International Journal of Science and Engineering Applications
Volume 13-Issue 11, 65 – 67, 2024, ISSN:- 2319 - 7560
DOI: 10.7753/IJSEA1311.1014

Optimization Design of IGBT Liquid Cooling Channel for Drive Motor Controller Based on Dendritic Bionic Theory

Weiwu Xu
College of Automotive Engineering
Zibo Vocational Institute
Zibo, China

Rongxin Cao
College of Automotive Engineering
Zibo Vocational Institute
Zibo, China

Yu Wang
College of Automotive Engineering
Zibo Vocational Institute
Zibo, China

Wenjing Xu
College of Automotive Engineering
Zibo Vocational Institute
Zibo, China

Hao Wang
College of Automotive Engineering
Zibo Vocational Institute
Zibo, China

Longjing Li
College of Automotive Engineering
Zibo Vocational Institute
Zibo, China

Abstract: Based on the dendritic bionic theory, this paper designed a heat dissipation model of the IGBT liquid cooling channel. ANSYS Workbench software was used for simulation studies of its internal flow field and temperature field. Results indicate that subsequent efforts can commence from optimizing the flow channels to make the flow field distribution more uniform. Besides, the designed IGBT heat dissipation module satisfies the heat dissipation requirements.

Keywords: IGBT; dendritic bionic theory; ANSYS Workbench

1. INTRODUCTION

Drive motor controllers are of crucial significance in the automotive field. Among them, the Insulated Gate Bipolar Transistor (IGBT)[1, 2], as the core power device of the controller, has its performance and reliability directly influencing the operation of the whole system. Under high - power operation conditions, the IGBT generates a large amount of heat. If the heat fails to be dissipated effectively, the chip temperature will be too high, thereby affecting its electrical performance, shortening its service life, and even causing malfunctions.

Traditional cooling methods are increasingly showing their limitations when handling the ever - growing heat dissipation requirements. Liquid cooling technology has become a research focus because of its highly efficient heat dissipation performance. Nevertheless, the existing designs of liquid cooling channels frequently have issues like uneven coolant flow, inability to effectively eliminate local hot spots, and relatively large pressure losses. These problems have restrained the improvement of the heat dissipation efficiency and overall performance of the liquid cooling system.

The dendritic bionic theory offers new thoughts for resolving these problems. The dendritic structures in nature exhibit highly efficient capacities for material transport and energy distribution. The hierarchical network ranging from tree roots to branches can achieve the optimal allocation and even distribution of resources. By borrowing the features of such dendritic structures, innovative designs can be conducted for the liquid - cooling channels of the IGBT in drive motor controllers.

2. Model

2.1 Physical model

The heat dissipation model of the IGBT liquid cooling channel which is designed based on the dendritic bionic theory is presented in Figure 1.

Figure 1 IGBT Liquid Cooling Channel Model

2.2 Mesh model

The polyhedral meshes within Fluent Meshing were utilized to partition the grid of the IGBT heat dissipation model. The ultimately partitioned grid model is depicted in Figure 2, and the number of meshes amounts to 900000.

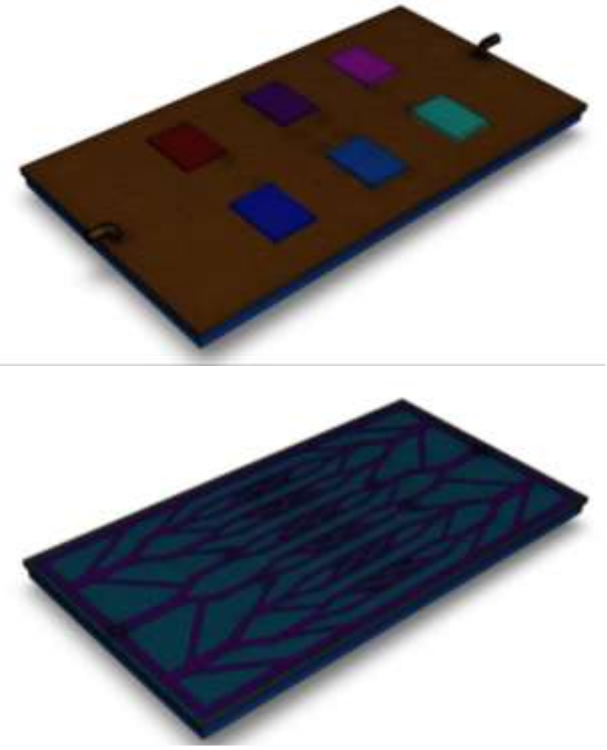

Figure 2 IGBT Mesh Model

3. Boundary Conditions and Material Settings

The simulation was conducted under the boundary conditions of velocity inlet and pressure outlet. The cooling medium was water. The material chosen for the IGBT chip was Si, the material of the planar liquid cooling plate was Cu, and the liquid cooling plate equipped with liquid cooling channels was fabricated from aluminum alloy. The material parameters are presented in Table 1.

