Numerical Simulation Study on Heat Exchange Effect of Open Computer

Xiangci Meng(✉)

The Computer Department, Jiangsu Automation Research Institute, Lianyungang, China
mengxiangci_hrbeu@163.com

Abstract. This article conducts a thermal simulation analysis of an open computer. Through the simulation results, the module structure and the chassis structure are optimized. And verify the reliability of thermal design of the chassis. It provides reference for thermal simulation analysis and thermal optimization design of other similar electronic devices.

Keywords: Natural convection · Chassis · Thermal simulation Optimal design

1 Introduction

With the continuous advancement of science and technology, electronic equipment, especially the field of military electronic systems, is becoming integrated and miniaturized, and the degree of integration of computer systems has increased at an unprecedented rate [1, 2]. Large-scale integrated circuits are commonly used in circuit design, and the functions of independent devices and modules have become increasingly complex, resulting in an increase in output power. A large amount of electrical energy is converted into heat energy, resulting in high heat flux and heat accumulation effects. The reliability of power devices is closely related to their temperature. It has been pointed out in the report that 55% of failures in electronic devices are caused by temperature, and the reliability of semiconductor devices is reduced by 50% for every 10 °C increase in temperature [3–6]. In the design process of computer products, designers need to consider the chassis structure and thermal design together to realize the collaborative design of the structure and thermal control.

Thermal design of electronic devices is based on three types of heat transfer: heat conduction, thermal convection, and thermal radiation. With the upgrading of computer hardware and the development of software integration technology, the use of numerical methods for thermal analysis of electronic devices has become the main means of thermal design of electronic devices. Compared with traditional thermal analysis methods, numerical simulation technology can effectively reduce design costs and shorten design time [7, 8]. The designer grasps the weak points in the design that are prone to problems and evades the design risks so as to increase the success rate of the products [9–11]. This paper adopts Icepak software with high precision and fast calculation speed to perform thermal design and thermal simulation analysis on an open

W. Xu et al. (Eds.): NCCET 2018, CCIS 994, pp. 83–90, 2019.
https://doi.org/10.1007/978-981-13-5919-4_8

chassis. The conclusion of this paper provides a reference for the thermal design and thermal simulation of this type of equipment.

2 Numerical Model

2.1 Chassis Structure and Module Structure

As shown in Fig. 1, the module of the open computer adopts the plug-in structure design. The external dimensions of the chassis (L × W × H) are 365 mm × 286 mm × 212 mm. The entire chassis consists of 2 power modules, 1 network module, 2 data exchange modules, 1 storage module, 5 waterproof modules, and 1 electrical connector module. The 12 module plugs are placed parallel to the inside of the chassis. The total heat consumption is 213 W. The heat dissipation components are shown in Table 1.

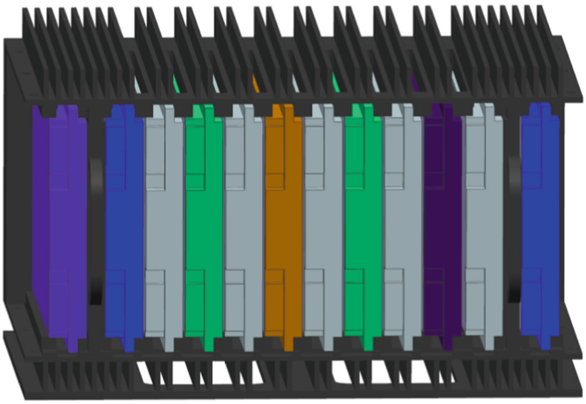

Fig. 1. Computer structure

Table 1. Power consumption table

Module	Quantity	Slot number	Power consumption (W)		
			CPU	Whole board	Total
Power module	2	2, 12		20	213
Network module	1	6		38	
Data module	2	4, 8	35	45	
Storage module	1	10	35	45	
Waterproof module	5	3, 5, 7, 9			
Electrical connector module	1	1			

