

Research on Battery Cooling Plates and Coolants

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Abstract: Heat dissipation has always been a key focus and challenge in the design of new energy batteries. As equipment advances toward higher precision and sophistication, the issue of heat dissipation has become particularly prominent. Existing cooling technologies face problems such as incomplete heat dissipation and heat accumulation. Therefore, this study aims to achieve efficient heat dissipation by improving the battery cooling system, adopting liquid cooling methods, and incorporating high-efficiency coolant. This paper introduces a cooling system for power battery compartments, which effectively addresses heat dissipation issues within limited space by integrating the structural layout of cooling pipes and selecting high-performance coolant. This research not only enhances the heat dissipation performance and stability of batteries but also extends battery life, improves energy density and operational efficiency, providing strong support for the performance enhancement of new energy vehicles.

Keywords: Liquid Cooling System; Heat Dissipation; Coolant; Structural Design; Numerical Simulation.

1. Introduction

With the increasing severity of global energy crises and environmental issues, as well as the rapid development of new energy vehicles, the heat dissipation problem of power batteries, one of the core components of the "three electric systems" in new energy vehicles, has garnered significant attention from designers [1]. New energy power battery technology has become a crucial direction for sustainable energy development, making the upgrading and optimization of battery thermal management technology increasingly urgent [2]. However, during the charging and discharging processes of new energy power batteries, a substantial amount of heat is generated. If the heat is not managed properly, excessively high temperatures can lead to a decline in battery performance and lifespan, and in severe cases, may even cause spontaneous combustion, posing safety risks to the vehicle [3]. These issues may result in reduced battery performance or even safety accidents. Currently, the heat generated by new energy power batteries is directed to a fixed device, but the heat remains on the device and continues to dissipate outward. The heat exchange efficiency of the battery compartment relying on external air is low, leading to heat accumulation on the outer surface and incomplete heat dissipation. By using SolidWorks software to model the battery pack and ANSYS Fluent software for mesh generation and preprocessing, as well as employing the control variable method to simulate and analyze three key parameters—cooling channel cross-sectional width, coolant mass flow rate, and coolant inlet temperature—that significantly affect the battery pack's heat dissipation performance, it was found that the cooling channel distribution scheme effectively reduces the maximum temperature and temperature difference during battery operation, enhancing the heat dissipation performance of the battery cooling system [4]. This study provides valuable insights for the development of heat dissipation technologies in new energy vehicle power batteries.

2. Design Analysis

2.1. Composition of the Liquid Cooling System

This paper introduces a cooling technology for power battery compartments to address the issue of poor cooling in existing battery compartments, which leads to heat accumulation. The liquid cooling system includes: liquid cooling plates, a coolant tank, and liquid cooling tubes. The liquid cooling plate serves as the core heat exchange interface of the system, made from high thermal conductivity materials, with its surface designed with a microchannel topology to form a dense heat dissipation network. The liquid cooling tubes employ a parallel multi-branch layout system, achieving dynamic flow balance through gradient cross-sectional design. The coolant tank is equipped with a dual circulating pump redundancy system to maintain flow stability. The tank integrates a phase change energy storage module to mitigate transient thermal load impacts. When heat reaches the device, it is exchanged and transferred to the liquid cooling plate, which directs and preliminarily dissipates the heat, then further transfers it to the liquid cooling tubes for additional dissipation. Finally, the liquid in the coolant tank circulates under convective heat transfer in the liquid cooling tubes, cooling the tubes.

2.2. Working Principle

In the cooling system, the heat generated by the battery compartment utilizes the natural rising characteristic of hot air, forming a directional heat channel along the fixed compartment's diversion structure. The heat first passes through the fixed compartment and then transfers to the liquid cooling plate, where part of the heat is dissipated, and the remaining heat is absorbed by the liquid cooling tubes, enhancing the heat exchange efficiency and allowing the battery compartment's heat to dissipate quickly. Simultaneously, bottom fans on both sides blow cold air inward to cool the liquid cooling mechanism, and the heat dissipated by the liquid cooling mechanism is expelled through the heat dissipation tubes.

