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Temperature Field Simulation Analysis of Bleeder Resistance Module

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Temperature Field Simulation Analysis of Bleeder Resistance Module

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Abstract. Based on the finite volume method, the Ansys thermal simulation module Icepak is used to simulate the temperature field of the bleeder resistance module in the large resistance cabinet. The temperature distribution of the resistance module during normal operation is obtained. And from the temperature distribution, the working status of the resistance module can be assessed. Based on the thermal analysis, the temperature distribution cloud map of the resistance module under normal operation is obtained; which provides suggestions for optimization of the internal cooling system of the resistance cabinet.

1. Introduction

In this paper, the resistance module is taken as the research object and its temperature distribution is analyzed. On the basis of the resistance module geometry and component parameters, the resistance module model is processed and established[1]. Then the mesh is divided and the calculation conditions are set. Finally, the temperature field of the resistance module is calculated and analyzed in Ansys Icepak[2-3]. The distribution map is summarized and the conclusions of the simulation analysis are summarized to provide suggestions for the optimization of the whole cabinet cooling system.

2.Basic theory of temperature field

2.1Basic theory of heat transfer

Heat transfer is a discipline that studies the law of heat transfer caused by temperature differences. There are two types of heat transfer problems. One is to focus on heat transfer rate and its control problems which is to enhance heat transfer, reduce equipment size, increase production capacity. The other is to focus on temperature distribution and its control issues.

2.2Basic way of heat transfer

Heat transfer can be summarized in three basic ways due to its different mechanisms. They are heat conduction, heat convection and heat radiation[4]. Heat conduction refers to the phenomenon of heat transfer caused by the thermal motion of microscopic particles such as molecules, atoms and free electrons between objects that are in contact with each other with different temperatures, or between different parts of the temperature inside the object[5]. The heat conduction expression is defined as:

$$Q = -\lambda A \frac{\partial T}{\partial x} \quad (1)$$

Where: Q is the heat conduction heat flow rate; λ is the thermal conductivity of the material; A is the cross-sectional area perpendicular to the direction of heat conduction; $\frac{\partial T}{\partial x}$ is the temperature gradient along the normal direction of the isothermal surface.

2.3Control equation

Fluid motion must follow three sets of equations, including mass conservation equations, energy conservation equations and momentum conservation equations[6-7]. Mass conservation equation is defined as:

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0 \quad (2)$$

Where: ρ is the density of the fluid; *u, v, w* are the speeds in the three directions of X, Y, and Z. Energy conservation equation is defined as:

$$\frac{\partial(\rho T)}{\partial t} + \frac{\partial(\rho u T)}{\partial x} + \frac{\partial(\rho v T)}{\partial y} + \frac{\partial(\rho w T)}{\partial z} = \frac{\partial}{\partial x}\left(\frac{\lambda}{C_p}\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\lambda}{C_p}\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(\frac{\lambda}{C_p}\frac{\partial T}{\partial z}\right) S_T \quad (3)$$

Where:C_p is the constant heat capacity; T is the temperature; S_T is the viscous dissipation term. Momentum conservation equation includes three direction momentums. X direction momentum is defined as:

$$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho uu)}{\partial x} + \frac{\partial(\rho uv)}{\partial y} + \frac{\partial(\rho uw)}{\partial z} = -\frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left(\mu\frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(\mu\frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu\frac{\partial u}{\partial z}\right) + S_u \quad (4)$$

Y direction momentum is defined as:

$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho vu)}{\partial x} + \frac{\partial(\rho vv)}{\partial y} + \frac{\partial(\rho vw)}{\partial z} = -\frac{\partial p}{\partial y} + \frac{\partial}{\partial x}\left(\mu\frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial y}\left(\mu\frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu\frac{\partial v}{\partial z}\right) + S_v \quad (5)$$

Z direction momentum is defined as:

$$\frac{\partial(\rho w)}{\partial t} + \frac{\partial(\rho wu)}{\partial x} + \frac{\partial(\rho wv)}{\partial y} + \frac{\partial(\rho ww)}{\partial z} = S_w - \frac{\partial p}{\partial z} + \frac{\partial}{\partial x}\left(\mu\frac{\partial w}{\partial x}\right) + \frac{\partial}{\partial y}\left(\mu\frac{\partial w}{\partial y}\right) + \frac{\partial}{\partial z}\left(\mu\frac{\partial w}{\partial z}\right) \quad (6)$$

Where: *u, v, w* are the speeds in the three directions of X, Y, and Z; S_u、S_v、S_w is the generalized source term of the momentum conservation equation.