The main heat dissipation methods of the open computer studied in this paper are natural convection heat transfer and heat radiation. For the entire computer, due to the non-compulsory heat dissipation method, the heat dissipation of the modules in the chassis is difficult. After the components are heated, they are transferred to their own cold plate mold through the thermal pad, and then the heat is transferred to the edge of the module through its own cold plate and heat conduction structure, and then transmitted to the side wall of the chassis through the locking device, finally through the cooling fins of the side plate of the chassis. Through the analysis of the heat dissipation conditions of the internal modules of the chassis, it can be seen that there are two main factors affecting the heat dissipation performance from the thermal conduction of the electrical components from the module to the side plates, the natural convection of the external walls of the side plates and the air: Thermal conductivity of module cold plate and heat-conducting structure/natural convection heat dissipation performance of cooling fins and external air; Thermal path as shown in Fig. 2.

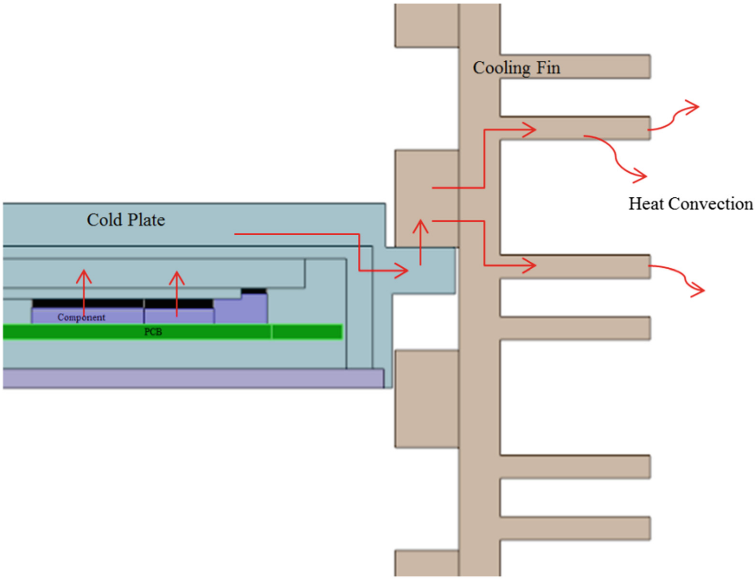

Fig. 2. The cooling path of the computer

2.2 Computational Models and Grids

For the open computer studied in this paper, the finite volume method is used for numerical calculation. In order to increase the efficiency of simulation and calculation, the chassis should be simplified first. Local details such as screws, nuts, fillets, mounting holes, etc. that have little effect on heat dissipation are ignored.

Based on the simplification of the model, the whole machine needs to be meshed. This chassis cooling simulation mesh adopts Mesh-HD mesh type that is provided by

Icepak. This grid can meet the calculation requirements. In addition, the cooling fins and module models have been refined to increase simulation accuracy, as shown in Figs. 3 and 4.

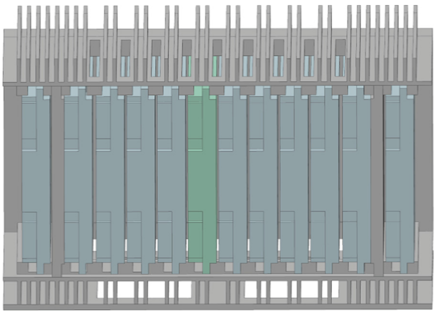

Fig. 3. Simplified model of open computer

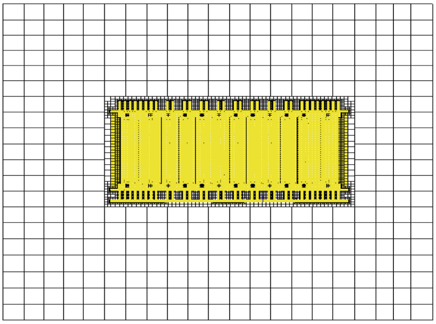

Fig. 4. Computational mesh

2.3 Boundary Conditions

For the numerical simulation analysis of chassis heat dissipation, the correct boundary condition setting is an important guarantee for good results. The simulation calculation domain is 4 times the chassis size, and the contact resistance between the module cold plate and the chassis is 0.56 °C/W. The power consumption of each module is shown in Table 1. The working environment of the computer is −20 °C to 50 °C. This article only performs simulations for the case where the maximum temperature is 50 °C. The specific boundary conditions are set as follows:

	Parameters
Heat-conducting gasket	7.2 W/m·K
Environment temperature	50 °C
Thermal contact resistance	0.56 °C/W

2.4 Analysis of Simulation Results

The final simulation results are shown in Figs. 5 and 6.

Figure 5 shows the open computer temperature cloud diagram; Fig. 6 shows the temperature distribution of the local module.

From the open computer temperature cloud diagram in Fig. 5, it can be seen that the internal maximum temperature is 98.98 °C when the operating conditions are stable. At the same time, it can be seen from Fig. 6 that the highest temperature region is the CPU of the data module. The junction temperature of this CPU is 95 °C, so the temperature is too high, which seriously affects the normal operation of the computer and requires optimization and improvement of the structure.

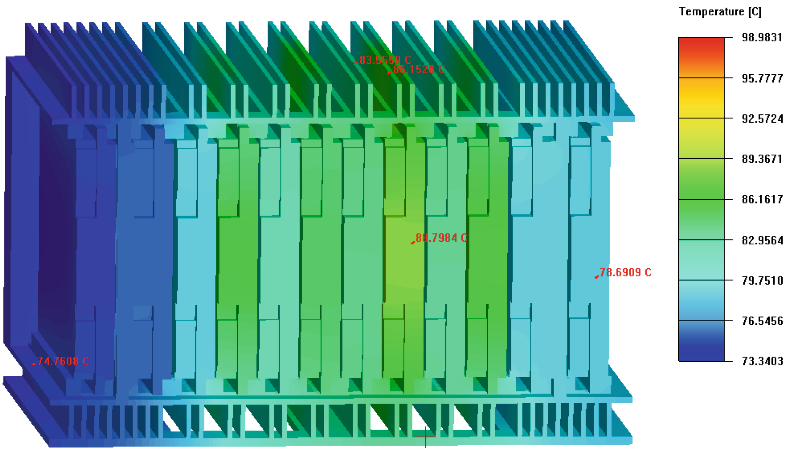

Fig. 5. The temperature of the computer

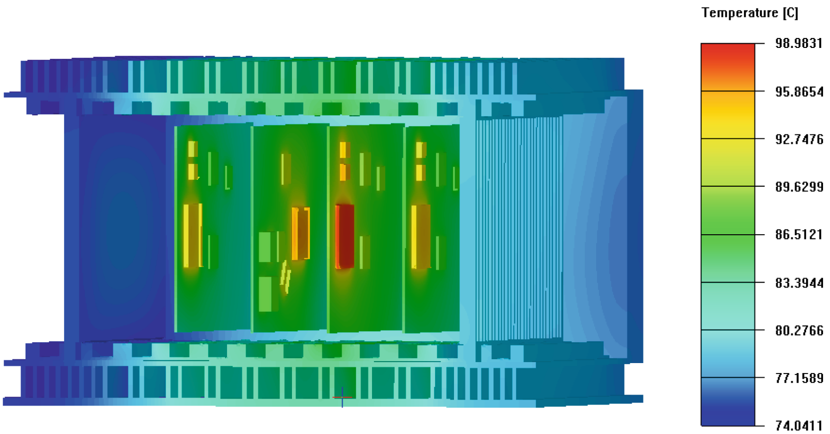

Fig. 6. The local temperature of the module

The temperature distribution of the chassis is analyzed and the following conclusions are drawn based on the analysis results:

(a) As can be seen from the temperature distribution of the heat dissipating fins in Fig. 5, the temperature of the fins corresponding to slot 7 is 83.5 °C. The temperature of corresponding fins in slot 8 is 86.2 °C, and the difference between them is 3 °C. This is because slot 7 corresponds to a power-free waterproof module, and slot 8 corresponds to a high-power data module. However, the existence of a temperature difference of 3 °C also indicates that the heat conduction path of the slot board on the chassis is unreasonable, thereby affecting the heat transfer between the adjacent heat dissipation fins.

