Proceedings of Mechanical Engineering Research Day 2015, pp. 35-36, March 2015

Inline pin fin heat sink model and thermal performance analysis for central processing unit

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Keywords: Heat sink; thermal; heat transfer

ABSTRACT – The thermal management issue is common in electronic products such as computers, projectors and others. The trend shows that by increasing the power density, indirectly it will increase the temperature and power dissipation in CPU processor. This is a major challenge to the product designer of electronics cooling system to find an alternative technique to solve the problem. Therefore, in order to control and minimize the heat produced by the CPU's processor, the conventional external heat sink is added to the overall thermal management mechanism. In this paper, 3D simulation inline pin fin heat sink is designed using COMSOL Multiphysics software. The outcome of this study hopefully can shed some light on how to optimize inline pin fin arrangement heat sink design.

1. INTRODUCTION

Nowadays, the demand of using high performance, functionality and small size electronic appliances such as computers and laptops are very popular. The advancement of microelectronic technology in producing high speed and small size system leads to an increase of heat generation per volume from each electronic components, hence could reduce the performance of the electronic component, effects its lifetime or even crashing the entire operation of the system if it does not managed correctly. This is a big obstacle to the product designers to tackle the problem by finding an alternative technique.

There are many cooling techniques and system designs is applied to remove the heat from the electronic devices. For example, in desktop computer, heat sink is used to dissipate heat from the CPU due to economical reason and practical. Heat sink is a device that allows the transfer of heat away from the heat source such as CPU processor, random access memory (RAM) and et cetera.

There are many heat sink design in the market such as plate fin and pin fin. Therefore, heat sink with high heat transfer rate is needed. The selection of suitable heat sink geometry is required not only to be able to fit inside a limited space in the motherboard, it also has to be lightweight, economical and the most important aspect is excellent characteristics of the heat dissipation.

According to Kim et al. [1], pin fin heat sink model with low power dissipation from the heat source provides small thermal resistance. Hence the pin fin heat sink should give better thermal management performance compare to the plate fin heat sin model [1-3].

In this paper, 3D simulation pin fin aluminum heat sink model with various inline arrangement is design by using COMSOL Multiphysics software. The model which is applied on the CPU Intel® Atom™ Processor N450 by mounting it on top of the CPU processor chip. More than 30 models were simulated and important data such as the maximum temperature generation from the temperature profile is gathered. A few assumptions to minimize the complexity of modelling such as air box channel dimension, velocity of air inlet from the blower fan, heat sink design such as base, pin dimension and total number of pin, power dissipated from the chip and chip dimension.

2. METHODOLOGY

Heat is defined as energy of the temperature value. In thermodynamics, heat transfer is a process of thermal energy movement from hot area to cold area. There are three fundamental mechanisms in heat transfer which are conduction, convection and radiation. The 3D heat conduction equation is described as equation (1) below.

$$\rho C_p \frac{\partial T}{\partial t} - \nabla.(k\nabla T) = Q \qquad (1)$$

Where ρ is density (kg/m^3), C_p is the heat capacity (J/Kg^{o}C), k is thermal coefficient of the material (W/mK) and Q is volume heat source (W/m^3). Then heat convection equation as equation (2).

$$n \cdot (k\nabla T) = q + h(T_{amb} - T) \qquad (2)$$

Where n is the normal vector of the heat flux, $h(T_{amb}\text{-}T)$ as known Newton law of cooling, which is use to specifies the heat flux cause by forced (airflow) or natural convection process, and T_{amb} is ambient temperature.

The overview of modelling development is shown in Figure 1 which comprises of four stages. The operating condition and model parameter values for heat sink model are listed in Table 1.

