

A Simulation Investigation into HPD Power Modules

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Abstract

HPD power semiconductor modules are widely used in new energy vehicles, serving as the core of the entire automotive power conversion system and playing a critical role in ensuring the stable operation of functions such as vehicle driving and charging. This paper employs simulation methods to investigate the stray inductance and operating temperature of IGBT modules, the impact of fluid flow velocity on chip temperature, and the effect of pin-fins with different shapes on the heat dissipation performance of the modules.

Three-Dimensional Model

Name	Material	d(mm)	k(W/m*K)
Chip	Si	0.12	100
Solder	SAC305	0.1	67
AMB-Cu	copper	0.3	394
AMB	Si3N4	0.32	90
Solder-2	SnSb10	0.2	55
Heat sink	copper	3+6	394

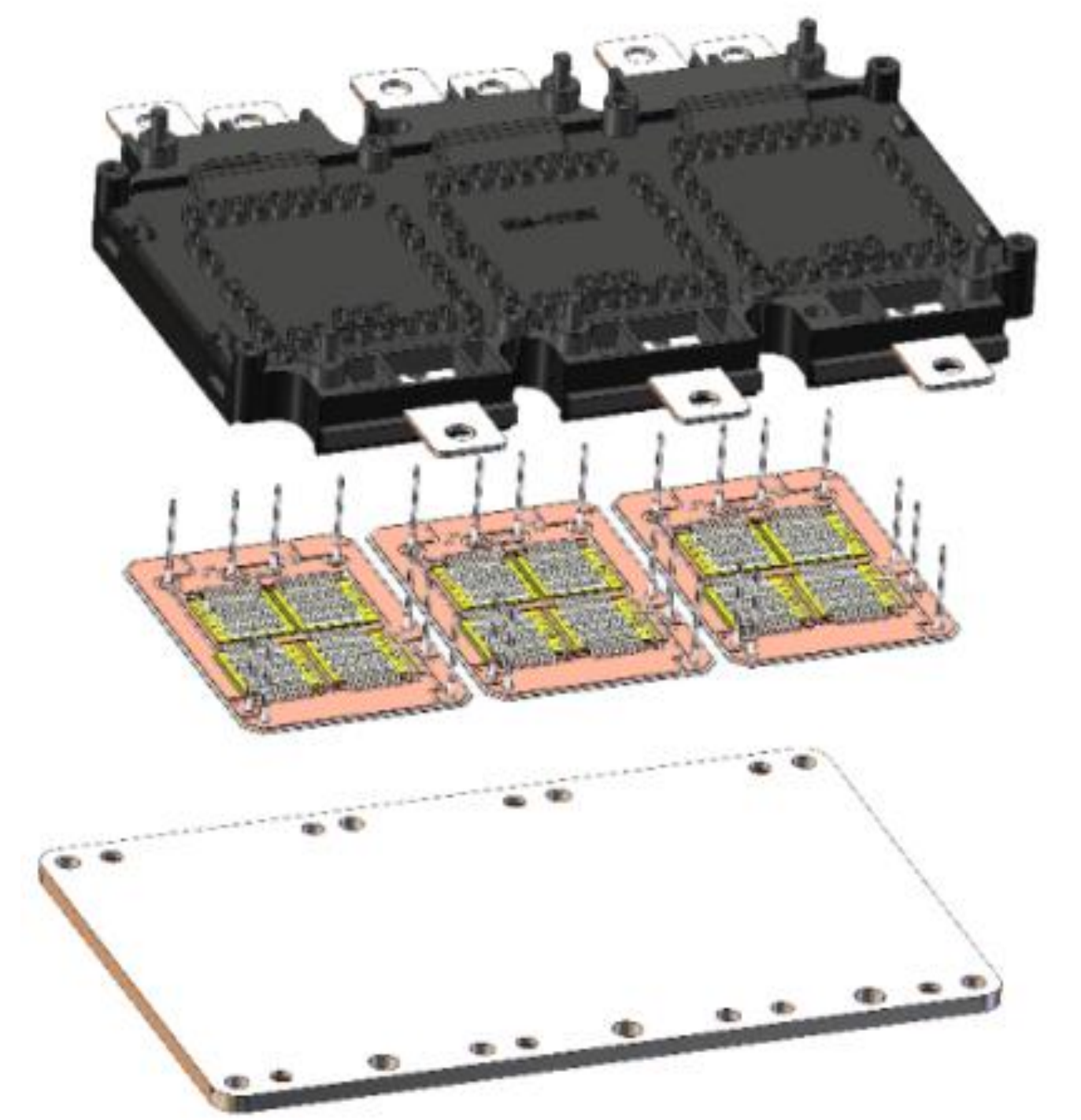


Figure 1. Exploded 3D view of HPD module.

