Comparative assessment of a temperature distribution into different CPU coolers

DUMITRU CAZACU
Electrical Engineering Department
University of Pitesti
1 Targul din vale, 110040, Pitesti, jud Arges
ROMANIA
cazacu_dumitru@yahoo.com

Abstract: - In this paper the temperature distribution in two CPU sink devices is evaluated using the finite element method. The influence of the geometry, heat power dissipated by the CPU, heat sink materials, fan speed and environment temperature are evaluated.

Key-Words: - CPU heat sink, finite element method

1 Introduction

Heat generated by electronic devices must be dissipated to improve reliability and prevent premature failure. Techniques for heat dissipation can include heat sinks and fans for cooling. Heat sinks are widely used in electronics and have become essential to modern CPUs. In common sense, it is a metal object in contact with an electronic component having high temperature. In many cases there is a thin thermal interface material between the two surfaces. Microprocessors and power handling semiconductors are examples of electronic devices that need heat sink for heat dissipation, primarily by convection and conduction. A heat sink usually consists of a metal structure with one or more flat surfaces to ensure good thermal contact with the components to be cooled and an array of fins to increase the surface contact to the air and so the rate of heat dissipation. A cooler is, in most of the cases, used together with a fan to increase the air flow over the heat sink (Fig.1).

Fig.1 CPU heat sink with fan attached

There is a rich literature in this field [1], [2], [3], [4].In [5] 3D cylindrical models are considered.

In this paper two different 3D CPU cooler geometries are considered and compared. In order to compare the temperature distribution certain parameters were taken into account: materials, CPU heat power, environment temperature and the speed of the fan. The thermal contact resistance between the CPU and the heat sink device wasn't considered.

2 Problem Formulation

The general structure of the simulated model has two components: the cooler and the CPU. In the processor as well as in the heat sink device the heat transfer is governed by the heat equation:

$$\rho \cdot c_p \cdot \frac{\partial T}{\partial t} + \nabla \cdot (-k \cdot \nabla T) - Q = 0 \qquad (1)$$

where $\rho[Kg/m^3]$ is the material density, $c_p[J/Kg \cdot K]$ is the heat capacity, $k[W/m \cdot K]$ is the thermal conductivity and Q is the volumetric heat source.

Two CPU coolers were considered: one with a symmetric geometry and the other with a non symmetric geometry (Fig.1.a and b).Input parameters of the finite element models were: the heat transfer coefficient h [W/m^2 K], T_{inf} the environment temperature and the heat power generated by the CPU. First the heat transfer process will be considered without a fan. In this case there is no forced convection and only the conduction and natural convection are considered.

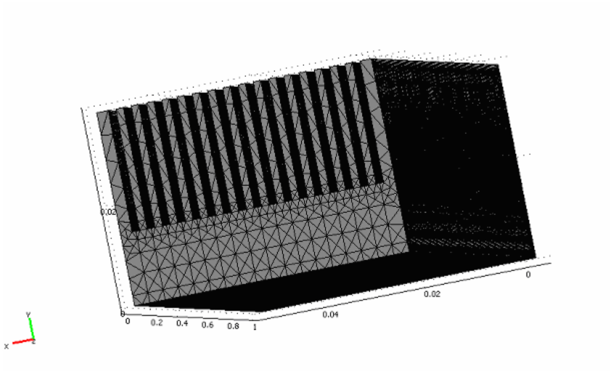

Fig.2.a Symmetric cooler

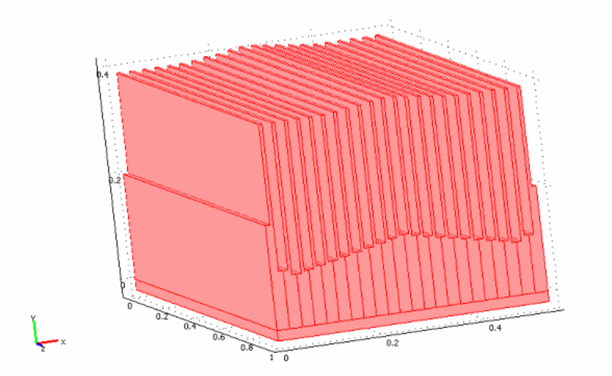

Fig 2.b Non symmetric cooler

3 Problem Solution

Because of the symmetry of the cooler from Fig.1.a, in order to decrease the computational cost, only a fin of it was modeled (Fig.2 a).The dark side represents the silicon made CPU. The boundary conditions are so called Neumann type that specify the outward heat flux, $\overline{n}\cdot(k\nabla T)$ where $\overline{n}$ is the outward surface normal. On the exterior of the heat sink device the outer flux is set equal to the convective heat flux $h\cdot(T_{\inf} - T)$ where h is the heat transfer coefficient and $T_{\inf}$ is the temperature of the environment. At the computational domain symmetry boundaries the outward heat flux is set to zero. No heat transfer by radiation is considered.