3.Establish temperature analysis model

3.1Structural composition

The structure of the resistance module is shown in Figure 1. The electrode is used to connect external circuits and input electric energy. There are a total of 8 resistance elements which are heat soureces when the module works. The electrode is used for electrical connection of the resistance elements. Water cooling is used to take away heat that is produced by resistance elements. There is a insulation between the electrode and the water cooling plate. The insulation is composed of 0.3mm rubber pad, 0.075mm polyimide film and 0.3mm rubber pad(not shown in the figure due to the small thickness).

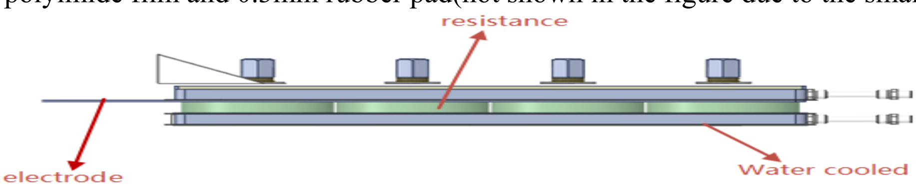

Figure 1. Schematic diagram of the bleeder resistance module

According to the second law of thermodynamics, the heat transfer in the resistance module is shown in Figure 2.

Figure 2.Schematic diagram of heat transfer in the bleeder resistance module

In geometric model of resistance module, the most components are CAD bodies which will lead to complex analysis of temperature field of resistance module. So it is necessary to simplify method before temperature field analysis. The methods to simplify the model are listed as follows:

1) External air is not established during modeling. It is specified that all solid boundaries are insulation except the contact surfaces.

2) The thermal contact resistance between components is not considered.

3) Since the water-cooling plate in the model is an irregular CAD body, the water-cooling plate is cut into a small part of irregular CAD arc bodies and regular cylinders.

After model processing, the water cooling model and the final analysis model of resistance module are shown in figures 3 and figure 4 respectively.

Figure 3 .Water-cooling model

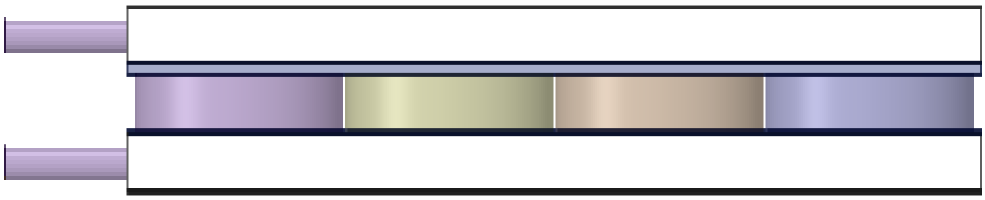

Figure 4.Overall model of the resistance module

3.2Meshing

In the analysis model, a small part of the CAD bodies are divided by the Mesher-HD mesh type, and the remaining regular models are divided by the Hexa Unstructrued mesh type. A grid screenshot of resistance elements and water cooling are shown in figure 5 and figure 6 respectively. In order to better capture the temperature gradient, at least two layers of mesh are divided in the thickness direction of the electrode plate, the silicone pad, the polyimide film and the stainless steel.

