A Study on The Optimization of Heat Sink's Heat Performance about Tip Clearance and Shape

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Abstract: - Heat sink is a very important product and widely used for cooling, and its thermal performance is usually determined by the shape and sizes of itself such as the fin numbers, the fin height, the fin width, the fin gap, and the basement thickness. With the development of computational techniques and numerical method, design and analysis of heat sink using CFD method instead of conventional experimental method becomes popular and practical. In this study, the design optimization of a plate-fin type heat sink cooled by impingement jet is presented. To study the performance of the heat sink and acquire the optimal shape, both CFD analysis and surrogate model based optimization are adopted.

Key-Words: - Heat sink, CFD, optimization, Tip clearance

1 Introduction

With the fast development of electronic technology and system, effective cooling of electronic devices become a significant challenge recently, since electronic devices become smaller, more advanced and leads to a rapid increase of heat generation. In the past decades, various types of cooling methods and/or technologies such as water cooling, jet impingement cooling, heat pipe and phase-changing cooling, have been developed and applied to meet the high heat dissipation or transfer rate requirements[1][2]. Among these technologies, a heat sink is the most widely used type of cooling device/technology due to its high heat dissipation rate and easy fabrication. Heat transfer between the source and the sink through the heat sink is very simple. First, heat generated from the electronic device is transferred to the heat sink through the contact surface, and then carried away from the large surface area of heat sink by airflow. The airflow can be nature or forced airflow driven by the jet impingement or fan. Despite the materials and interfaces of the electronic device and heat sink, many other factors relative to the configuration of the heat sink itself and the airflow enhanced equipment such as impinging jet and fan play important roles on the capability of heat transfer.[3][4]

In this paper, selected 18 cases models and approach is proposed for the analysis and optimization of thermal performance of plate-fin heat sink under jet impinging condition. As well, CFD analyses instead of experiments are carried out for the assessment of the thermal performance of the plate-fin heat sink[5]. However, many CFD analyses have been conducted not for the direct comparison the heat sinks with different sizes, but used as the sampling data for the subsequent trend analysis and the design optimization of the heat sink with specific jet impingement. The result show the effect of heat performance about heat sink shape and tip clearance.

2 Problem Formulation

2.1 Thermal performance metrics

Heat sink is a device that facilitates heat exchange between environment and a heat source, which usually is a processor or chip in electronic industry. To systematically study and optimized the thermal performance of the heat sink, it is essential to define the metrics of thermal performance. There have been many different metrics available to evaluate the thermal characteristics or capabilities of heat sink. In this study, average temperature on the base is used to evaluate the performance of the heat sink.

The average temperature of heat sink has the following formula:

$$T_{avg} = \sum_{i=1}^{n} T_i S_i \Big/ \sum_{i=1}^{n} S_i$$

where Ti is the temperature of i-th element, Si is the area of the element. The lower the average temperature, the more heat can be transferred through the heat sink.

2.2 Fluid Analysis

In order to analyze the fluid performance of heat and cooled, we used ANSYS CFX. As the turbulence model, SST (shear stress transport) based on *k-ε* was used, and for convection scheme. And The 1/2 model is selected for the calculation on CFX, in order to reduce the interpretation time. The form and size of the heat sink used in the present study are suggested in the Table 1 while the distance between duct and heat sink is 5mm as shown in the Fig. 1. The area and height of fin has been adjusted on the heat sink which has a single form of base plate. The velocity of a fluid running into the heat sink is measured separately depending on the value of Reynolds number 5000 to 15000[6].

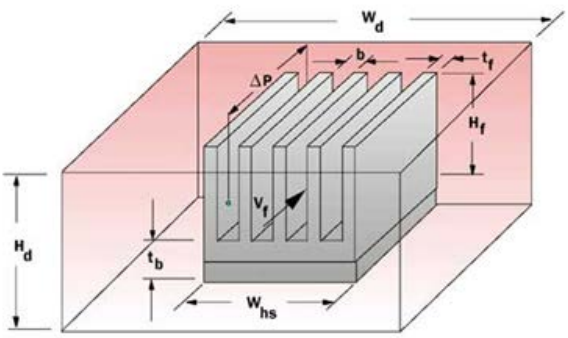

Fig.1 Schematic diagram of geometry

Table 1 Experimental variables

Base Plate	Width(W_{hs})	30mm
	Length(△P)	32mm
	Thickness(t_b)	2mm
Fin	Number	9
	Thickness(t_f)	1.5, 2, 2.5mm
	Height(H_f)	6, 8, 10, 10.5, 11mm
Duct	Height(H_d)	14mm
	Width(W_d)	40mm

3 Problem Solution

The thermal resistance, criteria for thermal performance of fin of each case, is represented in the Fig. 2, while the thermal distribution of heat sink is suggested in the Fig. 3, 4, 5. Also size of heat sink's cases are show in the Table 2.