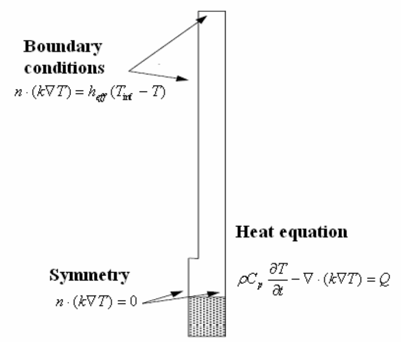

Fig.2.a Boundary conditions on the fin

Equation (1) was solved using Comsol Multiphysics finite element from COMSOL AB Sweden. The heat transfer module was used and transient analysis was performed using Lagrange quadratic elements [6]. In Fig.3 the temperature distribution for an aluminum fan is presented for T_{inf} = 25 C and the heat transfer coefficient h = 10. The heat power generated by the CPU is 40 W.

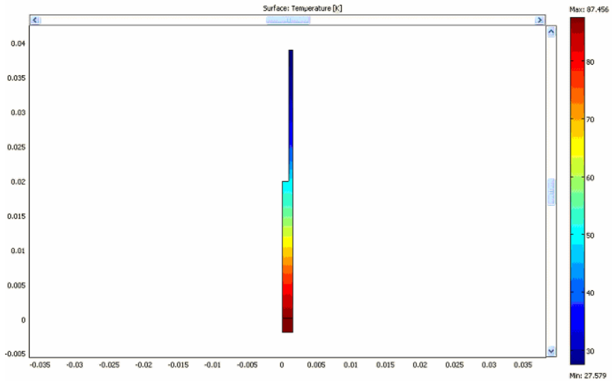

Fig.3

In Fig.4.a and 4.b, the temperature distribution in the cross section of symmetric cooler is presented, as a map representation and as contour lines respectively.

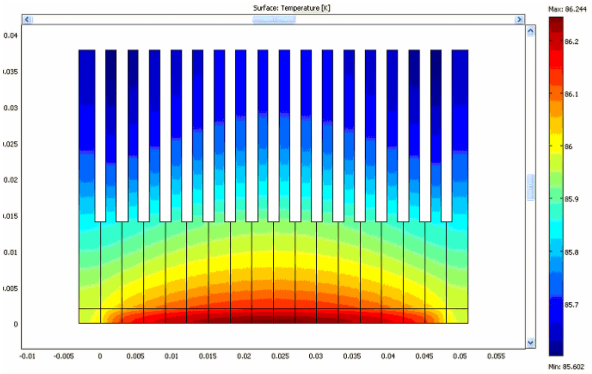

Fig.4.a Steady state temperature distributions over the fins

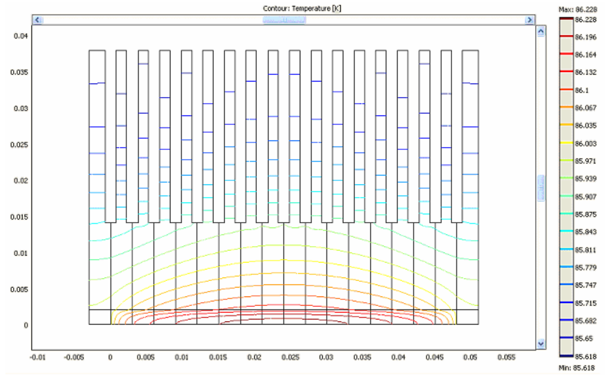

Fig.4.b Temperature contour plot

The temperature distribution for the second cooler (Fig.2.b) is presented in Fig.5.

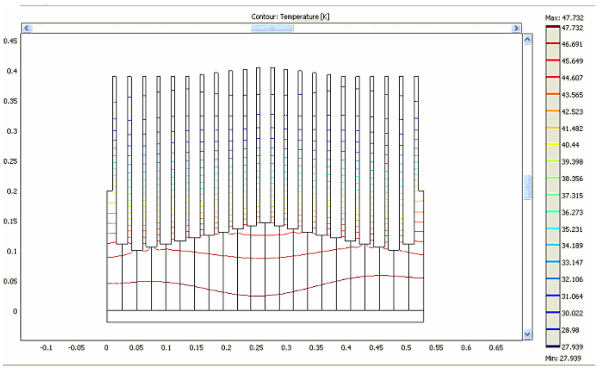

Fig.5 Temperature contour plot for the second cooler cross section

It can be seen that the above cooler is more efficient for dissipating the CPU heat.