The Stray Inductance and Power Loss Simulation

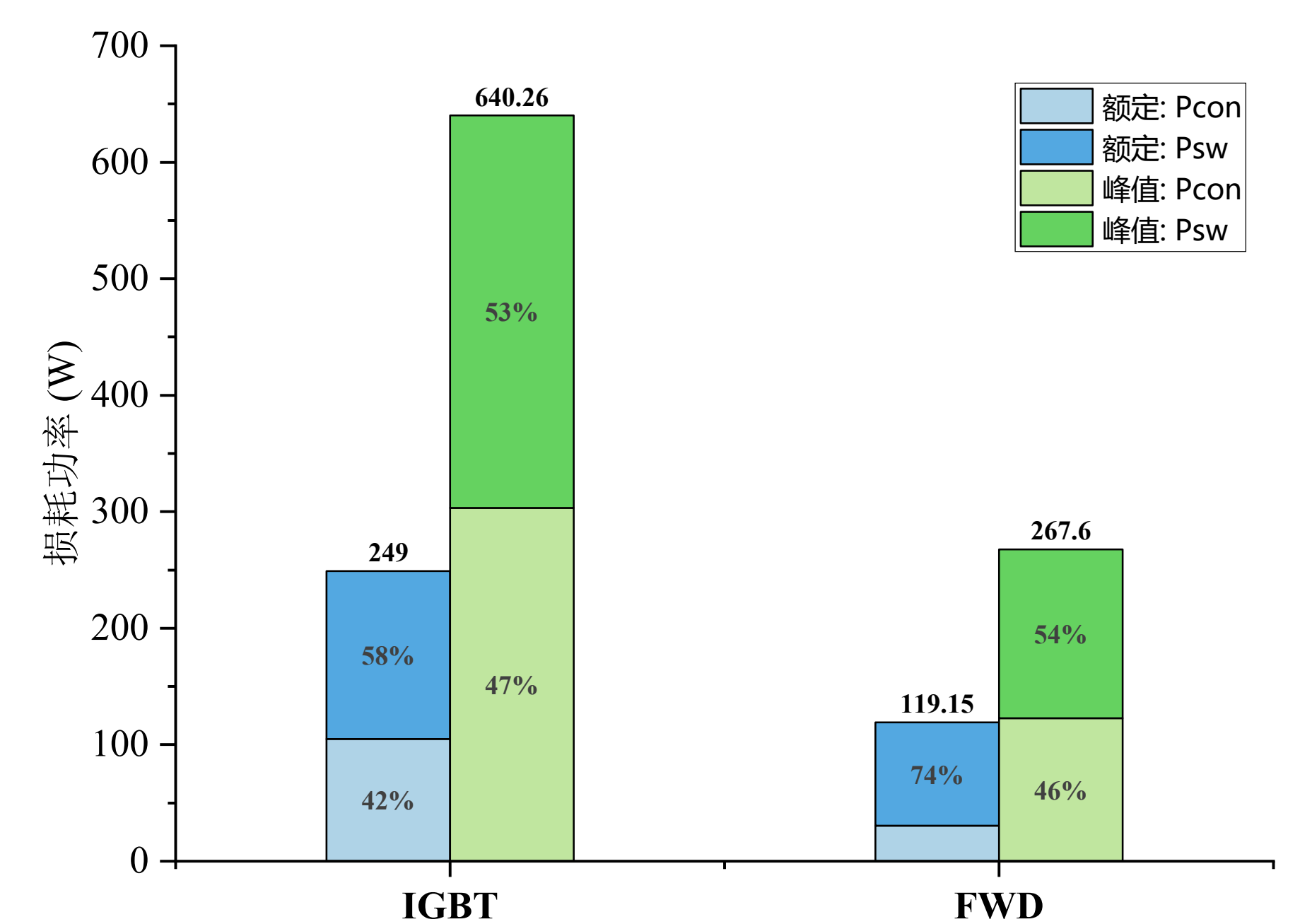
