CFD & Thermal Analysis of Heat Sink and its Application in CPU.

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Abstract—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 with a commercial package provided by ANSYS-FLUENT. The geometric parameters and design of heat sink for improving the thermal performance is experimented. This paper utilizes CFD to identify a cooling solution for a desktop computer, which uses a 5 W CPU. The design is able to cool the chassis with heat sink attached to the CPU is adequate to cool the whole system. This paper considers the circular cylindrical pin fins and rectangular plate heat sink design with aluminium base plate and the control of CPU heat sink processes.

Keywords—Computational Fluid Dynamics (CFD), CPU Cooling, Pin Fins, Heat Sink, Rectangular Plates, Thermal Analysis.

I. INTRODUCTION

Today’s rapid IT development like internet PC is capable of processing more data at tremendous speed. This leads to higher heat density and increased heat dissipation, making CPU temperature rise. CFD is gaining popularity especially as a decision support tool for the product design process. Even a decade ago, commercial CFD software packages were rarely used for heat transfer analysis, owing to lack of tools or a lack of details for heat transfer in them. Especially, analyzing conduction and radiation together with convection was not possible. Currently, all popular CFD software packages have tools for handling coupled conduction, convection and radiation problems.

Most of the commercial CFD packages in the market today include supplementary tools for electronic cooling applications. As the software gets more complex, these front end or preprocessing tools become more useful in modelling.

The seemingly simplified and quicker modelling process sometimes may have hidden weaknesses that the user may not be aware of. This research stands to the challenges posed by increasing chip heat flux, smaller enclosures and stricter performance and reliability standard. In this paper, the heat sink with base plate, proper vents for air flow are designed and implemented for better performance. In this study, various geometry heat sink with base plate is used to cool CPU’s. Computational Fluid Dynamic Analysis and Thermal Analysis of heat sink i.e. pin fins as well as rectangular fins.

II. LITERATURE SURVEY

[1] Deepak Gupta, Momin Nausheen, A.D. Dhale, “CFD Analysis & Simulation of Pin Fin for Optimum Cooling of MotherBoard”, IEDR, Volume 2, Issue 2, 2014 2321-9939. As day by day our work load is increasing and hence our use of computers are increasing which leads to increase in heat and hence consequence is sabotage of computer with our work. So it’s a great challenge to packaging engineers to remove the heat generated by the chip efficiently. Many researches are going on in this direction for the past few decades. In the last decade or so CFD simulations have become more and more widely used in studies of electronic cooling. Validation of these simulations has been considered to be very important. The computational fluid dynamics is concentrated on the natural air cooling of the CPU using a heat sink.

[2] R. Mohan and Dr. P. Govindarajan, “Thermal analysis of CPU with composite pin fin heat sinks”, International Journal of Engineering Science and Technology, Vol. 2(9), 2010, 4051-4062. The computational fluid dynamics is concentrated on the forced air cooling of the CPU using a heat sink. This paper utilizes CFD to identify a cooling solution for a desktop computer, which uses an 80 W CPU. In this study a complete computer chassis with different heat sinks are investigated and the performances of the heat sinks are compared.
III. METHODOLOGY

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.

The viscous dissipation term is omitted. Therefore, the governing equations for the fluid flow and heat transfer are the following form of the incompressible continuity equations, Navier – stokes equations x-y and z direction momentum, and energy equations together with the equation of state.

Governing Equations:
The continuity Equation
\[ \nabla \cdot \rho \nabla = 0 \]

The X, Y, Z Momentum Equations
\[ \nabla (\rho \mathbf{v}) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} + \beta_x \]
\[ \nabla (\rho \mathbf{v}) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial z} + \beta_y \]
\[ \nabla (\rho \mathbf{v}) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + \beta_z \]

The Energy Equation
\[ \nabla (\rho h \mathbf{v}) = -p\nabla \mathbf{v} + \nabla (kT) + \Phi + S_h \]

Where \( \rho \) is the fluid density, \( \mathbf{v} \) is the fluid velocity vector, \( \tau_{ij} \) is the viscous stress tensor, \( p \) is pressure, \( \beta \) is the body forces, \( t \) is time, \( \Phi \) is the dissipation term, \( h \) is the total enthalpy, \( u, v \) and \( w \) are velocity components, \( \nabla \) is the velocity vector.