(b) It can be seen from Fig. 6 that the CPU temperature of the data module is too high. According to the principle of heat exchange, it can be seen that the chassis and the outside air are cooled by the natural convection heat transfer method. The heat dissipation of this heat exchange method has a large relationship with the heat transfer area. Increasing the heat dissipation effect of the whole machine while changing the heat transfer path is the key to lowering the temperature.

3 Optimization Measures

According to the simulation results, we optimized the chassis as follows:

(a) Open the corresponding slot with high power consumption, and the corresponding slot of the waterproof module does not turn on. This will not only ensure that the heat of the high-temperature main board can be transferred to the outside of the chassis through convection heat transfer, but also optimize and improve the heat transfer path.
(b) Change the cooling fins from the original 3 mm width to 2 mm width, and change the heat dissipation fin pitch from the original 8 mm to 6 mm to increase the effective heat dissipation area of the cooling fins.

The improved open chassis structure is shown in Fig. 7.

Finally, the simulated temperature distribution can be improved as shown in Fig. 8.

It can be seen from Fig. 9 that the maximum temperature of the whole machine after the improvement is 94.85 °C, which is 4 °C lower than the temperature before the improvement. The maximum CPU temperature of the module at this time is 94.8 °C.

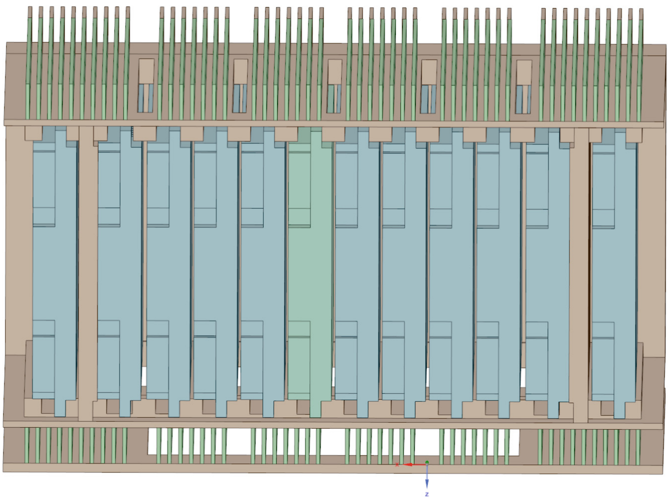

Fig. 7. Schematic diagram of the optimized chassis

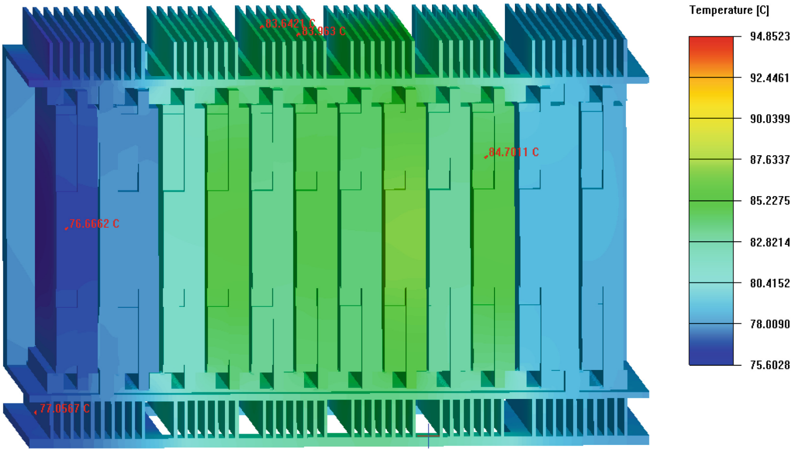

Fig. 8. The temperature of the complete machine after improvement

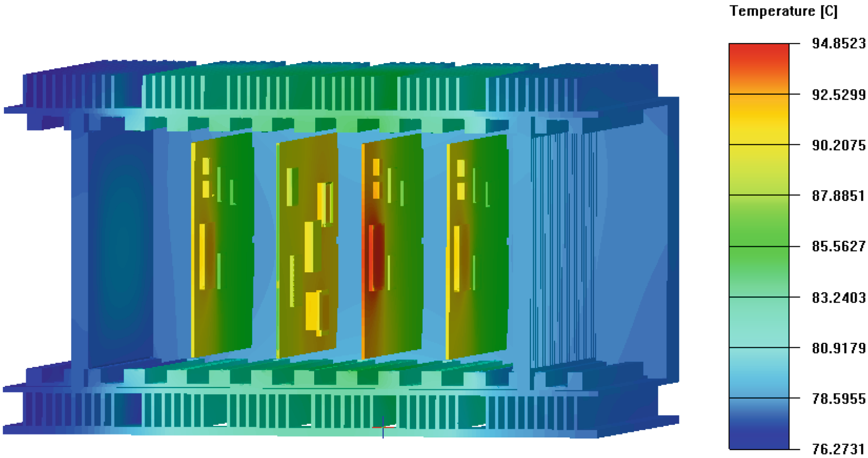

Fig. 9. The temperature of the local module after the improvement

4 Conclusion

