat sink geometry is selected and modified in order to reduce maximum temperature distribution and hot spots of heat sink at center by changing the geometry design and adding one more base. They were observed that flow obstructions in the chassis and the resulting air recirculation affect the heat sink temperature distribution.

Carlos A. Rubio-Jimenez et.al [2] has proposed a novel micro pin fin heat sink configuration with variable fin density is proposed and analyzed. This configuration offers a reliable cooling system capable of dissipating high heat fluxes at a low pressure drop while maintaining uniform junction temperature.

D. B. Tuckerman et.al [3] explored the pioneering concept of micro channel heat sink. They used micro channels that had a width of 50 μm and a depth of 302 μm and showed that high heat rates of 790 W/cm2 could be removed by silicon micro channel heat sinks using water as the cooling fluid through the micro channel.

Mathias Ekpu et.al [5] proposed an ideal heat sink material exhibits high thermal conductivity, low coefficient of thermal expansion, low density, and low cost. Based on this four selection criteria, AI/SiC has superior property potentials and it is recommended as a near optimum material for a laptop computer heat sink.

Denpong Soodphakdee et.al [7] proposed the heat transfer performance of various commonly used fin geometries is compared. In all cases, staggered geometries perform better than inline. At lower values of pressure drop and pumping power, elliptical fins work best. At higher values, round pin fins offer highest performance.

III. IDENTIFICATION OF PROBLEM

In the cooling enhancement of current electronic industry, heat sink is extensively used to provide cooling function for electronics components. The most common method for cooling electronic devices is by finned heat sinks made of aluminum. These heat sinks provide a large surface area for the dissipation of heat and effectively reduce the thermal resistance. In order to design an effective heat sink, some criterions such as a large heat transfer rate, a low pressure drop, an easier manufacturing, a simpler structure, a reasonable cost and so on should be considered. Unfortunately, heat sinks often take up much space and contribute to the weight and cost of the product. Consequently, the need for new design and more effective ways to dissipate this energy is becoming increasingly urgent. Thus, high performance of heat sinks can be acquired through the design optimization which maximizes heat transfer and minimizes pressure drop. To achieve an optimum design of heat sink for an effective heat transfer a newer methodologies is to be identified for desirable heat sink.

IV. AIMS AND OBJECTIVES

The following are the aims and objectives of the Project

- To study of new material i.e., graphene as a heat sink material
- To compare the total heat transfer rate of passive heat sink with industrial heat sinks and experimental heat sinks.

V. METHODOLOGY

This research paper investigates a well-known commercial application solved by CFD technique by modeling and analyzing the cooling of a heat sink. For that there is a need of new design with a base plate material and different compositions to enhance the rate of heat transfer and efficiency of a heat sink and this can be comparing with experimental data. An investigation will be made regarding the temperature and pressure distribution profiles occurred when certain thermal considerations are applied. Position, geometrical characteristics and the number of fins will be altered to study the thermal effects.

In CFD calculations, there are three main steps: Pre-Processing, Solver Execution, Post-Processing. Pre-Processing is the step where the modelling goals are determined and computational grid is created. In the second step numerical models and boundary conditions are set to start up the solver. Solver runs until the convergence is reached. When solver is terminated, the results are examined which is the post processing part.

CFD analysis

Governing equations

The following assumptions are made for the numerical simulation of fluid flow and heat transfer in the unit cell: Steady state fluid flow and heat transfer; Laminar flow; Incompressible fluid; Negligible radiation heat transfer; Constant solid and fluid properties. Based on these assumptions, the governing differential equations for fluid flow and heat transfer in the unit cell are solved by Autodesk® Simulation CFD. For the liquid region, the governing equations are continuity equation, Navier Stokes or momentum equations, and energy equation. For solid region, the only governing equation is the energy equation.

Navier-Stokes Equation Applying the mass, momentum and energy conservation, we can derive the continuity equation, momentum equation and energy equation as follows.

Continuity Equation

$$\frac{D\rho}{Dt} + \rho \frac{\partial U_i}{\partial x_i} = 0$$

Momentum Equation

$$\underbrace{\rho \frac{\partial U_j}{\partial t}}_{I} + \underbrace{\rho U_i \frac{\partial U_j}{\partial x_i}}_{II} = \underbrace{-\frac{\partial P}{\partial x_j}}_{III} - \underbrace{\frac{\partial \tau_{ij}}{\partial x_i}}_{IV} + \underbrace{\rho g_j}_{V}$$

Where

$$\tau_{ij} = -\mu\left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right) + \frac{2}{3}\delta_{ij}\mu\frac{\partial U_k}{\partial x_k}$$

I: Local change with time

II: Momentum convection

III: Surface force

IV: Molecular-dependent momentum exchange (diffusion)

V: Mass force

Energy Equation

$$\underbrace{\rho c_\mu \frac{\partial T}{\partial t}}_{I} + \underbrace{\rho c_\mu U_i \frac{\partial T}{\partial x_i}}_{II} = \underbrace{-P\frac{\partial U_i}{\partial x_i}}_{III} + \underbrace{\lambda \frac{\partial^2 T}{\partial x_i^2}}_{IV} - \underbrace{\tau_{ij}\frac{\partial U_j}{\partial x_i}}_{V}$$

I : Local energy change with time

II: Convective term

III: Pressure work

IV: Heat flux (diffusion)

V: Irreversible transfer of mechanical energy into heat

To simplify the Navier-Stokes equations, we can rewrite them as the general form.

$$\frac{\partial(\rho\Phi)}{\partial t} + \frac{\partial}{\partial x_i}\left(\rho U_i \Phi - \Gamma_\Phi \frac{\partial \Phi}{\partial x_i}\right) = q_\Phi$$

When $\Phi = 1, U_j, T$, we can respectively get continuity equation, momentum equation and energy equation.