Table 2 Information of Case Number

Case 1,2,3	Fin Height	6mm
	Fin Thickness	1.5,2,2.5mm
Case 4,5,6	Fin Height	8mm
	Fin Thickness	1.5,2,2.5mm
Case 7,8,9	Fin Height	10mm
	Fin Thickness	1.5,2,2.5mm
Case 10,11,12	Fin Height	10.5mm
	Fin Thickness	1.5,2,2.5mm
Case 13,14,15	Fin Height	11mm
	Fin Thickness	1.5,2,2.5mm

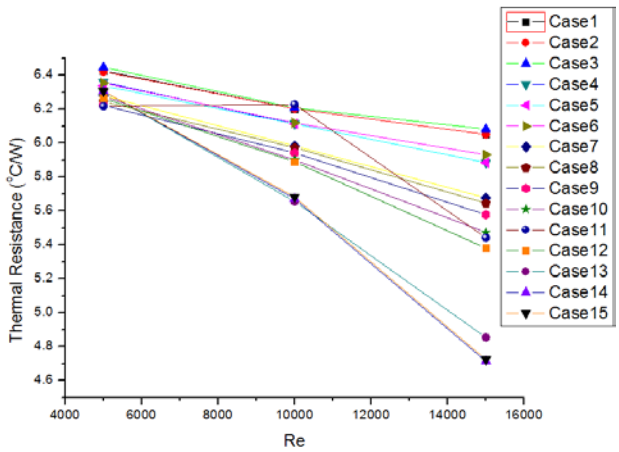

Fig.2 Effect of thermal resistance for various Reynolds numbers with 5000 to 15000

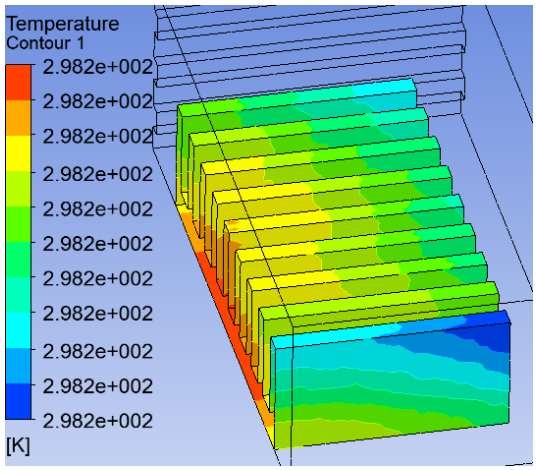

Fig. 3 Contour of Heat sink's Heat Area (Height 6mm)

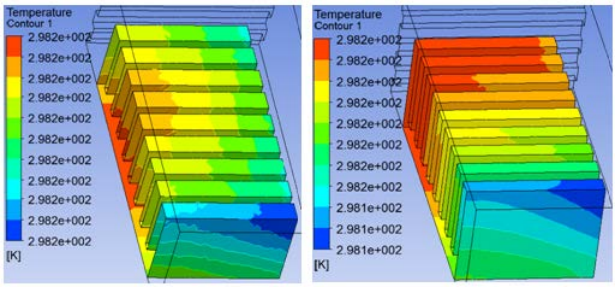

Fig. 4 Contour of Heat sink's Heat Area
(Height 8mm and 10mm)

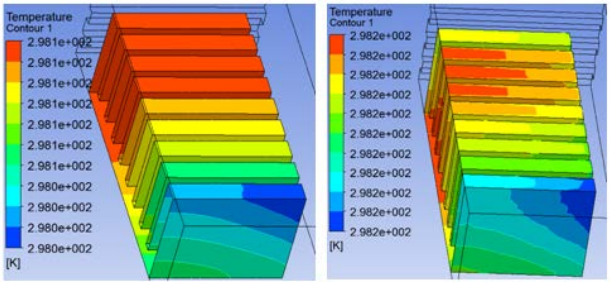

Fig. 5 Contour of Heat sink's Heat Area
(Height 10.5mm and 11mm)

Fig. 6 shows us, fin heights is 11mm, stream line is not through to top of heat sinks. But unit area is wider, thermal performance is better than others.

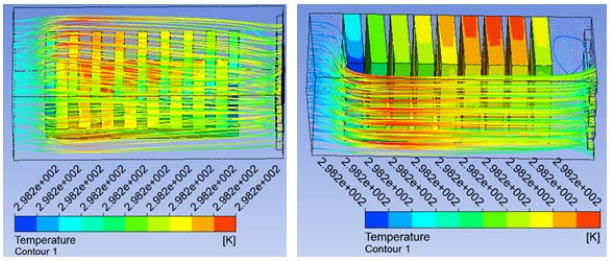

Fig. 6 Compare stream line about fin's height

4 Conclusion

In this study, the thermal performance is measured depending on the changes in the height and area of the fin. The results are like the followings,

1. When the size of base plate is same, the highter of the fin is, the lower than thermal resistance is.
2. With same heights, he thickness is the more thicker fin is, and the narrow the gap is, then the better the thermal performance gets.
3. The thermal resistance is lower than ever in the Case 9, where the pin end of the heat sink and the cellar is 0mm.
4. The thermal performance gets better as the unit area is wider. And if do not flow smoothly, heat distributions are not uniform, but cooling effect is best of cases.
5. When the proper unit area can be reflected, it is expected to get less production cost and higher cooling effect.

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