2.3. Key Technologies

This design improves the battery cooling system by optimizing the structure of the energy battery, installing liquid cooling tubes, fans, liquid cooling plates, and a liquid cooling tank to achieve efficient heat dissipation. The dynamic circulation of liquid within the liquid cooling tank reduces energy consumption and improves the battery's energy conversion efficiency, optimizing energy consumption and meeting energy-saving requirements.

2.4. Structural Description

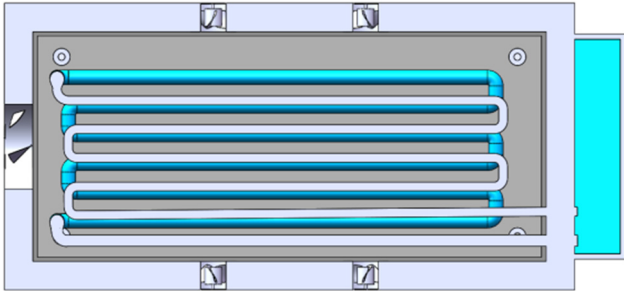


Figure 1. Schematic Diagram of the Device

As shown in Figure 1, the device is divided into three parts for structural explanation.

1) Liquid Cooling Mechanism

The liquid cooling mechanism includes a coolant tank located outside the fixed box, with the coolant connected to the liquid cooling plate, and coolant is introduced into the liquid cooling tubes. A liquid cooling plate is installed on the inner wall at the bottom of the fixed box; liquid cooling tubes are arranged in a loop above the liquid cooling plate, and the liquid cooling tubes are connected to the coolant tank. The connection of the external liquid cooling tank makes the liquid in the liquid cooling tubes more efficient and improves the utilization efficiency of the liquid, protecting the cooling device and ensuring efficient processing of heat by the cooling device, avoiding heat circulation within the system. (The liquid cooling mechanism includes: liquid cooling plate, coolant tank, and liquid cooling tubes.)

2) Air Cooling System

The air cooling system consists of two bottom fans and one central fan. The two bottom fans are symmetrically distributed on both sides of the outer wall of the fixed box, adopting an axial flow structure, and are arranged towards the liquid cooling mechanism inside the fixed box; the central fan is located on the opposite side of the liquid cooling tank, symmetrically arranged with the coolant tank, and its air outlet is equipped with a honeycomb rectifier grid to effectively eliminate vortex interference, with the central fan's airflow directed towards the inside of the fixed box. When the liquid cooling system experiences abnormal pressure drops or excessive coolant temperature rise, the air cooling system quickly initiates a response. The bottom fans prioritize enhanced heat dissipation on the surface of the liquid cooling plate, while the central fan accelerates air replacement inside the fixed box through negative pressure drainage. The air-cooling system plays an auxiliary role in the heat dissipation process, mainly when the liquid cooling system fails to dissipate sufficient heat, it will quickly work to effectively expel part of the internal heat from the device, preventing excessive heat accumulation on the surface of the battery components, which could affect battery performance.

3) Phase Change Overheat Plate

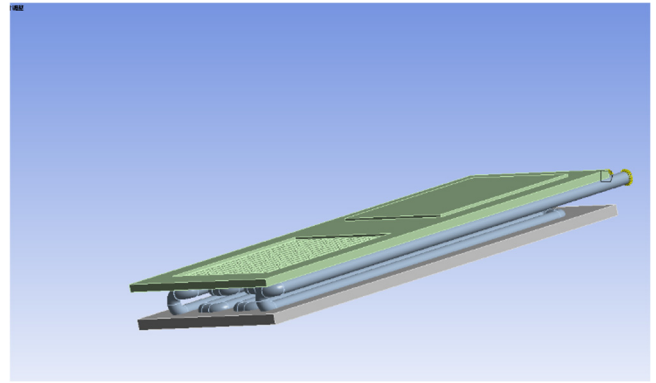


Figure 2. Cross-section of Phase Change Overheat Plate, Liquid Cooling Tubes, and Support Liquid Cooling Plate

The phase change cover is integrated at the top of the fixed box, using paraffin-based phase change material to achieve phase state conversion energy storage within a certain temperature range, capable of absorbing instantaneous thermal load impacts from the battery compartment. The bottom of the cover is equipped with an array of heat conduction fins.