Boundary conditions

- Base plate, fins : Graphene properties are assigned
- Base top wall : heat flux is applied [100w/cm2]
- Fin bottom, front face, left, right, rear faces (walls)
- Heat transfer to surroundings atmosphere by convection.
- Inlet (velocity inlet) : air enters into the heat sink with 10-12 m/s
- Outlet : Outlet atmospheric pressure is assigned

The properties of the solid and fluid are assigned the default values in Ansys-Fluent 2015.

Meshing and solving

As mentioned earlier, the commercial CFD code, ANSYS-FLUENT 2015 is used for the numerical simulation. Unstructured mesh is used for meshing the physical model. Autodesk® Simulation CFD employs finite element method for discretizing the governing partial differential equations together with the boundary conditions. The result is a set of algebraic equations at discrete points or nodes on every element of the computational domain. The resulting set of algebraic equations is solved to determine the values of the dependent variables at the nodes on the finite elements.

Validation of numerical result

In order to check the validation of the results, we are comparing simulation result with experimental result.

Modelling of a heat sink

Design Specifications of heat sink

Length - 45 mm, Height - 53 mm, Fin height - 40 mm, Spacing between fins horizontal - 5 mm

Spacing between fins vertical - 5 mm, Number of fins – 35.

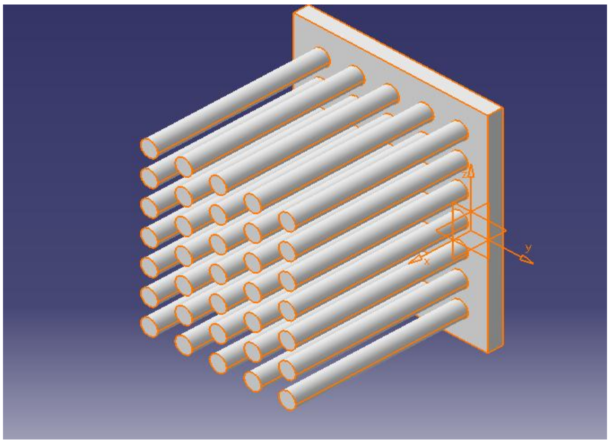

Fig (2) .Geometry of Circular pin fins heat sink

TABLE 1: Comparison analysis of different materials for heat sink

S. No	Material	Thermal conductivity-W/mK	Coefficient of thermal expansion 1O-6K-1	Density Kg/m3	Ref
1	Aluminium	220	22-24	2700	[10]
2	SiC/Aluminium	170 – 220	6.2-7.3	3000	[10]
3	Boron/Aluminium	145	13-15	2700	[10]
4	Copper	400(390)	16-17	8960	[10]
5	Cu-coated Graphite/Cu	>400	2.8-3.5	5300	[10]
6	Copper/Tungsten	180-200	6.5-8.3	10080	[10]
7	Copper/Molybdenum	170-210	5.7-6.0	8400	[11]
8	Gold	315	14	19.32	[11]
9	Molybdenum	142	4.9	10.22	[11]
10	Tungsten	155	4.5	19.3	[11]
11	Diamond	2000	0.9	3.51	[11]
12	Beryllium oxide	260	6	3	[11]
13	Aluminium nitride	320	4.5	3.3	[11]
14	Silicon carbide	270	3.7	3.3	[11]
15	Graphene	5300	0.00035	2.2	[16]

VI. RESULTS AND DISCUSSIONS

From this comparison analysis of different heat sink materials we should come to know that graphene is having highest thermal conductivity, low density and low coefficient of thermal expansion so that this material is best suitable as the heat sink material because the mobility of graphene is very high which makes the material very interesting for electronic high frequency applications.

VII.CONCLUSION

Graphene is the fascinating material and this material can be applicable for other applications also and the development of this new material opens new exiting possibilities. It is the first crystalline 2D-material and it has unique properties, which makes it interesting both for fundamental science and for future applications.

VIII. FUTURE SCOPE

Graphene can be used in applications such as touch screens, light panels and solar cells, where it can replace the rather fragile and expensive Indium-Tin-Oxide (ITO). Flexible electronics and gas sensors are other potential applications. The quantum Hall effect in graphene could also possibly contribute to an even more accurate resistance standard in metrology. New types of composite materials based on graphene with great strength and low weight could also becoming interesting for use in satellites and aircrafts.

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