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NUMERICAL ANALYSIS AND EFFICIENCY OF A VAPOR CHAMBER

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Abstract. *This article has as main objective to make a numerical analysis of the size relation that two different types of sets of heat dissipation can work in a forced convection environment. The first set, which will be called Model 1, is composed of a heat sink and an integrated circuit. The second set (Model 2) is composed of a heat sink, vapor chamber and integrated circuit.The numerical analysis will allow the user to verify which greater heat sink can be used effectively in each case. For the accomplishment of this work, a simple thermal resistors model was constructed using ANSYS Fluent software, student license, as computational fluid dynamics tool, represented by blocks with fixed thermal properties, modifying only the dimensions. The results demonstrate the behavior of the temperature in the heatsink and integrated circuit of each model and prove that the vapor chamber evenly distributes heat in the heat sink, decreasing the temperature of the electronic component.*

Keywords: *heat sink, vapor chamber, electronic component, numerical analysis, temperature*

1. INTRODUCTION

The heat sinks are metal objects usually made of aluminum or copper that serve to transfer heat by conduction. They are used to cool electronic components containing high heat dissipation, such as integrated circuits (IC) of computers with high processing capacity. With the constant evolution in electronic equipment, the electronic components became increasingly smaller, generating an increase in the heat flux inside them, and for cooling there was a need to look for new alternatives such as considerably increasing the size of the heat sinks. Recently, Peng, *et al*., 2013, stated that temperatures are so high that the traditional heat pipe can not dissipate all the heat generated.

For Koito *et al*., 2006, to solve this problem, the Vapor Chamber (VC) has emerged. An advanced cooling instrument that functions as an efficient conductor of heat, this device is located between the IC and the heat sink and causes the heat supplied by the electronic component, spread evenly on the heat sink. Cooler Master, (2013) stated that the coolant molecules are heated they change phases. The vaporized coolant convects freely through the chamber. The Molecules then condense on cold surfaces, dissipate their heat load, and are channeled back to the coolant reservoir. Since the rate of condensation depends on the temperature delta of the coolant and the contact surface, the coolant automatically streams towards the coolest surface area. This self-organizing active molecular coolant stream within the Vapor Chamber is responsible for its superior thermal properties. As a result it provides stable and evenly spread temperatures on all of its surfaces. But when should you use VC? Until when is it feasible to use only the heat sinks? Until what size ratio, can the VCs evenly spread the heat in the heat sink?

Recent research by Advanced Cooling Technologies (2018) provides information on case studies comparing heat sinks, vapor chamber and summarizing each technology. Tang, *et al*., 2013, proposed and tested a new VC with layered structures of sintered copper powders in their work and found that the heating area may influence the performance of CV, further stated that for a better performance the area of should be less than the CV area. Naphon, *et al*., 2012, experimentally investigated the thermal cooling of the VC and verified that it has a significant effect on the energy consumption and the thermal cooling of a CPU.

Several studies on CV performance have already been performed and in this article, using numerical analysis will be studied two types of models, the first one (Model I) using only the heat sink to cool the electronic component and the second (Model II) using a VC between the heat source and the heat sink. The objective is to verify the largest area in which each model works effectively in a forced convection environment and to examine when it is feasible or not to increase the size of the heat sink and that of the vapor chamber.

2. PROCEDURES AND NUMERICAL ANALYSIS

For the accomplishment of this work, a simple thermal resistors model was constructed using ANSYS Fluent software, student license, as computational fluid dynamics tool. The models created were based on real IC and VC, which can be purchased at specialized stores. The objective was to analyze sets of heat dissipators, vapor chamber and integrated circuit, very similar to reality. The models were constructed as blocks and each block represents a component, as described in section 2.1 of this article.

2.1 Description of components

The wind tunnel is the scenario in which the models were analyzed, it contains dimensions 200 x 300 x 50 [mm], an ambient temperature of 20 ° C has been considered inside, the walls in the axes "x" and "z" are adiabatic, in other words, the walls in the axes "x" and "z" are adiabatic, that is, there is no passage of mass, heat and work between the interior and exterior environment (Fundamentals of Thermodynamics, 2011). In the y-axis the walls are opened and has an input velocity of 3 [m/s].

The printed circuit board has dimensions of 120.3 x 180 x 1 [mm] and it is composed of FR-4 material. The electronic component considered was the Intel Pentium N3520 processor (Intel, 2014), has dimensions 27 x 25 x 1 [mm], composed of Epoxy Resin-Typical material and power dissipation of 4.5 [W].