3.1 Dependence of the temperature distribution on the material of the cooler

Coolers made of three materials are considered: copper, aluminum and titan. The steady state temperature distribution of the temperature for the symmetric cooler, for each material, are presented in Fig.6, 7 and 8 respectively, at t= 2500 s.

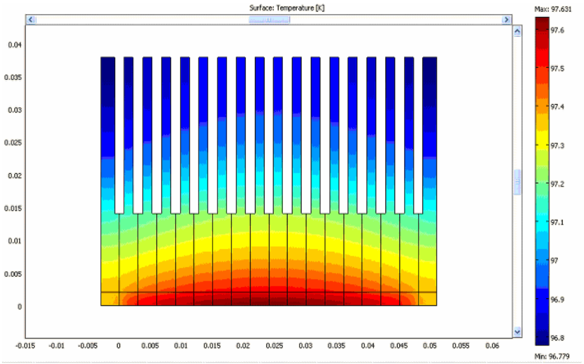

Fig.6 Temperature distribution for the copper cooler

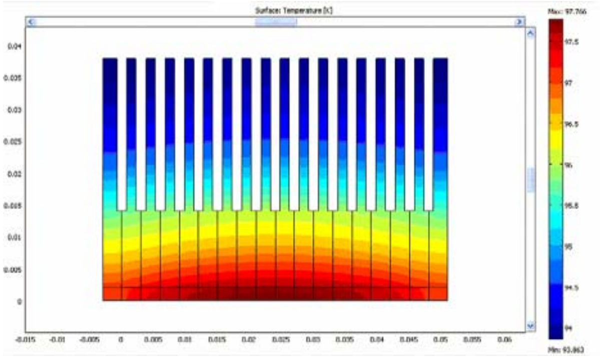

Fig.7 Temperature distribution for the aluminum cooler

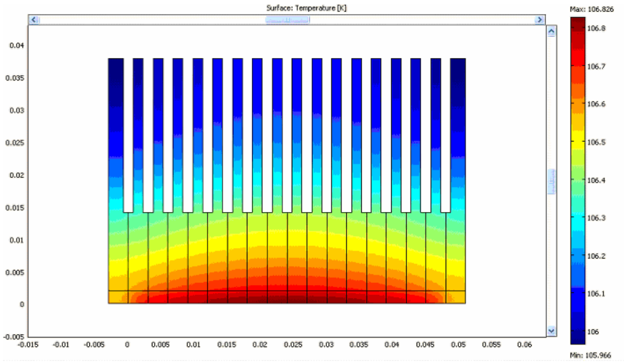

Fig.8 Temperature distribution for the titan cooler

The temperature distribution for the second geometry cooler, for each of the three materials, is presented in Fig.9, 10 and 11 respectively.