A phase change overheat plate is located below the phase change cover, as shown in Figure 2, the phase change overheat plate is inlaid with multiple unidirectional diamond-shaped overheat holes, designed with an asymmetric structure, and the inner walls of the holes are coated with nano-alumina coating, guiding heat transfer in a single direction through capillary effect. After the heat passes the phase change cover, it goes through the phase change overheat plate, which allows the heat to completely pass and reach the functional liquid cooling plate, which further directs and preliminarily dissipates the heat, and under the action of the air cooling mechanism, reaches the liquid cooling tubes and support liquid cooling plate for further heat dissipation, and finally, under the action of the air cooling mechanism again, the liquid cooling tubes, liquid storage plate, and any incompletely cooled heat enter the heat dissipation port and are expelled from the device through the heat dissipation tubes.

3. Verification Analysis

This paper uses ANSYS Fluent for simulation, simulating the local structure of the liquid cooling device in the cooling device, setting the liquid cooling tubes embedded in the support liquid cooling plate, with the phase change overheat plate existing above the liquid cooling tubes, by setting the upper part of the phase change overheat plate as a heat source to simulate the convective heat transfer between the liquid cooling tubes and the coolant and the heat, and the direct contact heat conduction between the liquid cooling tubes and the overheat plate, ensuring the temperature of the coolant through the continuous flow of the liquid and the dynamic circulation of the liquid in the liquid cooling tank.

During the simulation, the functional liquid cooling plate and the shell of the liquid cooling tubes in this paper are made of aluminum (AL), to facilitate faster heat transfer to the liquid cooling tubes, the shell of the overheat plate is set to copper (Cu), and the overheat plate is connected to a small liquid cooling plate through a flange.

During the mesh division operation, the phase change overheat plate and the support liquid cooling plate are

automatically divided, and the method dominated by hexahedrons and the order of linear elements are set, in the edge size adjustment, the number of partitions at the exchange port of the liquid cooling tubes and the coolant tank is set to 20, and the expansion method for the liquid inside the liquid cooling tubes is set, including a transition ratio of 0.272, a maximum number of layers of 2, and a growth rate of 1.2, with the boundary being the shell of the liquid cooling tubes, ensuring the flow of liquid in the liquid cooling tubes and no liquid leakage or additional heat loss at the exchange port with the liquid cooling tank.

The diameter of the liquid cooling tubes is 10mm, and the length of a single layer of tubes is 190mm; in addition, the phase change overheat plate is 180*80mm, and the support liquid cooling plate is 180*80mm. The initial velocity at the tube port of the exchange port between the liquid cooling tubes and the coolant tank is set to $V=0.15\text{m/s}$.

This paper iterates the simulation 300 times to fully reflect multiple trials to minimize errors as much as possible.

3.1. Verification of the Coolant Adaptation Device

By comparing the cooling effects of different coolants, it is verified that ethylene glycol is more suitable for this liquid cooling system.

The initial temperature of the coolant is set to room temperature of 25°C, the initial temperature of the support liquid cooling plate is set to room temperature of 25°C, and the initial temperature of the heating surface of the phase change overheat plate is set to 100°C.

From the simulation data:

Table 1. Simulation Results of Average and Maximum Temperatures of Different Liquids

	Ethylene Glycol	Water	Ethanol	Methanol
Maximum Temperature(°C)	78.15	86.17	82.79	81.29
Average Temperature (°C)	34.67	52.76	46.87	39.27