A. Computer Chassis

The computer chassis consists of inlet which allow air for cooling and discharges hot air through outlet.It also consists of printed circuit board(PCB), heat source, and heat sink with base plate.

B. PCB:

A printed circuit board (PCB) mechanically supports and electrically connects electronic components. PCBs require the additional design effort to lay out the circuit but manufacturing and assembly can be automated.

Manufacturing circuits with PCBs is cheaper and faster than with other wiring methods as component are mounted and wired with one single part. Furthermore, operator wiring errors are eliminated.

The PCB is made of material “Board”

Density = 1250kg/m\(^3\); \( C_p = 1300 \) J/kg K; Thermal conductivity 0.35 W/m K..

C. Heat source:

We need to set the thermal power (5W) dissipated by this component. The heat source volume is 4.332x10-6 m\(^3\). Hence, the volumetric source is 1154201 W/m . Create 1 constant energy source with the above value.

The HeatSource is made of material “Component”

Density = 1250kg/m\(^3\); \( C_p = 1300 \) J/kg K; Thermal conductivity 10 W/m K.

D. CPU heat sink:

The most important object in the computer chassis is the heat sink various model have been created for the investigation of cooling characteristics of different heat sink in every model, only the heat sink geometry is changed. All the other objects remained unchanged this is most complicated object of all model. Therefore it takes more time to create this geometry since there is no CAD geometry available ,some model are created by measuring the dimension of the actual heat sink and or by using the dimension given by the manufactures. Heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool central processing units or graphics processors. A heat sink transfers thermal energy from a higher temperature device to a lower temperature fluid medium. The fluid medium is air.

The Heat sink is made of material “Aluminum”

Density = 1250kg/m\(^3\); \( C_p = 1300 \) J/kg K; Thermal conductivity 220 W/m K.
IV. RESULTS AND CALCULATION

A. Thermal Analysis of Heat Sink

Fig 1. Mesh of cylindrical pin fins

Fig 2. Temperature Distribution of cylindrical pin fins

Fig 3. Heat Flux Distribution of cylindrical pin fins

Fig 4. Mesh of rectangular plates

Fig 5. Temperature Distribution of rectangular plates

Fig 6. Heat Flux Distribution of rectangular plates

Fig 1, 2, 3, 4, 5, 6 Shows a results of Thermal Analysis which was carried out using Ansys after applying all the parameters such as boundaries condition as temperatures and convection. To be more clear about its results let us see its application in CPU and its total heat dissipation.
B. CFD Analysis of Heat Sink in CPU

A figure below shows a geometry of CPU which includes PCB, Heat Source, Heat Sink such as cylindrical pin fins i.e. 100 pin fins. This geometry was created in catia and then imported to ANSYS-Fluent in its format. After applying a unstructured fine mesh and then applying all the above given boundary conditions and parameters we got its corresponding post processing results and total heat transfer rate.

Fig 7. Geometry of CPU with cylindrical pin fins

A figure below shows a geometry of CPU which includes PCB, Heat Source, Heat Sink such as rectangular plates. This geometry was created in catia and then imported to ANSYS-Fluent in its format. After applying a unstructured fine mesh and then applying all the above given boundary conditions and parameters we got its corresponding post processing results and total heat transfer rate.

Fig 8. Geometry of CPU with rectangular plates

Fig 9. Converging Graph and Calculation

An above figure shows a converging graph and calculation of cases that has been solved in this paper. 225 iteration were taken with the help of above three governing equations such as continuity equation, momentum equation in the form of velocity in x, y, z direction and energy equation. Taking flow as laminar and applying all boundaries conditions to the parameters the post processing results got is shown below.

Fig 10. Postprocessing result of cylindrical pin fins in CPU

Fig 11. Postprocessing result of rectangular plate fins in CPU
TABLE 1
Results and their comparison

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Results and Comparison</th>
<th>Heat Sink</th>
<th>Number of fins within same dimension</th>
<th>Total Heat Transfer rate in W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Cylindrical pin Fins</td>
<td>100</td>
<td>8.046</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Rectangular plates</td>
<td>14</td>
<td>13.47</td>
</tr>
</tbody>
</table>

From above table we can conclude that total Heat Transfer rate of rectangular plates fins is greater than cylindrical pin fins with applying same dimensions and boundaries condition.

REFERENCES