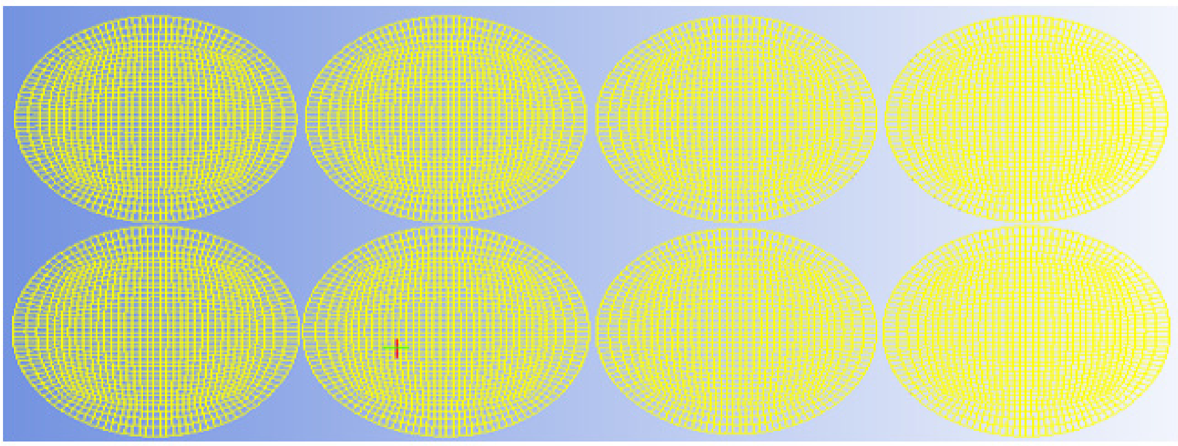

Figure 5. Grid diagram of the resistance elements

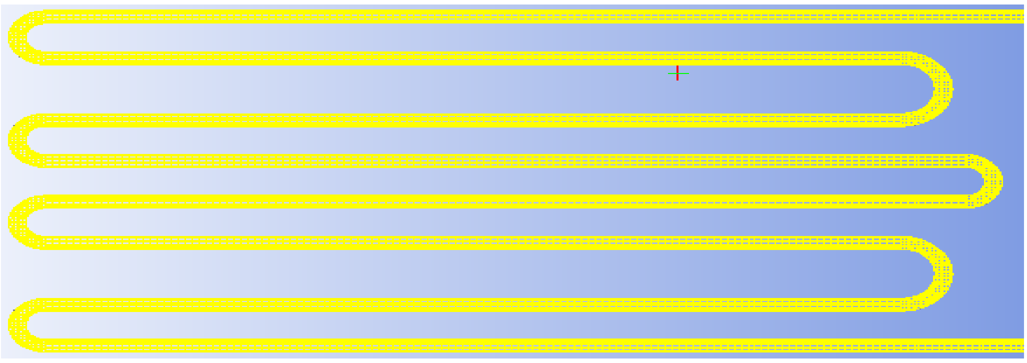

Figure 6. Grid diagram of water cooling plate

3.3Boundary conditions

The physical parameters of the temperature field analysis of resistance module are set which are listed in table 1.

Table 1.Parameters of the main device

Device	Material	Density (kg/m^3)	Specific heat (J/kg·K)	Heat conductivity (W/m·K)
resistance	Carbon material	2610	700	5.1
pipeline	Steel-316L	7980	870.9	16.2
electrode	AL-5052	2680	899.3	138
water	water	997.6	4181.7	0.62
rubber	rubber	2600	1040	1.5
polyimide	polyimide	1400	1090	0.3
Watercooled	AL-A356	2760	728.3	159

The water cooling inlet boundary conditions are specified according to the test conditions, that is, the inlet temperature is T_0=24℃;and the cooling water inlet flow rate is 1.247 m/s.

4.Simulation results and analysis of temperature field of resistance module

4.1System temperature field simulation results

The temperature field simulation of the resistance element is shown in figure 7.