The heat sink was created based on the work of Haskell, (2010), in which the author studies different equipment of materials for heatsinks. It is made of extruded aluminum, its fins have a thickness of 0.4 [mm], height 9 [mm] and distance between fins of 0.664 [mm]. The base of the heatsink has a thickness of 1 [mm] and its dimensions change according to the model created, which will be shown in section 2.2.

The vapor chamber was made from the datasheet of vapor chambers of Wakefield-Vette, (2017). The model taken as base is the VC 90-90-3, has 3 [mm] thick and a thermal resistance of 0.143 °C/W.

To carry out the work is necessary the thermal conductivity of the steam chamber which was not provided in the datasheet. However it was possible to determine it using the thickness and the thermal resistance of the IC. Equation (1) and Equation (2) represent the thermal conductivity and thermal resistance equations respectively (Incropera, 2002).

$$k = q / (dT / dX) \quad [W/(°C.m)] \tag{1}$$

$$Re = L / (k \cdot A) \quad [°C/W] \tag{2}$$

Onde:
k = thermal conductivity
q = heat flux
dT / dX = change in temperature in relation to the thickness
Re = thermal resistance
L = length
A = area

By analyzing the two equations, it can be seen that the thermal conductivity is the inverse of the thermal resistance divided by the thickness of the object, so the conductivity of the vapor chamber can be calculated by Eq.3:

$$kv = (1 / Re) / e \quad [W/ (°C.m)] \tag{3}$$

Onde:
kv= thermal conductivity of the vapor chamber
Re = thermal resistance of the vapor chamber
dT / dX = thickness of the vapor chamber

Solving Eq. (3) with the vapor chamber data provided in item 2.1, we have that the thermal conductivity is 2231 [W/(°C.m)].

2.2 2.2 Description of the models

The Model 1 consists of wind tunnel, printed circuit board, electronic component and heat sink. This model was analyzed in 7 different configurations: Model 1.1, Model 1.2 ... and Model 1.7. For each of these models, the dimension of the heat sink was increased by 12.768 [mm] in the direction of the x-axis, this corresponds to an increase of 12 fins in the heatsink, and 25.536 [mm] in the y-axis direction, this generates a increase in the length of the heatsink. In the direction of the z-axis the model remained constant. For example, the heatsink of the first set (Model 1.1) has dimensions 27 x 25 x 10 [mm] and 26 fins as shown in Fig. (1), so in the second set (Model 1.2) the of the heatsink will have 39,768 x 50,536 x 10 [mm] and 38 fins. In both cases the heatsink had a height of 10 [mm], 9 [mm] referring to the height of the fins and 1 [mm] referring to the base of the heatsink. In both cases too, the printed circuit board had a thickness of 1 [mm] and the electronic component also had a thickness of 1 [mm].

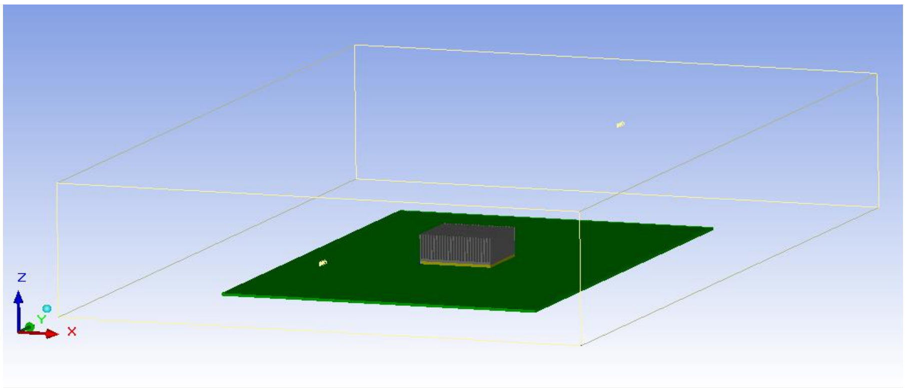

Figure 1. Model1.1 without vapor chamber and heat sink with 26 fins

The Model 2 is composed of the same elements of Model I with the addition of the vapor chamber. The vapor chamber used for this model is 3 [mm] thick. In addition, the vapor chamber was modeled as a solid material with a thermal conductivity of 2231 [W/(°C.m)], as explained in item 2.1. As in the previous case, this model was also analyzed in 7 different configurations: Model 2.1, Model 2.2 ... Model 2.7. The components in common of the two models have the same dimensions and mechanical properties and their size has been increased in the same way as Model 1. Figure 2 shows the Model 2.7, the largest model, containing 98 fins and dimensions 103,608 x 178,216 x 10 [mm].

