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Retraction

Retracted: Collaborative Control and Optimization Mechanism of Thermal Management of New Energy Vehicles

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] J. Huang, "Collaborative Control and Optimization Mechanism of Thermal Management of New Energy Vehicles," *Advances in Multimedia*, vol. 2022, Article ID 8759557, 10 pages, 2022.

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Research Article

Collaborative Control and Optimization Mechanism of Thermal Management of New Energy Vehicles

Jin Huang

School of Electronics and IoT Engineering, Chongqing Industry Polytechnic College, Yubei District, Chongqing 401120, China

Correspondence should be addressed to Jin Huang; huangjin@cqipc.edu.cn

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Global issues such as global warming, rising sea level, melting Arctic and Antarctic glaciers, deterioration of the natural environment, and depletion of fossil energy have attracted increasing attention. As the concept of environmental protection has become increasingly popular, the concept of new energy automobiles has been proposed to keep the heat up. Especially in recent years, with the advantages of energy conservation, environmental protection, and low noise, new energy automobiles have changed from concept to industry and have been generally accepted and recognized by consumers in the consumer market. The increasingly stringent energy crisis and emission regulations have put forward more stringent requirements for modern automobiles. The thermal management of the new generation of intelligent automobiles is not only limited to simply solving the problem of engine heat dissipation but also involves reliability, power, economy, emissions, and comfort. It is an important vehicle development technology with many performances such as performance. The integrated thermal management of new energy vehicles includes engine cooling, oil cooling, air conditioning refrigeration, HVAC heating, supercharged intercooling, low cycle thermal fatigue, and thermal damage. For new energy vehicles such as hybrid and pure electric vehicles, it also includes motor cooling, motor controller cooling, and power battery temperature control. For the purpose of vehicle thermal management optimization design, this paper innovatively proposes IVTM technical solutions, relying on multidimensional numerical calculation coupling and multiobjective collaborative optimization control to integrate system design, scheme evaluation, performance analysis, dynamic control, and collaborative optimization. Through the integrated thermal management collaborative control strategy based on the full operating conditions of the new energy vehicle, the comprehensive improvement of multiple evaluation indicators such as system design performance, thermal management, and control performance and economy is achieved.

1. Introduction

It has been increasing for people's desire to buy things [1]. According to statistics published by the China Automotive Industry Association, in 2017, China's automotive sales were 29.151 million and 28.878 million [2]. However, the main emissions of traditional internal combustion engine cars are carbon dioxide, nitrogen oxides, hydrocarbons, etc. These exhaust gases may cause or exacerbate the problems of photochemistry smoke and greenhouse effect in cities, which have a great negative impact on people's lives, health, and living environment. In addition, as car ownership continues to increase, the gap between them is increasingly worrying [3]. Hence, for these two which are environment pollution and the needy resources, many countries come to deal with the problems which can generally be divided into three categories: different technical routes [4] (large): pure electric vehicle (BEV), hybrid electric vehicle (HEV), and fuel cell electric vehicle (FCEV) [5]. Table 1 shows the characteristics of the three types of electric vehicles. In addition, other new energy vehicles using high-efficiency energy storage such as supercapacitors and flywheels are also under study [6].

Compared with advanced countries such as Europe and America, China's traditional car production technology has been at a low level for a long time. Especially, the market of medium and high-end cars is monopolized by foreign brands, resulting in a huge capital loss [7]. The world today is a period of great technological innovation. In the new

Table 1: Characteristics of three types of electric vehicles.