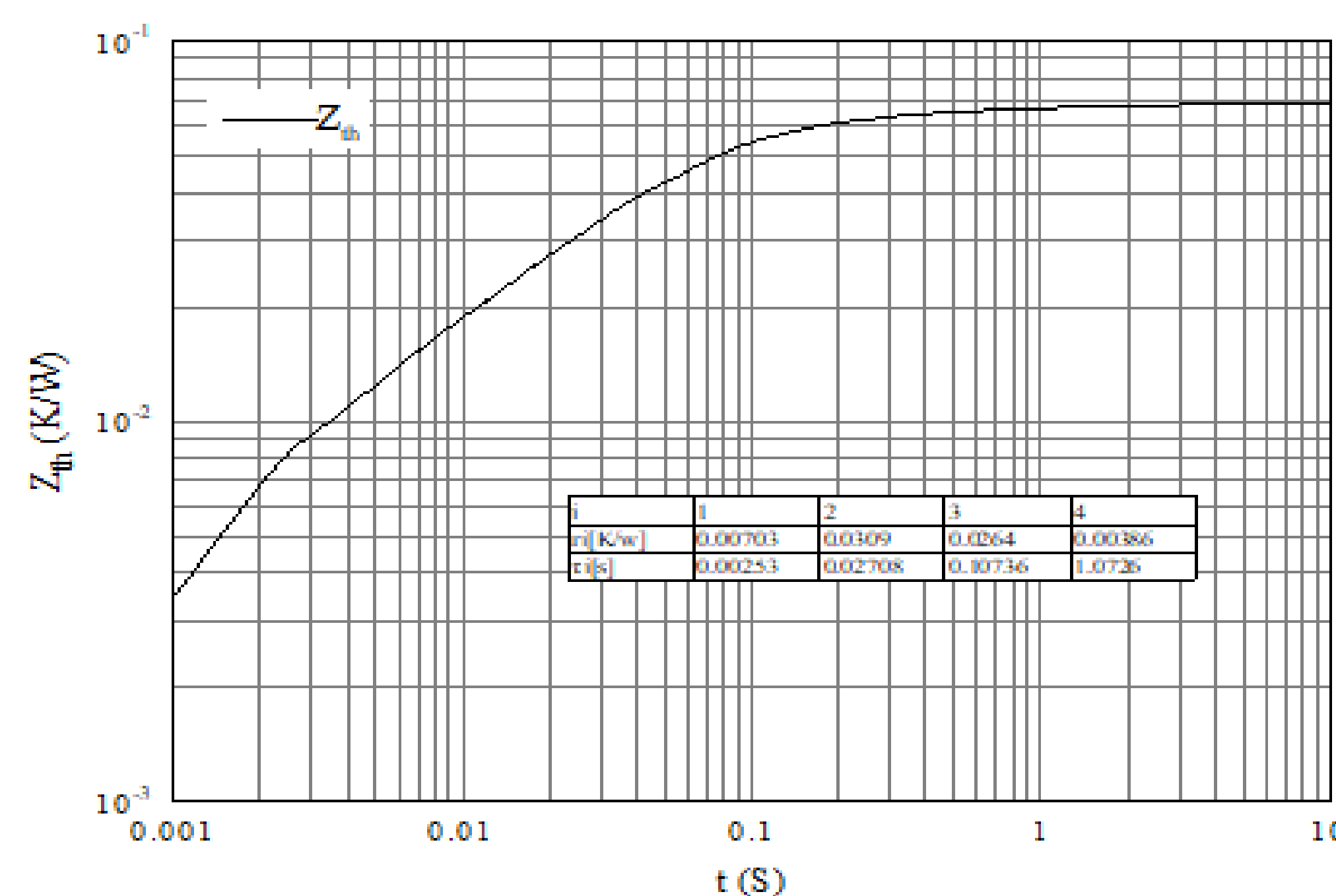
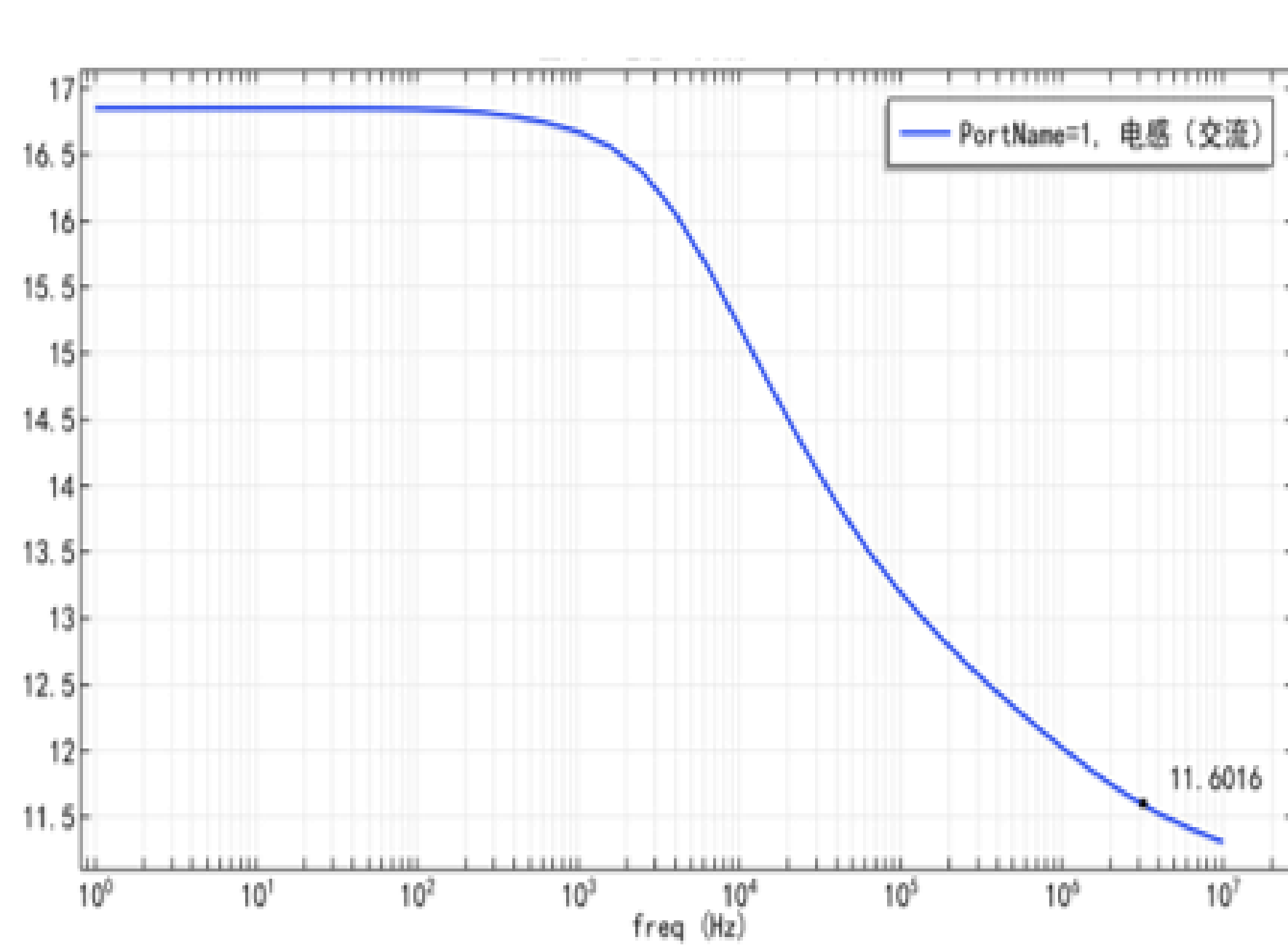


