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Research on IGBT Thermal Management of New Energy Vehicle Drive Motor Controller Based on CFD

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Abstract: In the context of severe global environmental issues, new energy vehicles have become an important strategic direction for countries to promote green travel with low carbon emissions. The electric drive system is the core power source of new energy vehicles. Among them, the motor controller is extremely important, and IGBT is the core component of the drive motor controller. IGBT is composed of BJT and MOS. When the battery discharges to drive the motor, it converts direct current into alternating current and controls the alternating current motor. The IGBT module generates a large amount of heat during operation. An increase in temperature will increase the failure probability, affect performance and reduce the working life. Based on the CFD method, this paper uses Fluent software to study the heat dissipation process of traditional IGBT, analyzes the internal flow field and temperature field, provides data support and technical support for the development of a new high-efficiency heat dissipation system, and is of great significance for promoting the development of new energy electric vehicles.

Keywords: IGBT; Heat dissipation; CFD

1. INTRODUCTION

Under the continuous aggravation of global environmental issues, new energy vehicles have attracted wide attention due to their characteristics of low carbon emissions and have become a key strategic direction for countries to promote green travel [1]. As the core power source of new energy vehicles, the performance of the electric drive system directly determines the overall performance of new energy vehicles. The electric drive system is mainly composed of parts such as motors, controllers, power supplies, transmission systems, and charging systems. In this complex system, the motor controller plays a crucial role. And in the drive motor controller, IGBT (Insulated Gate Bipolar Transistor) is regarded as the most core element [2].

IGBT is a composite fully controlled voltage-driven power semiconductor device composed of BJT (bipolar junction transistor) and MOS (insulated gate field effect transistor). When the battery discharges to drive the motor, through the circuit composed of IGBT, direct current can be converted into the alternating current required by the alternating current motor, and at the same time, the frequency conversion and voltage transformation of the alternating current motor are controlled. The IGBT module will generate a large amount of heat during the working process and is the main heat source of the motor controller. As the temperature rises, the failure probability of the IGBT power module will increase significantly. When the working temperature is too high, the internal parameters of the device and the semiconductor physical constants will change, resulting in deteriorated performance such as switching off speed, on-state voltage drop, current tailing time and loss. The IGBT module cannot work normally and even reduces its working life [3].

Based on the CFD method, this paper uses Fluent software to study the heat dissipation process of traditional IGBT, analyzes the internal flow field and temperature field in the IGBT heat dissipation process, provides data support and technical support for the development of a new and efficient IGBT heat dissipation system, and is of great significance for promoting the development of new energy electric vehicles.

2. PHYSICAL MODEL

The model of the traditional IGBT heat dissipation module is as follows: it contains six IGBT chips with a uniform size of 15mm×20mm×1.5mm. In addition, there is a liquid-cooled plate with an IGBT liquid-cooled channel, which has a size of 156mm×82mm×12mm (the flow channel depth is 10mm), and a flat liquid-cooled plate with a size of 156mm×82mm×2mm.

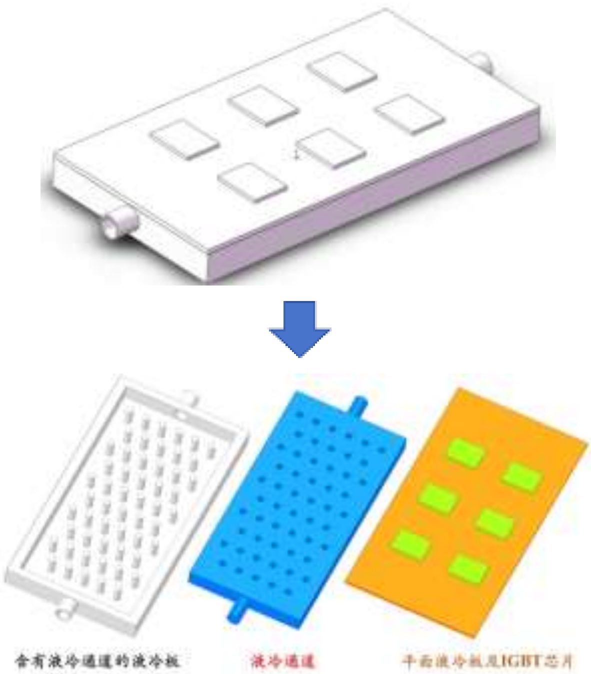


Figure. 1 Three-dimensional model of traditional IGBT heat dissipation module

3. MESH GENERATION AND BOUNDARY CONDITION SETTING

Fluent Meshing is used to divide the mesh of the IGBT heat dissipation model. In this study, the polyhedral mesh in Fluent Meshing is used to divide the meshes of the two IGBT heat dissipation models. This can not only reduce the number of meshes but also improve the calculation efficiency and solution accuracy. Figure 2 shows the mesh models of two IGBT heat dissipation modules.