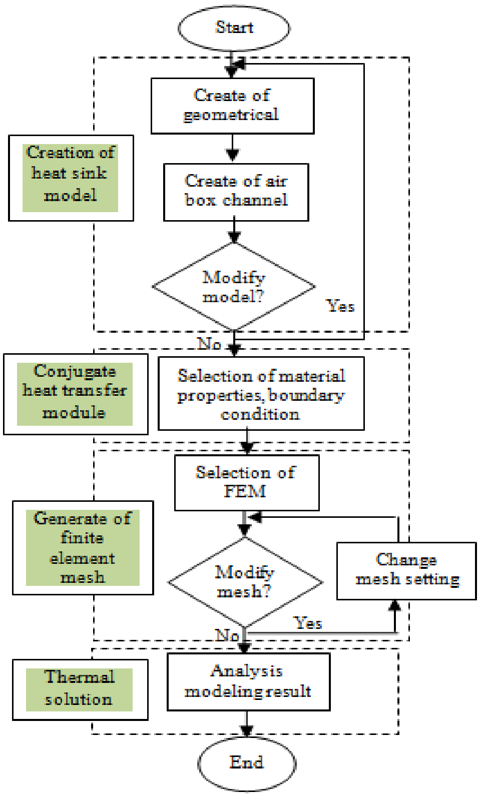

Figure 1 Heat sink modeling algorithm

Table 1 Inline pin fin heat sink model parameter

Parameter		Values
Air box Channel	Length	6 cm
	Width	5 cm
	Height	2 cm
CPU	Length	2.2 cm
	Height	0.1 cm
	Power dissipated	5.5 W
Pin fin	Height	1.7 cm
	Diameter	0.2 cm
	Number of pin	36
Heat sink base	Base thickness	0.2 cm
	Diameter	4 cm
Air flow inlet	Inlet velocity	10 cm/s
	Inlet temperature	20 °C
Material		Aluminium

3. SIMULATION RESULTS AND DISCUSSION

In this paper, the simulation was done using COMSOL Multiphysics software under Conjugate Heat Transfer module on a computer equipped with 12GB RAM and Intel i3-2120 3.30 GHz processor.

Figure 2 shows three 3D inline arrangement of pin fin heat sink thermal performance simulation results out of 30 models. The different is position between pin fins located on the base of heat sink. The analysis shows that different inline arrangement of pin fin mounted on the base heat sink gave different thermal management performance even though the cross sectional area of each model is constant. From the three types of arrangement, Figure 2(a) is designed based on 6 X 6 (x and y axis) selection design, which give optimum temperature of only 90.78°C lower than the remaining arrangement. These results show that a good heat thermal performances can be optimized by selecting the correct geometry of the pin fin.

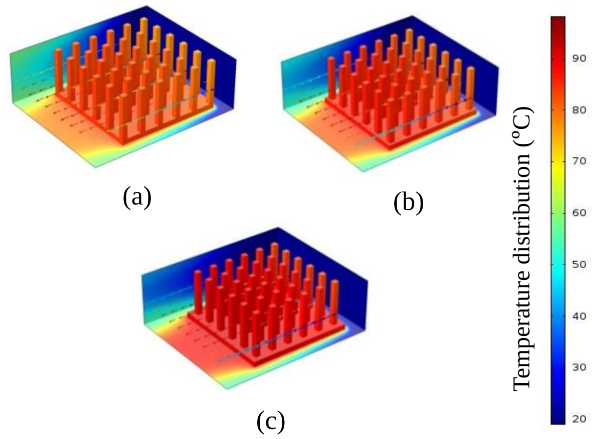

Figure 2 3D inline pin fin heat sink models with different alignment. (a) Model A (max temp: 90.78°C); (b) Model B (max temp: 93.2°C); (c) Model C (max temp: 97.26°C)

4. CONCLUSIONS

This paper has presented thermal performance of various inline arrangement of pin fin heat sink model for CPU Intel® Atom™ Processor N450. The simulation result showed that different inline arrangement of pin fin would give variable heat thermal performance. Therefore the selection of the suitable inline arrangement of pin fin is crucial during the product design stage. Apart from this method, a population based evolutionary algorithm optimization can be applied in order to find the optimal inline arrangement of pin fin. For future work, the focus will extend to other parameter of the heat sink, for example heat sink material, shape and position of air inlet.

5. ACKNOWLEDGEMENT

The authors appreciate the support granted by Universiti Teknikal Malaysia Melaka (UTeM) in pursuing this research.

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