Figure 2. The curve of stray inductance. **Figure 3.** The curve of thermal resistance **Figure 4.** The power loss of HPD module

The Temperature Simulation

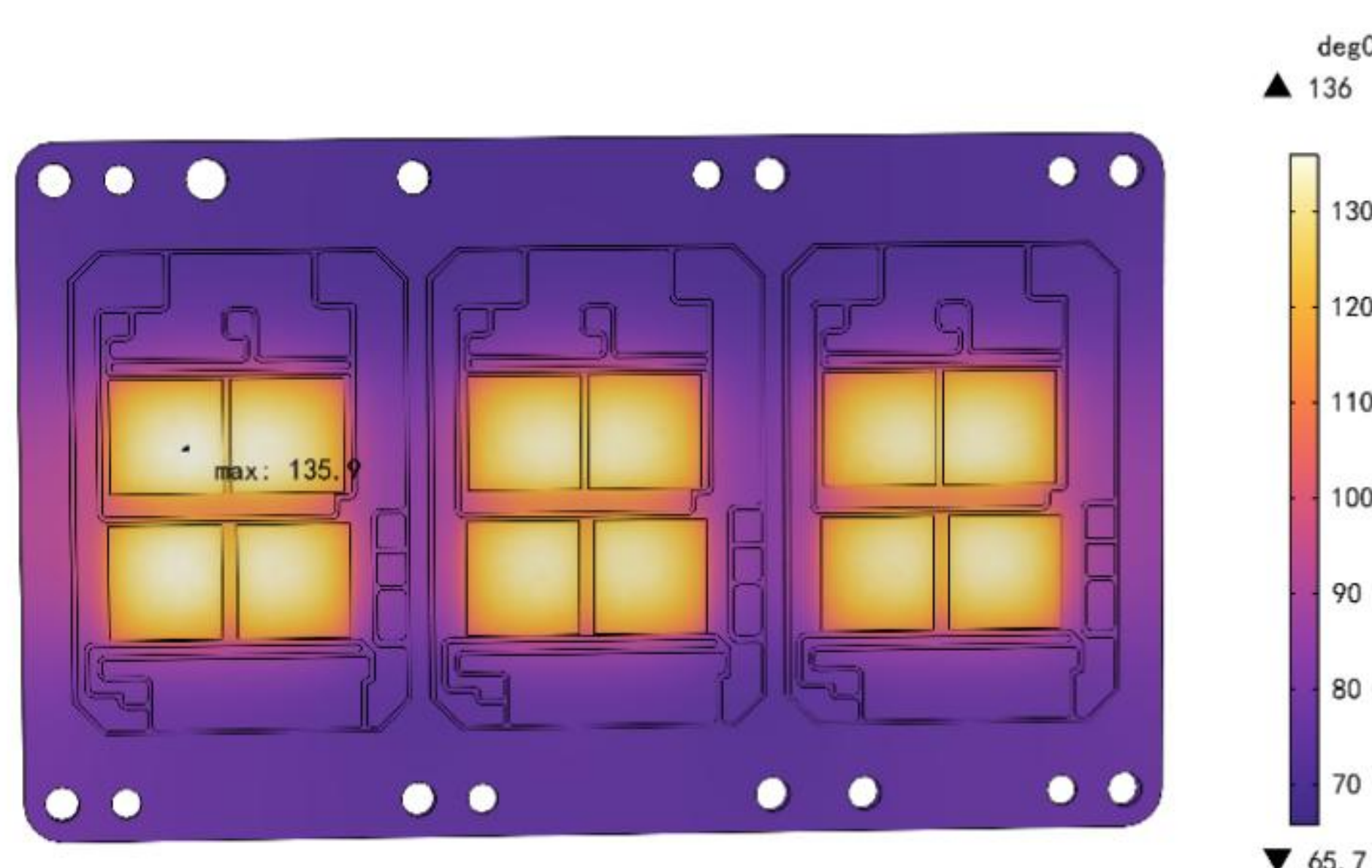


Figure 5. The temperature distribution of HPD module