Type	Features
Pure electric vehicle	Use battery as the only power source
Hybrid electric vehicle	Internal combustion engine and battery write each other
Fuel cell electric vehicle	Convert the chemical energy of fuel into electricity

energy vehicle industry, if we want to achieve "overtaking in a curve" on new energy vehicles, we must implement the "863" key project at the beginning of this century [8]. The main research directions are pure electric vehicles, hybrid electric vehicles, and fuel electric vehicles. On the core components, the motor and its control system, battery, and management system are the research objects, forming a research mode of "three vertical and three horizontal" [9]. Take pure electric vehicles, plug-in hybrid vehicles (excluding continued use) and fuel battery vehicles as the "three vertical" automobile technology innovation chain and build the technology supply of core parts in the "three horizontal" way. Chinese automobile manufacturers have acquired many core technologies in the automobile industry such as BYD automobile, Changan Automobile, and Chery Automobile through years of technology accumulation and have successively launched hundreds of new energy vehicles [10]. With pure electric vehicle, plug-in hybrid vehicle (including driving mileage), and fuel cell vehicle as "three portraits," lay out automotive technology innovation chain and build key parts technology supply system with power battery and management system, drive motor and power electronics, and network and intelligent technology as "three horizons." After years of technical tackling, Chinese automotive enterprises represented by BYD, Chang'an, and Chery have mastered a number of key technologies in related fields, and hundreds of new energy vehicles have been listed one after another.

However, in many important aspects such as range, safety and reliability, rear acceleration, and cost control, NEV is still limited by the technical level of key components such as batteries, motors, and electronic control [11], compared with conventional fuel. Among them, as one of the core components of electric vehicle, power battery and battery management system are the key factors that restrict the further development of new energy automotive industry. It is urgent to speed up the research pace [12]. Integrated heat management systems remain focused on engine heat management; prevent the boiling of coolant, high temperature, oil film sintering, cylinder pulling, etc. under high temperature and heavy load conditions; and ensure the reliability and life of key components such as power assembly cylinder block, air ring, oil ring, and piston. In addition, problems such as low temperature, high oil viscosity, and increased loss of mechanical friction should be avoided in cold environment.

2. State of the art

2.1. Research on Thermal Management Technology of New Energy Vehicles

2.1.1. Integrated Control of Thermal Management of Multiple Powertrains. To better achieve vehicle energy conservation and emission reduction, countries have successively listed new energy vehicle products such as new energy vehicles, extended-range electric vehicles, plug-in new energy vehicles, and pure electric vehicles as key national development strategies [13]. The working temperature of core components such as automotive motors and power batteries is directly related to the safety, efficiency, and energy consumption of the entire vehicle [14]. Therefore, the status and importance of thermal management technology in the research and development of new energy vehicle products are more prominent [15]. Among them, the typical representative of new energy vehicles, due to the variety of powertrain systems included, the complex power matching strategies for operating conditions, and the different thermal management requirements of components, the integration and synergy of the vehicle thermal management system are more demanding [16].

The concept of integrated thermal management system for new energy vehicles was proposed in the 1990s. It is mainly used to solve the problems of efficient cooling and temperature control of military vehicle engines, weapon equipment, air conditioners, vehicle motors, and batteries. The precise control of the flow rate of the air conditioner and the air flow rate enhance the heat transfer performance of the integrated thermal management system under special working conditions. Some people proposed an integrated thermal management system design scheme based on new energy vehicles (Figure 1), covering engine cooling, battery cooling and air conditioning refrigeration cycles, and applying multiobjective optimization algorithms to the dynamic control process of thermal management systems to improve integrate systems to improve efficiency and reduce energy consumption and environmental impact [17]. Through the analysis of decision variables and system constraints, the integrated system objective function is defined and multiobjective optimization is realized [18]. The Pareto boundary is determined and the ideal optimal solution is selected according to the LINMAP decision. The results show that the system efficiency can be improved by 14% and the energy consumption can be improved by 5% at the cost of 14% of the environmental impact, and the system efficiency can be improved by 13% and 5% of the environmental factors at the cost of 27% of the energy consumption. Impact is reduced [19].