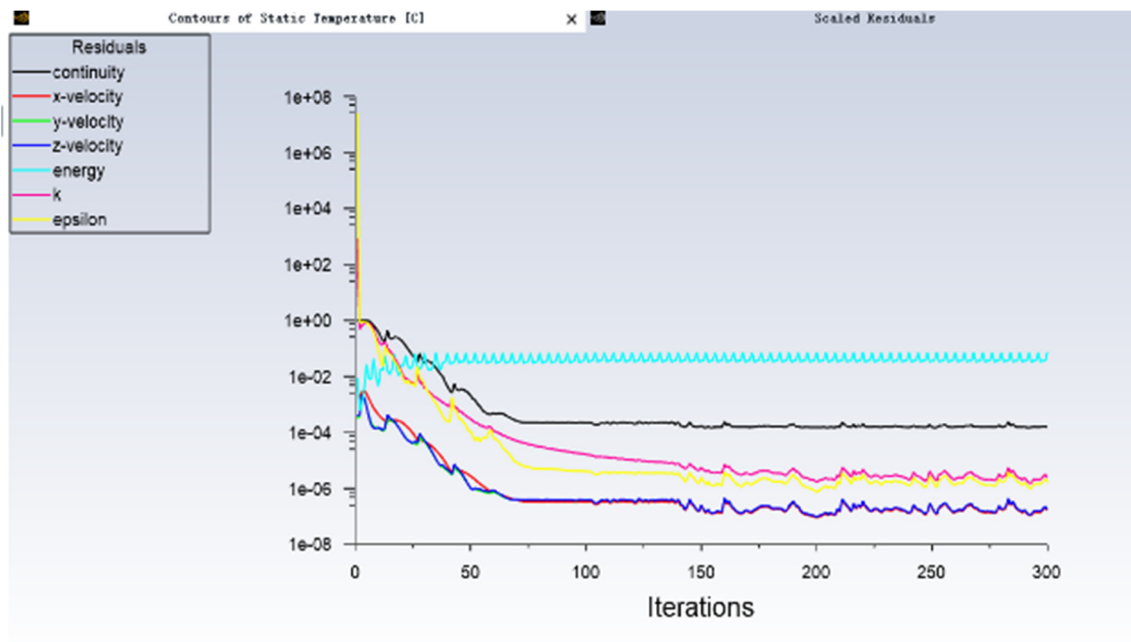


Figure 3. Liquid Fluctuation Residual in Liquid Cooling Tubes - Ethylene Glycol

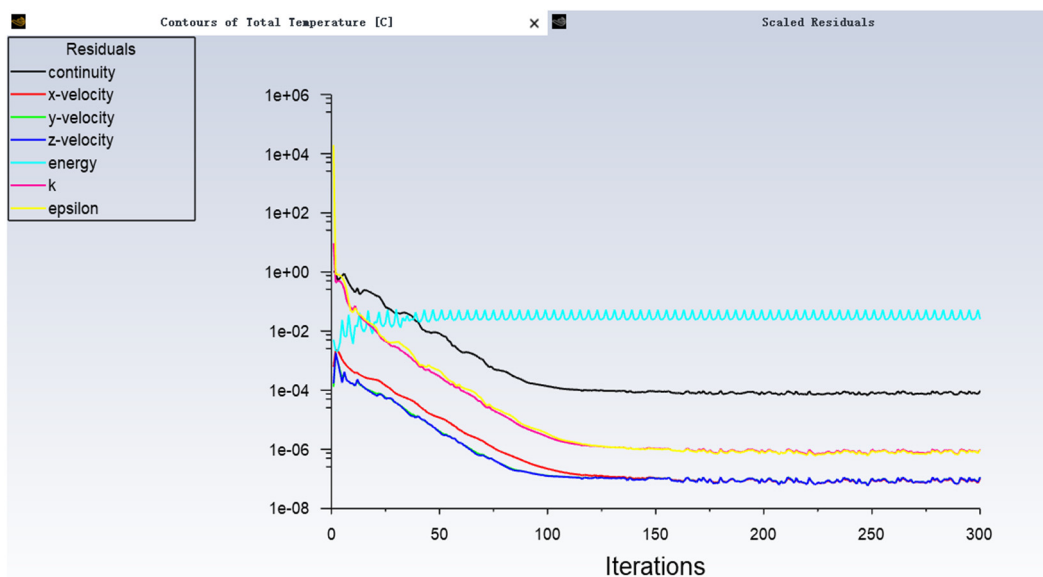


Figure 4. Liquid Fluctuation Residual in Liquid Cooling Tubes – Water

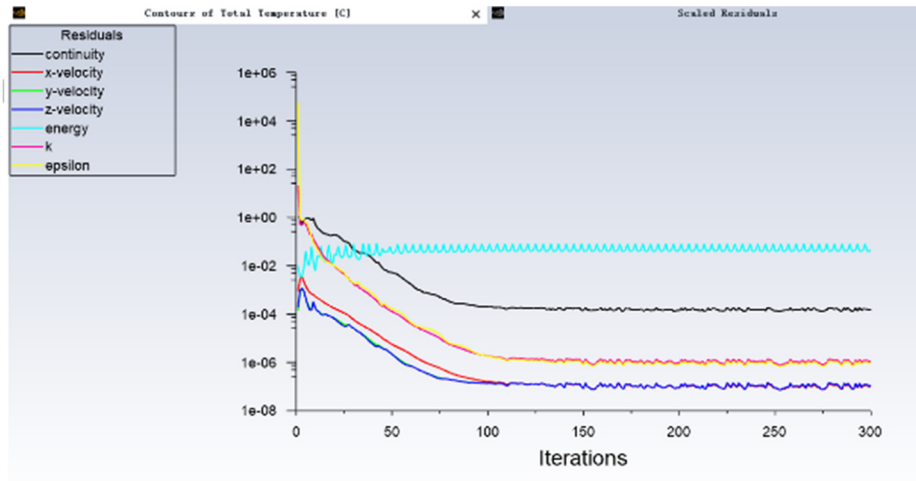


Figure 5. Liquid Fluctuation Residual in Liquid Cooling Tubes – Ethanol

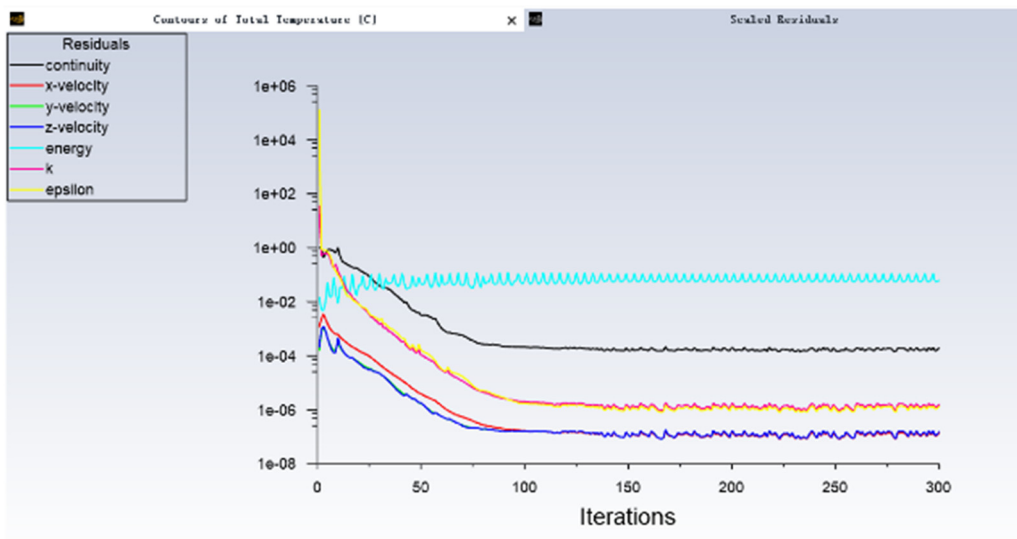


Figure 6. Liquid Fluctuation Residual in Liquid Cooling Tubes – Methanol

Comparing Figures 3, 4, 5, and 6:

The continuity analysis of the liquid in the tubes shows that the residuals are relatively stable, without significant fluctuations, indicating good flow stability and control of

flow turbulence, preventing non-investigative data from affecting the simulation results. Among them, ethylene glycol and methanol show relatively stable speeds in space, with only ethylene glycol showing significant strain.