Table 1 Parameters of the 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

4. Result

Figure 3 shows the internal flow field of the IGBT heat dissipation module. It can be observed from the figure that the flow velocity within the flow channel situated in the middle part of the IGBT is relatively high, whereas the flow velocities in the flow channels on both sides are relatively low. However, overall, the distribution of the flow velocity is relatively even.

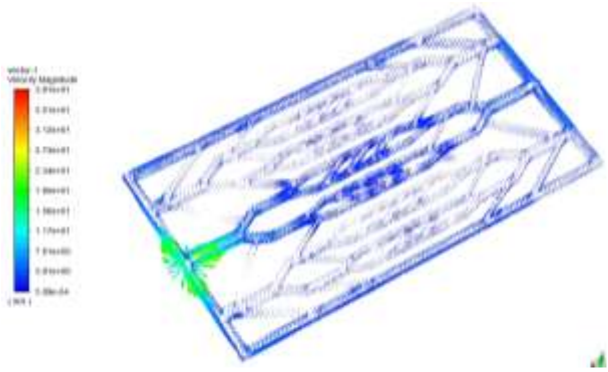

Figure 3 Internal Flow Field of IGBT Heat Dissipation Module

Figure 4 presents the temperature field of the IGBT heat dissipation module. It can be noticed from the figure that the maximum temperature of the IGBT chip is 70.8°C, while the minimum temperature is 62.6°C. Given that the maximum operating junction temperature of the IGBT chip is typically 150°C, the designed IGBT heat dissipation module fulfills the usage requirements.

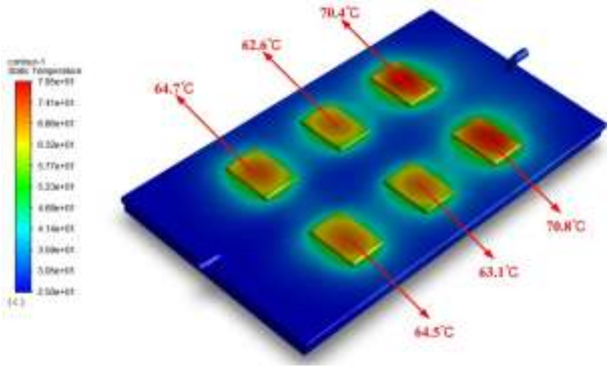

Figure 4 Temperature Field of IGBT Heat Dissipation Module

5. Conclusion

Based on the theory of dendritic bionic design, this paper conducted a bionic optimization design on the heat dissipation structure of IGBT. Additionally, the internal flow field and temperature field were simulated and studied with the application of ANSYS Workbench software. The following conclusions can be reached:

（1）The flow velocity within the flow channel section in the middle of the IGBT is relatively high, whereas that in the flow channels on both sides is relatively low. In the subsequent optimization and enhancement work, attempts can be made from this perspective to further optimize the flow channels and render the flow field distribution more even.

（2）The maximum temperature of the IGBT chip reaches 70.8°C, which is beneath the maximum operating junction temperature of the IGBT chip. Consequently, the designed IGBT heat dissipation module satisfies the usage requirements.

6. ACKNOWLEDGMENTS

The author sincerely thanks the College of Automotive Engineering, Zibo Vocational Institute for its strong support of this research.

7. REFERENCES

[1] Li, G. Liu, S.H. and Wang Y.K. Numerical Analysis of the Heat Transfer Characteristics of the Heat Dissipation Structure for High-Power IGBT Modules[J]. Motor Technology, 2024, (03): 38-42.

[2] Zhang, X. Tu, C. and Yan, Y. Physics-informed neural network simulation of conjugate heat transfer in manifold microchannel heat sinks for high-power IGBT cooling[J]. International Communications in Heat and Mass Transfer, 2024, 159: 108036-108036.