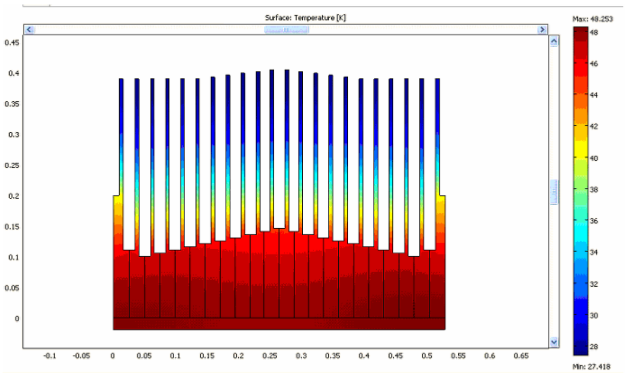

Fig.9 Temperature distribution for the copper cooler

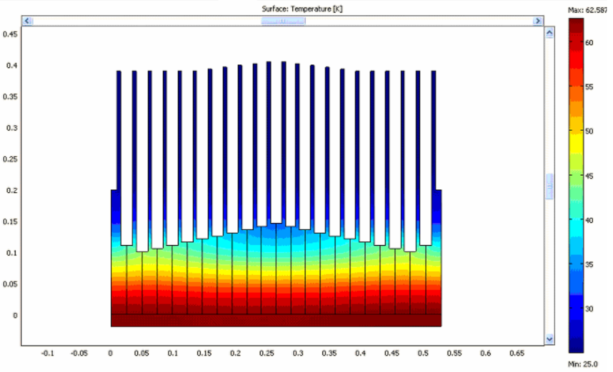

Fig.10 Temperature distribution for the aluminum cooler

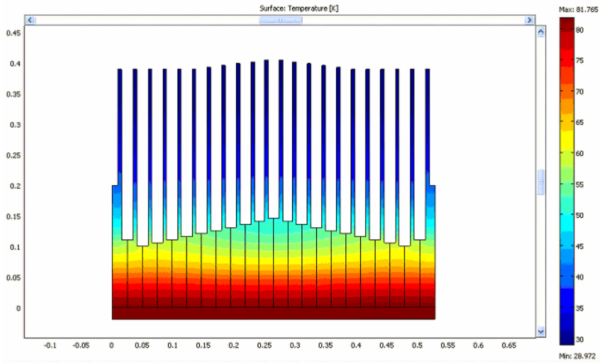

Fig.11 Temperature distribution for the titan cooler

From figures 6, 7, 8,9,10, 11 can be noticed that the second geometry is much more efficient for the heat dissipation, considering the same material.

Also can bee seen that the copper is better in comparison with aluminum and titan from the heat dissipation point of view.

3.2 Dependence of the temperature distribution on the heat power dissipated by the CPU

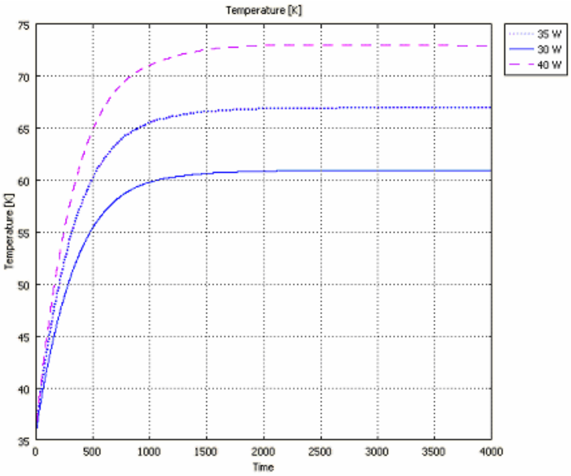

Fig.12 Temperature distribution for the titan cooler

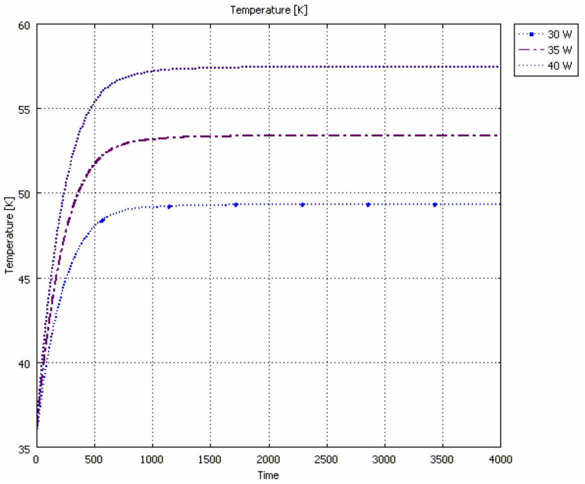

Fig.13 Temperature distribution for the titan cooler

From figures 12 and 13 can be seen that the steady state temperature, at the same CPU power heat generated, is lower for the second geometry.

3.3 Dependence of the temperature distribution on the fin speed

The effectiveness of the heat dissipation will be evaluated for different fan speed (Fig.14 and 15). Initial fan speed is 5 % from the maximum. Considering a certain fan speed the temperature at the control point is 35 C initially. The control point is placed at the bottom of the fin; in the middle point of it (node 4).The value of the heat transfer coefficient is 100 in full speed.