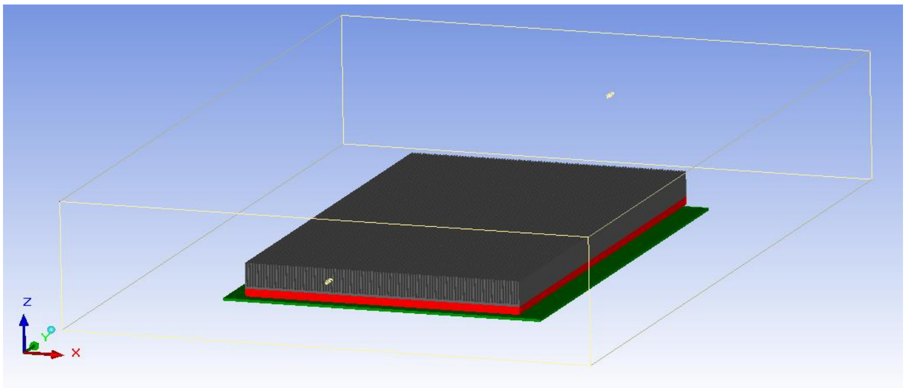

Figure 2. Model 2.7 with vapor chamber and heat sink with 98 fins

3. RESULTS AND CONCLUSIONS

From the tests carried out, we have that the vapor chamber distributed very well the heat dissipated by the electronic component. When comparing model 1.7, Fig. (3) with model 2.7, Fig. (4), it can be noted that the temperature variation in the heatsink of the former is approximately 5 ° C, in addition, the side fins are close to ambient temperature (20°C). This means that these fins are working as much as the middle fins. In model 2.7, the temperature varies about 1 ° C, this shows that the vapor chamber is evenly spreading the heat generated by the electronic component in the heatsink.

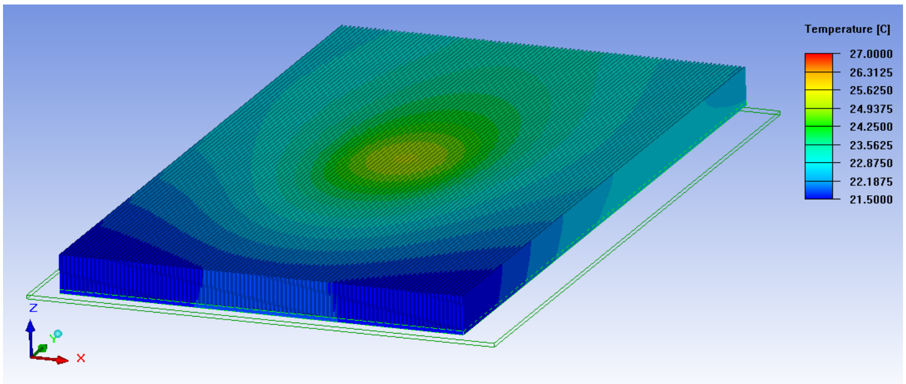

Figure 3. Contours of temperature in the heat sink without vapor chamber

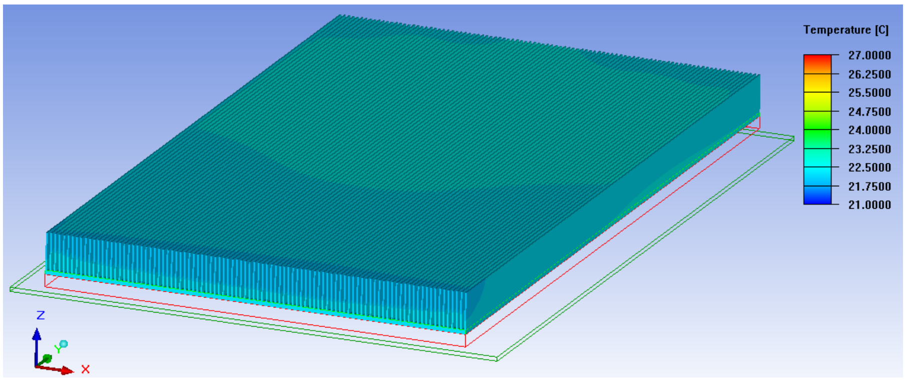

Figure 4. Contours of temperature in the heat sink with vapor chamber

Table 1 and Table 2 respectively show the heat sink area and surface temperature data of the electronic component of Model 1 and Model 2.