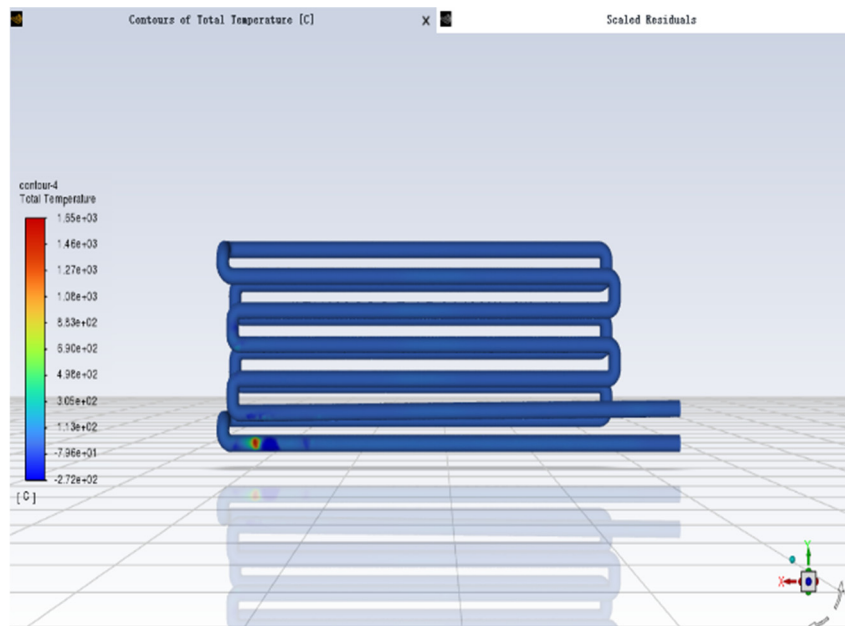


Figure 7. Temperature Diagram of Liquid Cooling Tubes at the End of Simulation - Ethylene Glycol

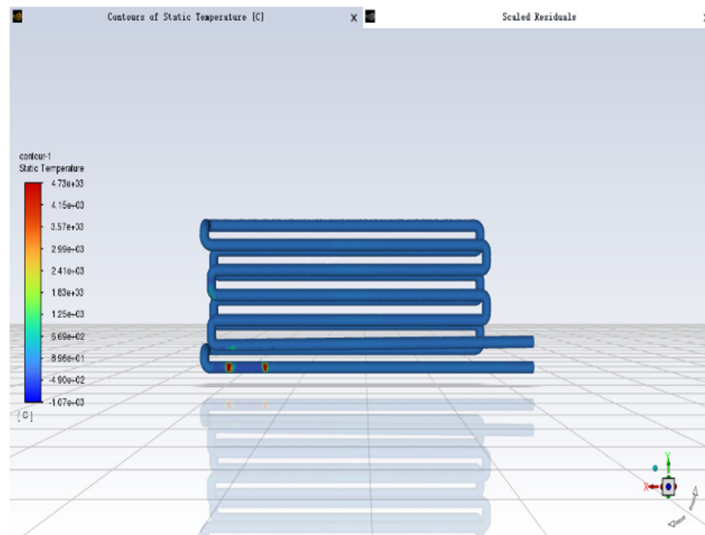


Figure 8. Temperature Diagram of Liquid Cooling Tubes at the End of Simulation – Water

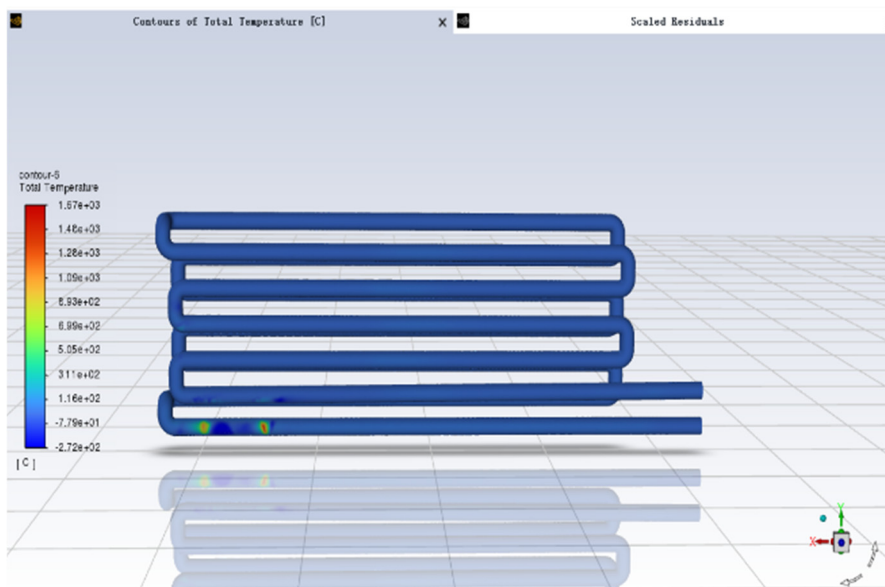


Figure 9. Temperature Diagram of Liquid Cooling Tubes at the End of Simulation - Ethanol