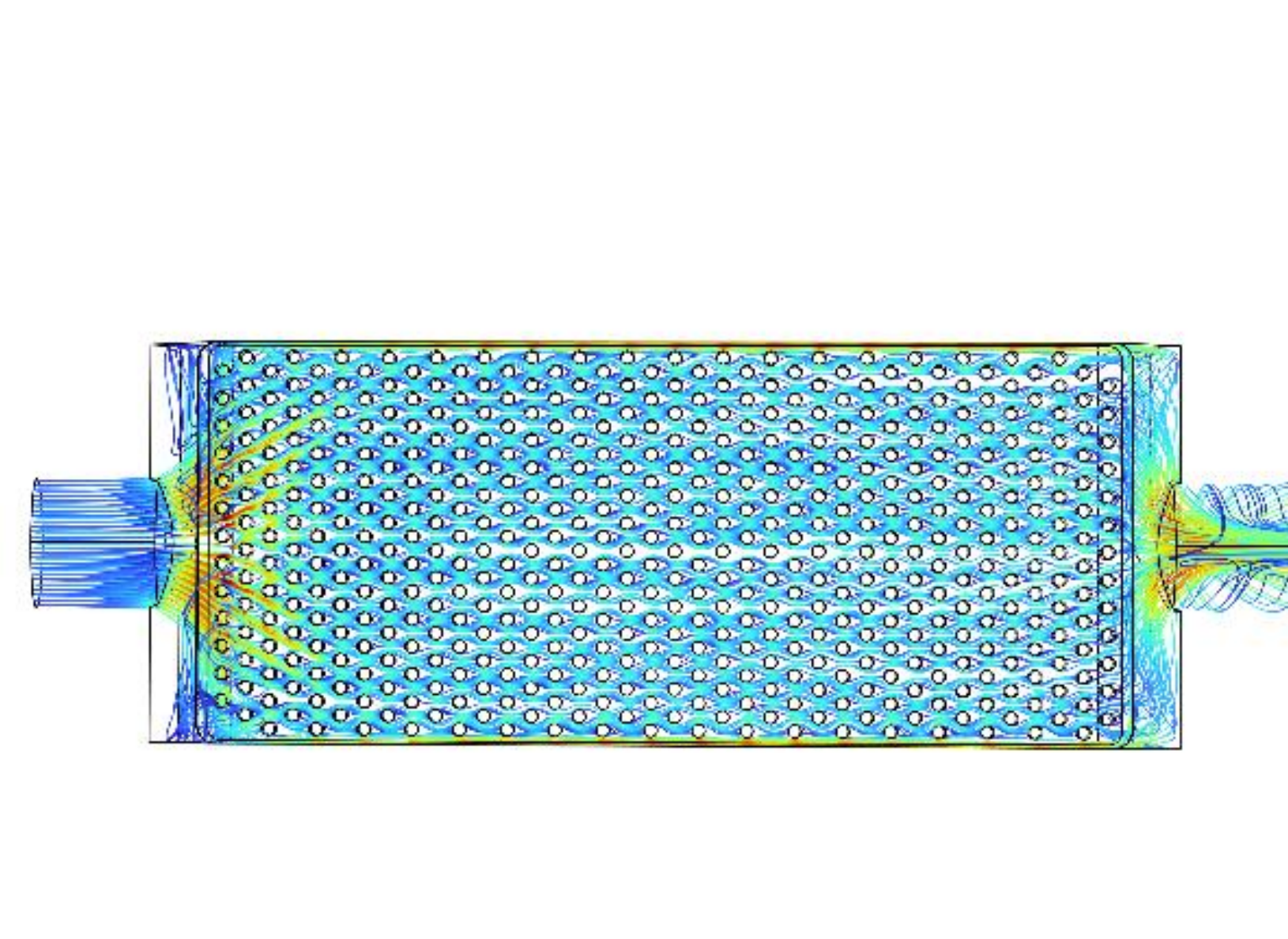


Figure 6. The flow velocity distribution of coolant

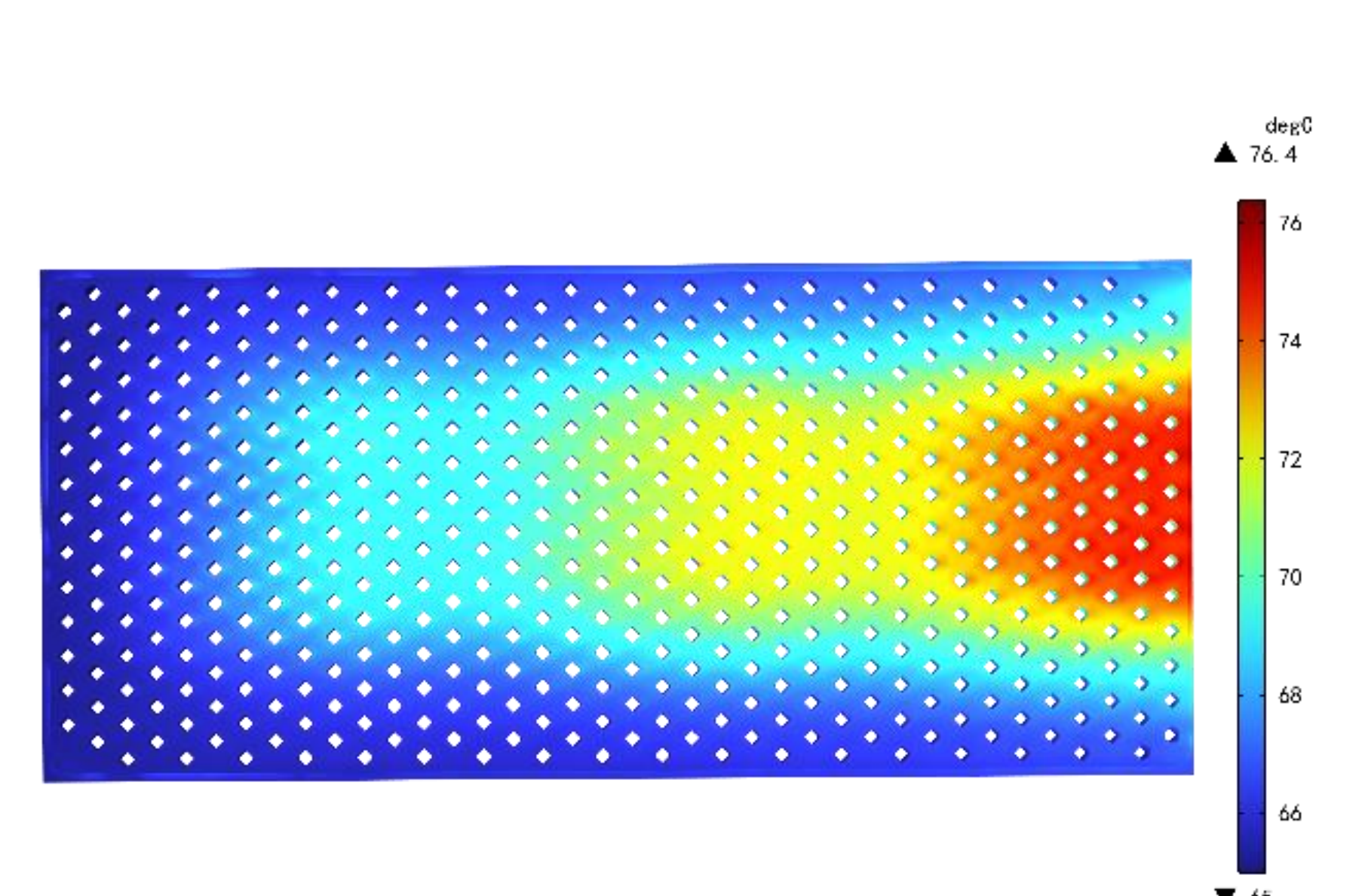


Figure 7. The temperature distribution of coolant

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The temperature simulation of module B