Table 1. Model 1 heatsink and processor data

Modelo	Nº de aletas	Área da base do dissipador m²	Temperatura na superfície do processador °C
1.1	26 aletas	0,000675	57,2
1.2	38 aletas	0,002009	39,6
1.3	50 aletas	0,003995	32,9
1.4	62 aletas	0,006635	29,5
1.5	74 aletas	0,009926	27,2
1.6	86 aletas	0,013869	26,1
1.7	98 aletas	0,018465	25,5

Tabela 2. Model 2 heatsink and processor data

Modelo	Nº de aletas	Área da base do dissipador m²	Temperatura na superfície do processador °C
2.1	26 aletas	0,000675	44,4
2.2	38 aletas	0,002009	36,6
2.3	50 aletas	0,003995	30,2
2.4	62 aletas	0,006635	26,9
2.5	74 aletas	0,009926	24,9
2.6	86 aletas	0,013869	23,5
2.7	98 aletas	0,018465	22,7

Figure 5 shows the temperature plot on the surface of the electronic component relative to the base area of the heatsink from the data in Table 1 and Table 2.

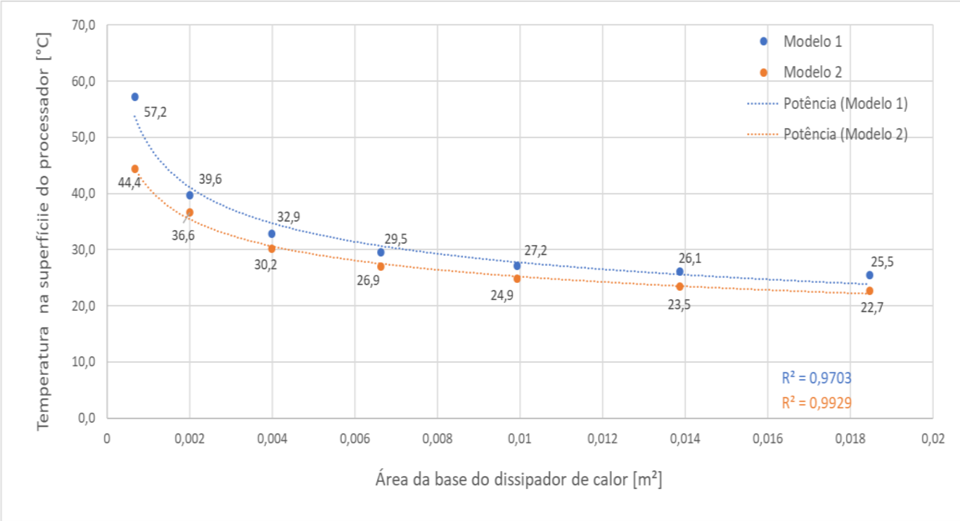

Figura 5. Temperature on the surface of the electronic component x base of the heat sink

According to the graph, it can be noted that the two curves have very similar behavior, but the temperatures of Model 2 are lower than those of Model 1.

We may also note that from a certain point, increasing the area of the heat sink does not effectively reduce the temperature of the electronic component (in both cases), thus it is not feasible to increase the heat sink from this point.

When only the heat sink is used, a large increase in its area is not plausible because, as the heat is not uniformly distributed, the end flaps work very little, not considerably influencing the IC temperature reduction. When analyzing the graph it is observed that from the fifth point (27.2°C) the temperature variation in the electronic component is very low, approximately 1°C.

Com a utilização da “vapor chamber”, a distribuição de calor é melhor, tornando possível aumentar o tamanho do Modelo 2. No gráfico, pode-se observar que até o sexto ponto (23,5 °C) a temperatura do processador cai significativamente, a partir disso a variação de temperatura é menor que 1°C, porém o calor continua sendo bem distribuído entre as aletas.

With the analysis of this work, it can be concluded that by using the heat sink without the aid of the steam chamber it is advantageous to increase the area of the heat sink by only 14.7 times more than the area of the processor (which corresponds to heat sink with 74 fins). With the use of the vapor chambre – heat sink assembly it is feasible to increase the area of the assembly by up to 20.5 times more than the processor area (which corresponds to the heat sink with 86 fins).

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5. RESPONSIBILITY NOTICE

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