This paper optimizes the design of a computer through numerical simulation. By changing the thermal conduction structure of the chassis and the heat dissipation area to enhance the heat dissipation of the computer, increasing the area of the heat dissipation fins can effectively increase the heat dissipation of the computer. The maximum temperature of the computer was reduced from the original 98.98 °C to 94.8 °C, and the CPU can work stably in a safe environment.

References

1. Tang, J., Guo, J., Hou, C., Cheng, Z., Wei, J., Zheng, R.: Research on Secondary Cooling Device for Vehicle-mounted Electronic Equipment. Electro-Mechanical Engineering (2007)
2. Hu, J., Chen, E., Hou, C., Jiang, Y., Zhong, G.: Design of Vehicle Radar Liquid Cooling System - Fluid Machinery (2006)
3. Ren, H., Liu, W., Huang, J., Hong, D.: Icepak Based Thermal Design of Confined Enclosures. Electronic Science and Technology (2015)
4. Li, K., et al.: Structural design and dynamics simulation for anti-adverse circumstance cabinet. Mech. Des. Manuf. **9**(9), 35–37 (2012)
5. Zhao, H., Jiang, J.: The construction design about a military ruggedized cabinet. In: Proceedings of the Conference on Mechanical and Electrical Engineering for the Year 2005. Electronic Industry Press, Nanjing (2005)
6. Yuan, L.: A small cabinet structure and strengthening protection design. Mod. Manuf. Eng. **7**, 123–125 (2012)
7. People's Republic of China National Military Standards, GJB/Z299B-99. The Reliability of Electronic Equipment Design Handbook. The General Armament Department Military Standard Publishing Unit, Beijing (1999)
8. Hui, L.: Reinforced VXI Test Chassis Development. Harbin Institute of Technology, Harbin (2010)
9. Sun, Y.: Electromagnetic shielding design of military portable reinforced computer. Comput. Eng. Appl. **44**(1), 238–239 (2008)
10. Wang, S.: Prediction Research on Shielding Effectiveness of Electronic Equipment Box, p. 3. Harbin University of Science and Technology, Harbin (2010)
11. Lu, H., Yu, Z., Li, W.: Engineering Electromagnetic Compatibility. Xi'an University of Electronic Science and Technology Press, Xi'an (2012)