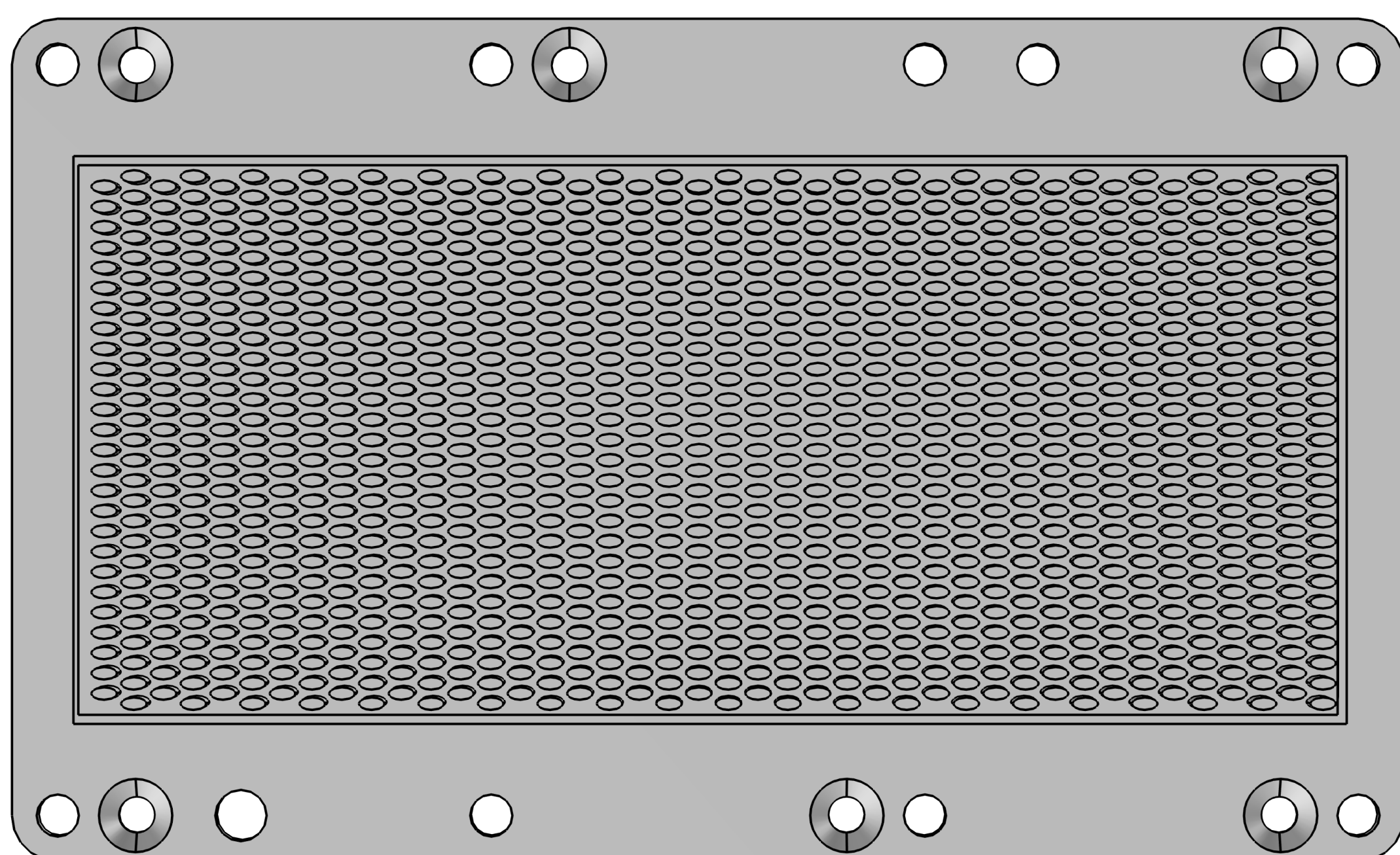


Figure 8. The HPD module of elliptical cylindrical pin-fins

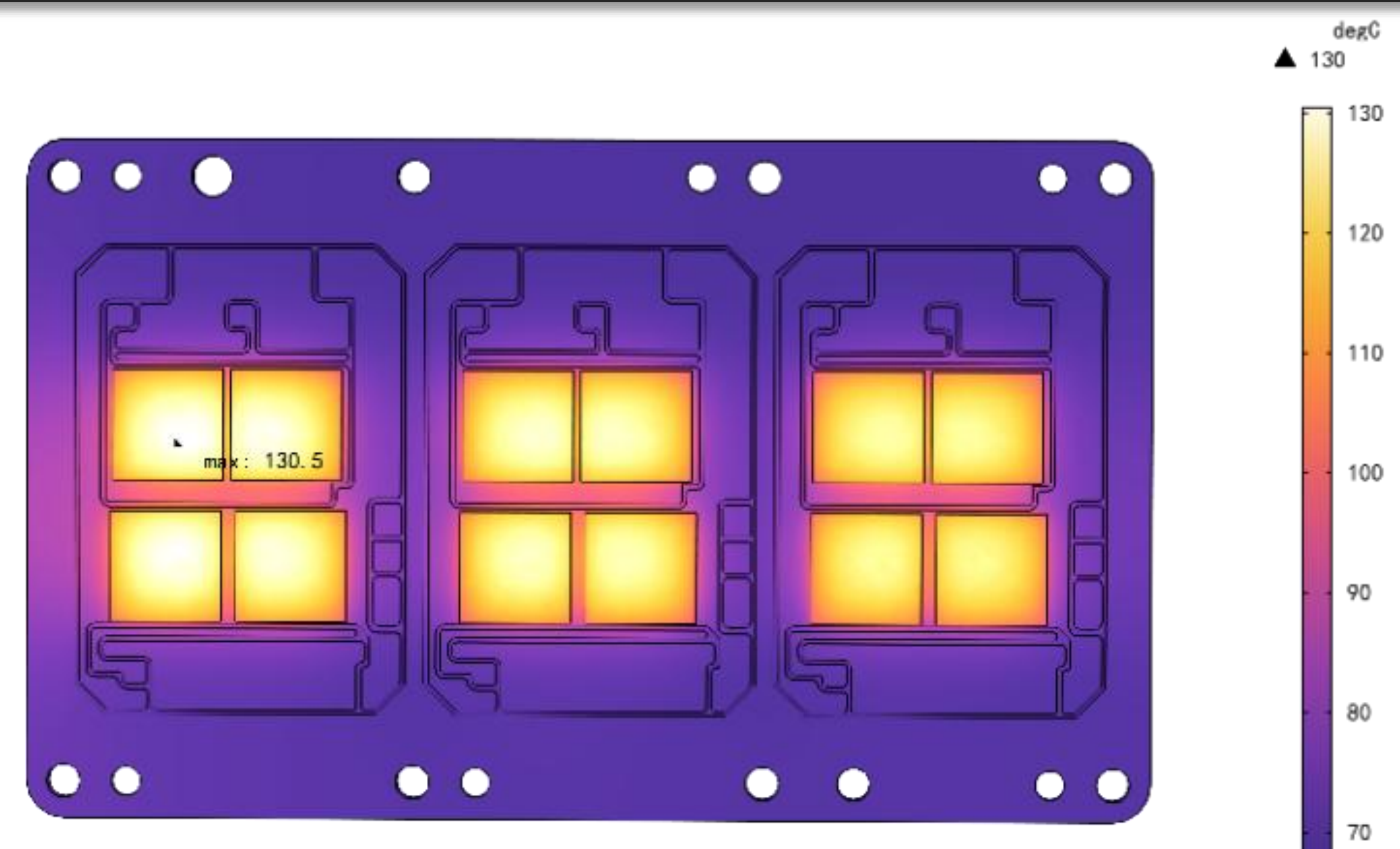


Figure 9. The temperature distribution of elliptical cylindrical pin-fins

The temperature simulation of module C

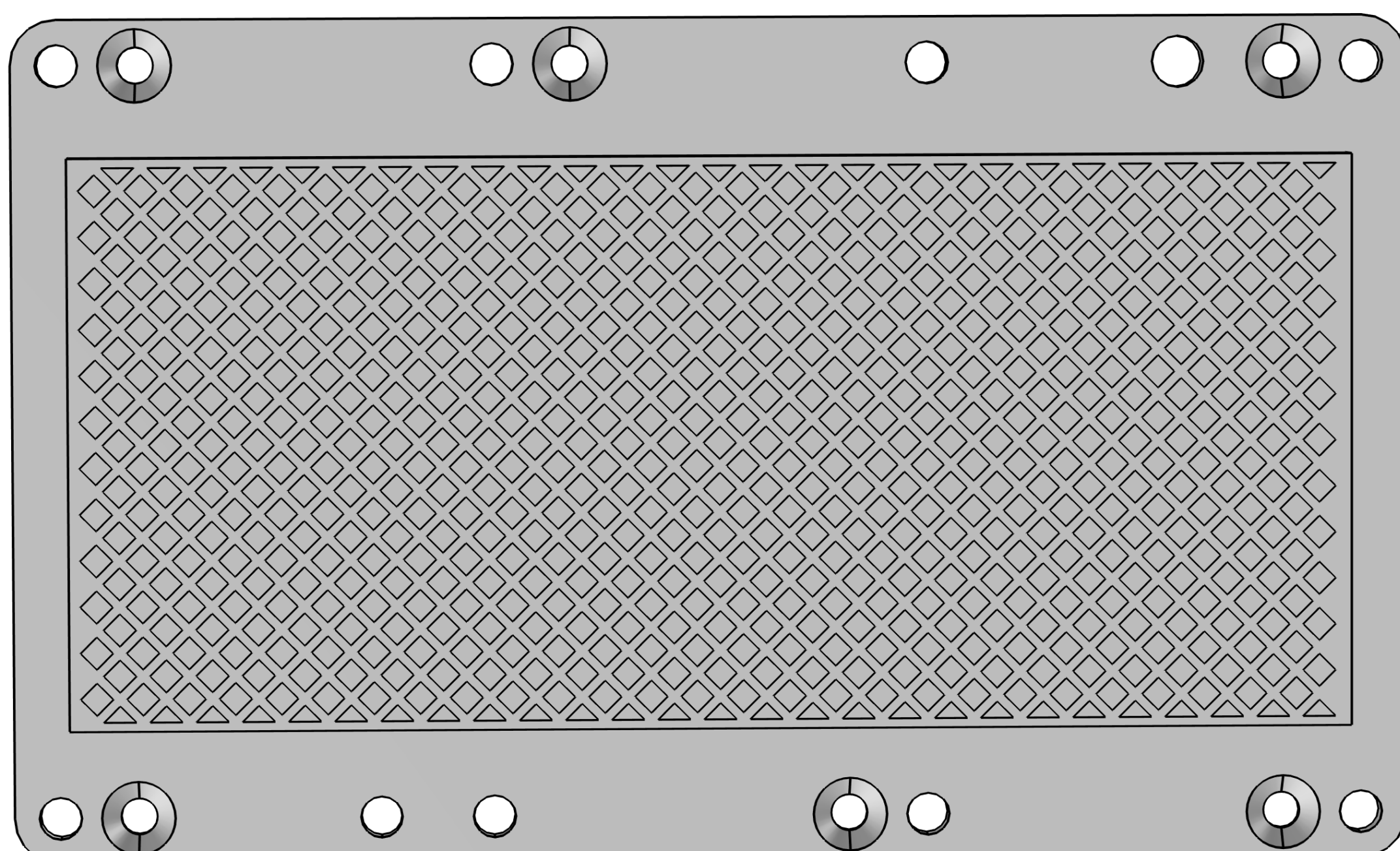


Figure 10. The HPD module of elliptical prismatic pin-fins

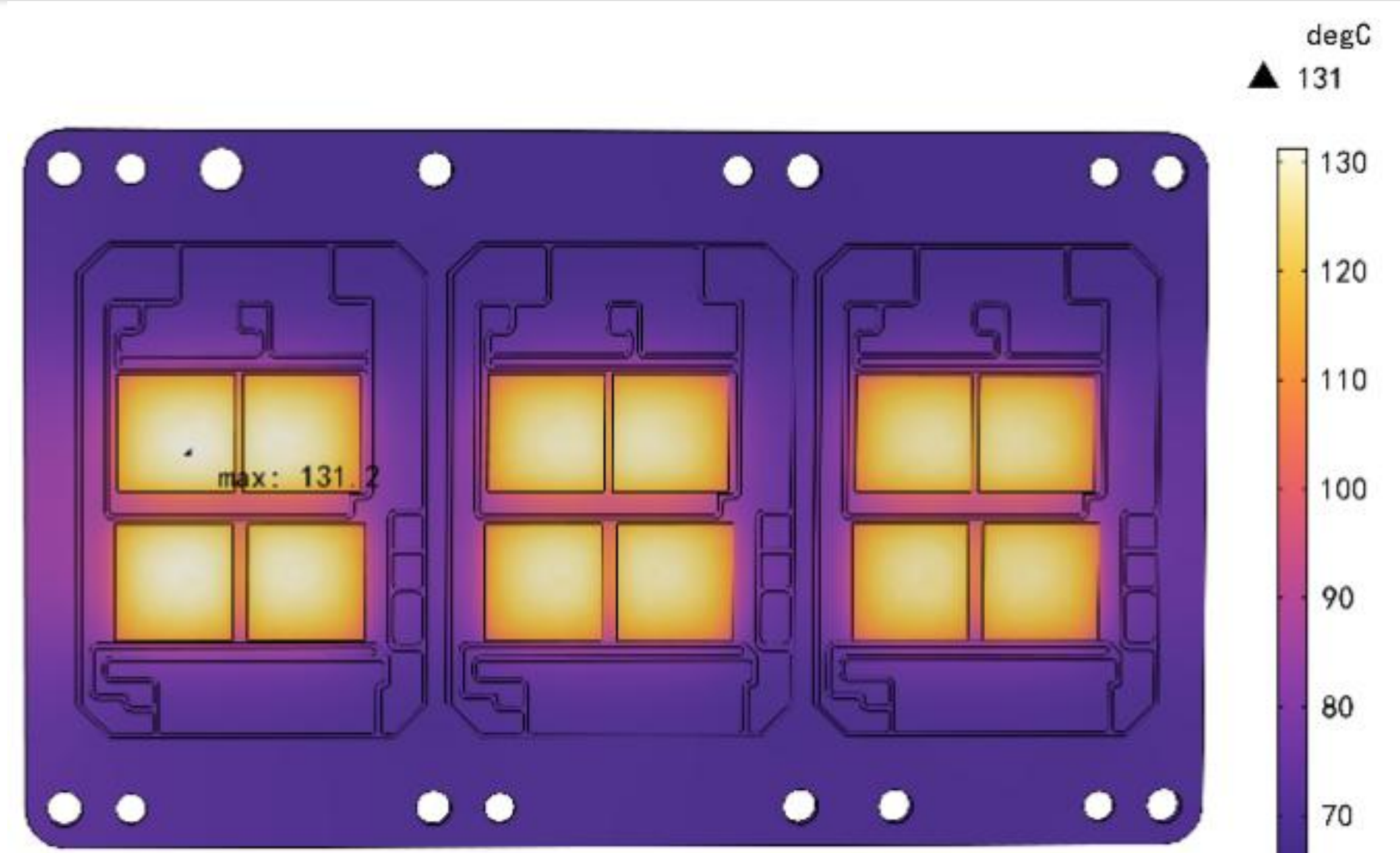


Figure 11. The temperature distribution of prismatic pin-fins

Conclusion

This paper conducts systematic simulation research on high-power HPD-packaged IGBT modules for new energy vehicle motor drives. It analyzes the module's topological structure, stray inductance characteristics and operating power loss based on a three-phase full-bridge inverter model, confirming that switching loss dominates the module's heat generation.

Electro-thermal-fluid coupled simulations are performed to validate the thermal performance of the pin-fin liquid cooling structure. By comparing elliptical cylindrical and prismatic pin-fin structures, the study verifies that the elliptical cylindrical structure enlarges the heat exchange area and strengthens fluid disturbance, effectively reducing the maximum chip junction temperature.

This work provides valuable references for the structural and thermal reliability optimization of HPD IGBT modules and benefits the stable operation of new energy power electronic devices.

References

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