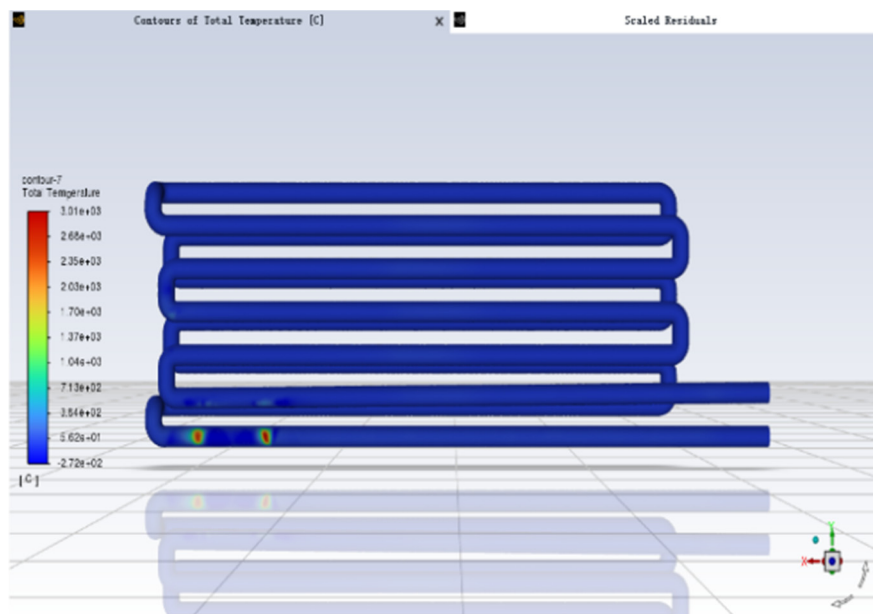


Figure 10. Temperature Diagram of Liquid Cooling Tubes at the End of Simulation – Methanol

comparing Figures 7, 8, 9, and 10:
There are noticeable temperature changes near the set inlet

of the liquid cooling tubes.
Overall, the temperature performance is relatively good,

indicating the prominence of this structure; locally, only ethylene glycol shows a significant temperature change in part of the grid, while the other three show changes in two places.

Thus, this paper can conclude that ethylene glycol has more prominent characteristics in dynamic circulation ability compared to other liquids for this device.

3.2. Verification of the Feasibility of the Liquid Cooling Mechanism Device

To further verify the importance of the phase change

overheat plate in the cooling system, this paper removes the phase change material, overheat holes, and small liquid cooling plate from the phase change overheat plate and simulates the device again. Under the same physical and chemical configurations, with the heat source set above the heat plate, and because it is a single trial, the number of trials is increased to 600 iterations, resulting in a new temperature diagram of the liquid cooling tubes.

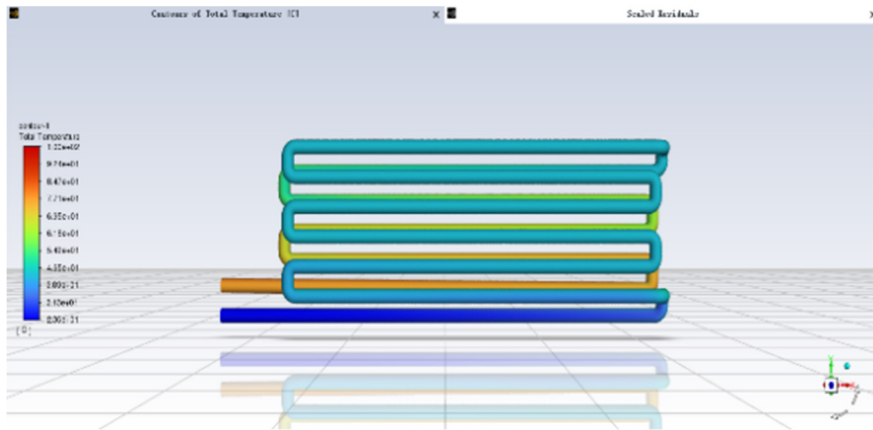


Figure 11. Temperature Diagram of Liquid Cooling Tubes at the End of Simulation with Removed Devices - Ethylene Glycol