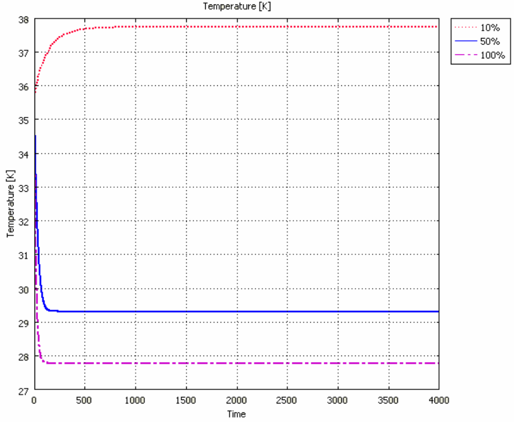

Fig.14 Temperature distribution vs. the fin speed
For the first cooler

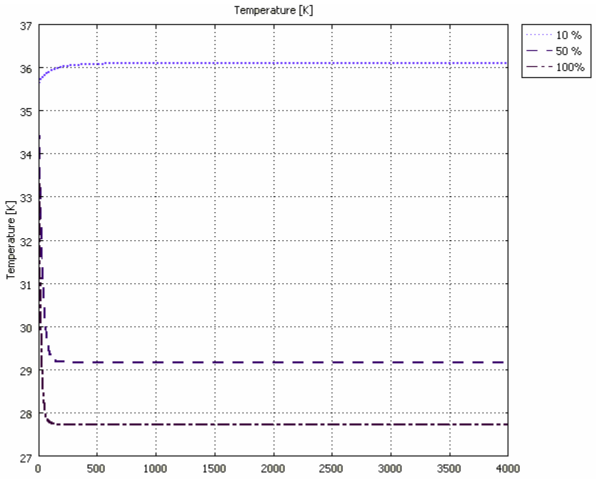

Fig.15 Temperature distribution vs. the fin speed for the first cooler

3.4 Dependence of the temperature distribution versus the environmental temperature

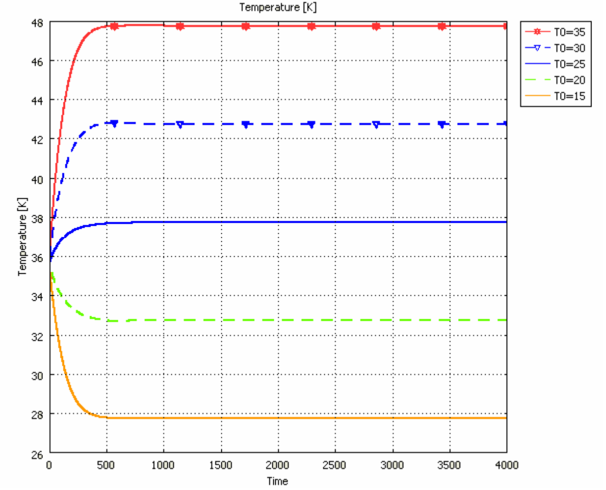

Fig.16 Temperature distribution versus the environmental temperature for the first cooler

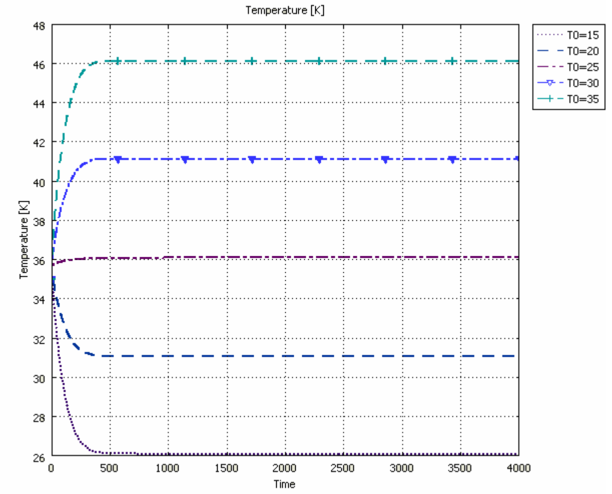

Fig.17 Temperature distribution versus the environmental temperature for the second cooler

Fig.16 and 17 present sudden changes of the environmental temperature influence on the CPU temperature.Also it can be seen that the influence is smaller for the second cooler than for the first.

4 Conclusion

This paper presented a comparison between two CPU cooler regarding the heat sink dissipation efficiency.The heat transfer phenomena were evaluated using the finite element software Comsol Multyphisics.Their heat sink properties were compared taking into account the cooler materials, the CPU heat power and the fan speed. In all cases, at the same conditions, the second cooler has proven a better efficiency for heat dissipation.This because it has bigger channels through which the air can flow and also the fins have bigger area for heat dissipation.When the environment temperature has changed, it influenced the CPU control point temperature: more for the second cooler than for the first one. In order to eliminate this reaction a Simulink controller will implemented and the results will be presented in a future work.Also the thermal contact resistance between the CPU and the heat sink device will be taken into account.

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[6] Comsol Multiphysics ver. 3.3 User's guide