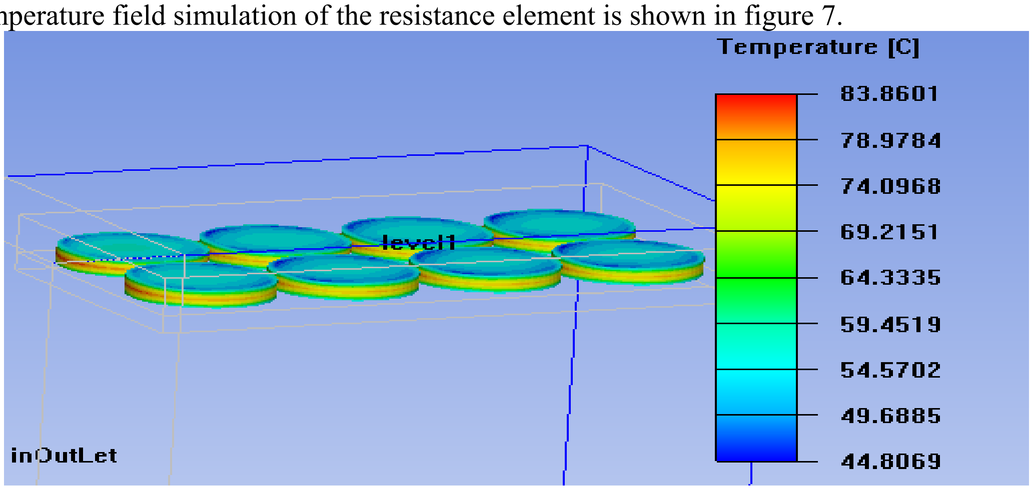

Figure 7. Temperature distribution graph of the resistance elements

From the temperature distribution of resistance elements above, the resistance elements have the highest temperature near the water outlet, about 84 ° C, and it can guarantee normal operation within its maximum tolerance.

The water temperature field in water cooling is shown in figure 8.

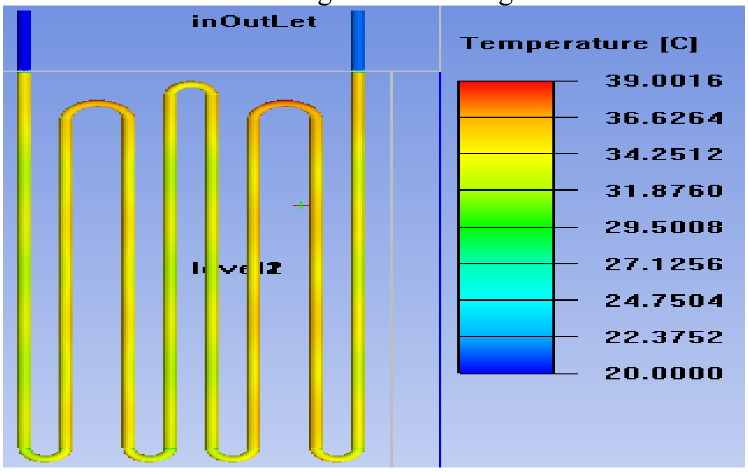

Figure 8. Water temperature cloud map

The temperature of water near the inlet is at the lowest, about 20 °C. When water flow through the water-cooling plate, its temperature is the higher and the highest temperature is about 39 °C. When water flow into the outlet, its temperature drops obviously, about 25 °C (Higher than the inlet temperature) .

4.2Analysis of simulation results

According to the simulation results and analysis of the system temperature field in section 4.1, the results can be gotten as follows.

1) The simulation results are in accordance with the second law of thermodynamics. The simulation algorithm has certain credibility and can provide reference for further improvement of the structure.

2) The error is within the allowable range of engineering calculation. The results can provide a certain reference for the temperature field simulation of the whole cabinet of the resistance cabinet.

3) Under the conditions of the water cooling inlet temperature is 20 °C and the water volume is 1.247 m⁄s, the temperature of resistance elements, electrode plate and the insulating layer are all within the highest tolerance range of the device. It indicates that the performance of the insulation layer, the electrode plate and the parameter design are reasonable. The normal heat dissipation requirement of the resistance elements can be ensured.

5.Conclusion

By analyzing the temperature field simulation of the resistance module, the following conclusions and recommendations can be drawn:

1) From the distribution of the fluid inside the resistance module, the water flows from the water inlet, and then flows through the water cooling plate and flows out from the water outlet. The flow path of the water conforms to the design route.

2) The amount of water entering the resistance module is basically equal to the amount of water discharged, which indicates that the overall layout inside the module is reasonable.

3) The temperature of resistance elements, electrode plate and the insulating layer is all within the highest tolerance range of the device. And there is still a certain redundancy from the highest temperature parameter of the device, which indicates that the performance and parameter design of the module are reasonable and can guarantee normal heat dissipation requirements of components.

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