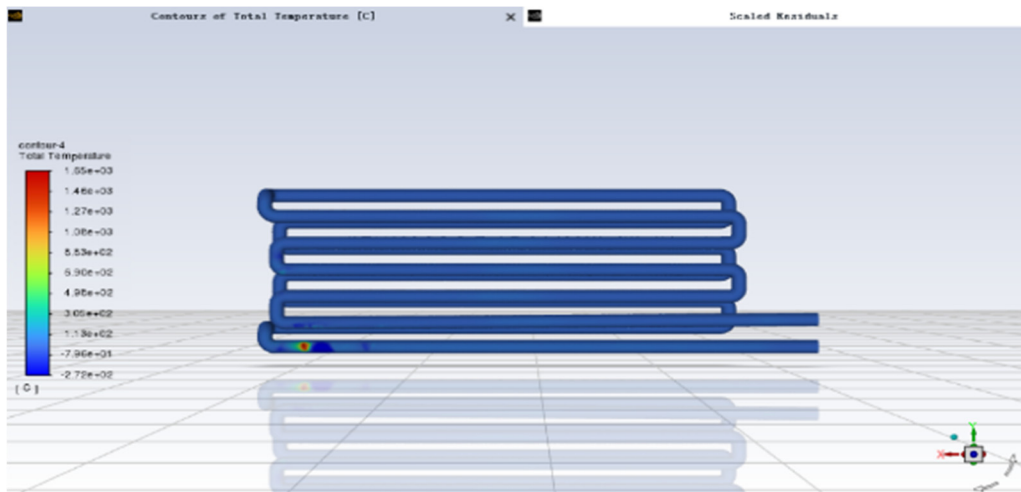


Figure 12. Temperature Diagram of Liquid Cooling Tubes at the End of Simulation - Ethylene Glycol

Comparing Figures 11 and 12, the maximum temperature of part of the fluid in the tubes reaches 99.13°C, with an overall average temperature of 68.72°C. The temperature of the liquid and the tubes has increased significantly. The temperature at the outlet has increased noticeably, while the temperature at the inlet remains relatively stable. Although the heat source can contact the liquid cooling tubes faster, the temperature change time of the liquid cooling tubes is slower than that of the complete liquid cooling system.

Thus, it can be verified that by setting a double-layer liquid cooling tube and a non-connected structure, and adding a small liquid cooling plate to the overheat plate, the liquid cooling system can be significantly improved; the phase change material not only accelerates the time for heat to reach the liquid cooling tubes but also promotes the expulsion of uncooled heat, enhancing the cooling system cycle. It can also be seen that the temperature of the liquid cooling tubes in this structure is significantly lower than that of the compared structure.

Comprehensive analysis of all result data shows the advantages of this design cooling system over general cooling systems and the better suitability of ethylene glycol for this device, indicating that the optimization scheme has certain merits, thereby verifying the research of this cooling system.

4. Conclusion

This paper utilizes Fluent software to conduct thermal simulation analysis on traditional battery packs and proposes structural improvement solutions based on the simulation results, optimizing the selection of liquid cooling materials and the cooling system of the battery compartment. This solution effectively reduces the temperature difference within the battery compartment, achieving an ideal state of temperature control in the model. Not only does it improve the structure of new energy power batteries, but the optimized cooling device also helps lower the operating temperature of the batteries, extend battery life, reduce replacement

frequency, and simultaneously decrease maintenance and replacement costs, aligning with the goal of resource conservation. It achieves cost reduction and efficiency improvement, effectively extending battery life. The thermal performance and stability of the batteries are enhanced, along with their working efficiency and energy density, which will ultimately improve the performance of new energy vehicles.

Acknowledgments

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