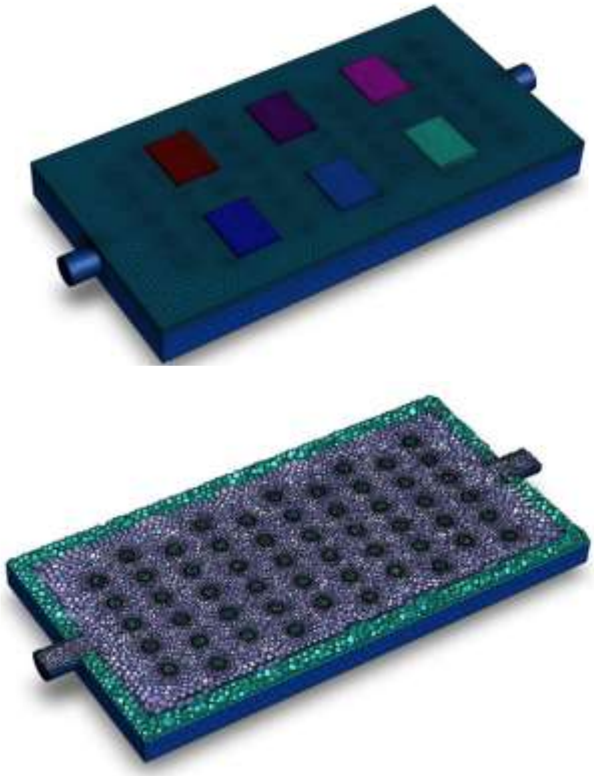
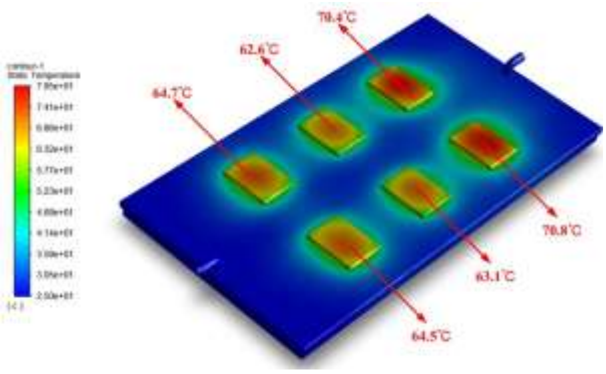


Figure. 2 Mesh model

In the simulation process, the k-ε turbulence model is used for calculation. The coolant adopts the boundary conditions of mass flow inlet and pressure outlet respectively. The inlet mass flow of the coolant is 0.163 kg/s, the inlet temperature is 25°C, the outlet pressure is atmospheric pressure, and the temperature of each interface is set as interface surface coupling transfer. A natural convection boundary is set on the surface of the IGBT heat dissipation model, and the convective heat transfer coefficient is determined to be 5 W/(m2·K), and the ambient temperature is 25°C. Based on the finite volume method to solve the control equation, the Standard pressure discretization format is selected, the transient calculation method is adopted, the initial time step is set to 0.001 s, and the step size is appropriately increased after the calculation is stable. The final time step is 1 s, the number of iterative calculation steps is set to 50, and the total simulation time is 1000 s.



4. MATERIAL PARAMETERS

Liquid water is selected as the cooling heat material, Si material is selected for the IGBT chip, Cu material is selected for the flat liquid-cooled plate, and aluminum alloy material is selected for the liquid-cooled plate with a liquid-cooled channel. The specific parameters of the selected materials are shown in Table 1.

Table 1. Parameters of selected materials

Name	Density/（kg/m^3）	Thermal conductivity/（W/m/K）	Specific heat capacity/（J/kg/K）
Si	2329	124	702
Cu	8940	398	386
Aluminum alloy	2800	193	880

5. RESULTS

Figure 3 shows the internal flow field of the IGBT heat dissipation module. As can be seen from the figure, the flow velocity at the inlet of the traditional IGBT heat dissipation structure is relatively large, while the flow velocity at the outlet is relatively uniform but the value is low, and there is obvious non-uniformity. This situation is easy to cause uneven temperature distribution of IGBT.

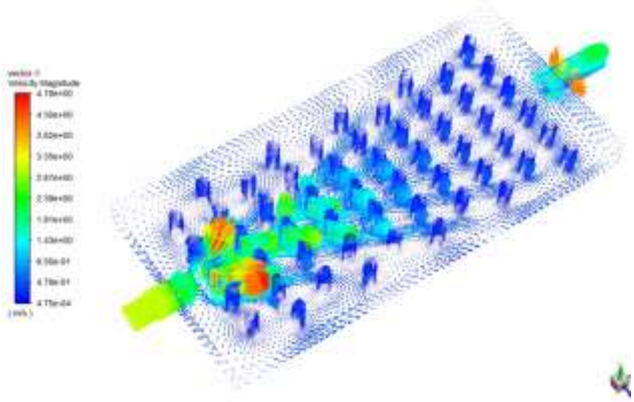


Figure. 3 Flow field distribution

Figure 4 shows the temperature distribution nephogram of the IGBT heat dissipation module. As can be seen from this figure, the temperature distribution of IGBT has great non-uniformity. The chip temperature at the inlet is relatively low, while the chip temperature at the outlet is relatively high. The maximum temperature difference can reach 8.2°C.

Figure. 4 Temperature field distribution

6. SUMMARY

Based on the CFD method, this paper uses Fluent software to study the heat dissipation process of IGBT in the drive motor controller of new energy vehicles. New energy vehicles are the strategic direction of green travel. The core of the electric drive system is the motor controller. IGBT is a key component and the heat dissipation problem affects its performance and lifespan. Through the physical model, including the sizes of IGBT chips, liquid-cooled plates, etc., the mesh generation and boundary condition settings are explained. Polyhedral meshes are used for division, and turbulence models, coolant boundary conditions, etc. are set.

Analyze different material parameters. For example, the cooling heat material is liquid water, and materials such as Si, Cu, and aluminum alloy are selected for different components. The research results show that the flow field analysis shows that the traditional IGBT heat dissipation structure has a large inlet flow velocity, a low and uneven outlet flow velocity, resulting in uneven temperature distribution; the temperature field analysis shows that there is a large non-uniformity in the temperature distribution of IGBT, and the maximum temperature difference reaches 8.2℃. This research provides data support and technical support for the development of a new and efficient IGBT heat dissipation system and is of great significance for the development of new energy electric vehicles.

7. ACKNOWLEDGMENTS

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