2.1.2. Optimization of High-Performance Cooling Structure for Electronic Components. Compared with the engine cooling and air conditioning refrigeration of traditional internal combustion engine vehicles, the powertrain of new energy vehicles also covers electronic components such as vehicle motors, power batteries, and motor controllers [20]. Research shows that the operating temperature of motors and batteries is directly related to the output of the electric power system. For important performances such as power, power generation rate, energy efficiency conversion rate, and safety and reliability, the importance of thermal management and temperature control requirements are higher. According to the different cooling medium, the motor thermal management can be divided into air cooling and liquid cooling. Compared with the liquid-

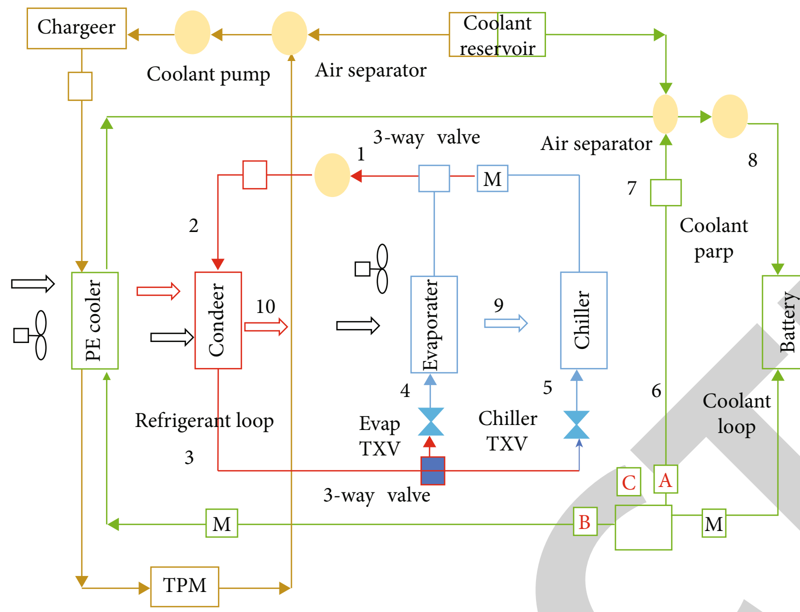

Figure 1: Integrated thermal management control system for new energy vehicles.

cooled method, the air-cooled method has the advantages of simple structure, convenient maintenance, and low cost and is generally used in light-duty hybrid vehicles with low motor output power and low degree of electric drive. However, with the improvement of the degree of electric drive of the whole vehicle, the increase of the capacity of the single machine, the increase of the power density, and the heat dissipation problem of the motor used in the vehicle are prominent. In order to solve the power bottleneck problem caused by the high working temperature of the motor, many car manufacturers choose to have a better heat exchange effect, a good way of liquid cooling.

2.2. Classification and Characteristics of New Energy Vehicle Power Batteries. At present, the main power batteries that can be widely used in commercial use are lead-acid batteries, nickel-cadmium batteries, nickel-metal hydride batteries, and lithium-ion batteries. In addition, some new power batteries, such as air batteries and sodium-sulfur batteries, are also being studied. Here are a few successful commercial power batteries:

(1) Lead-acid batteries

Lead-acid batteries invented by a factory in France in 1859 were the first widely used power batteries. It is still the preferred choice for low-speed electric vehicles because of its easy access to raw materials, low cost, safety, and reliability, suitable for high rate discharge, wide operating temperature, mature recycling technology, and so on.

(2) Nickel-cadmium batteries

Nickel-cadmium batteries were invented in 1899. They are widely used in small electronic products because of their high energy density, resistance to overcharge and discharge, and long cycle life. However, its serious memory effect and high toxicity of heavy metal cadmium seriously hinder its development, and its application in electric vehicles has been replaced by Ni-MH batteries.

(3) Lithium-ion batteries

Lithium-ion batteries were introduced in 1958 and grew rapidly in the 1970s and 1980s. Lithium-ion batteries have become the preferred chemical power source in various fields because of their high energy density, high power density, long cycle life, no memory effect, and low self-discharge. The benchmark Toyota Prius also replaced its fourth-generation model with lithium-ion batteries. Table 2 shows the performance comparison of the above power batteries with different material systems.

2.3. Necessity of Battery Thermal Management System for New Energy Vehicles. The charging and discharging of automotive battery is essentially carried out by chemical reaction between chemical energy and active materials in the battery. On this basis, a new type of catalyst was studied, which is a new type of catalyst.

Because chemical reactions within the battery mainly occur between active substances and electrolytes, when the temperature is too low, such as lithium-ion batteries below 0°C, the viscosity of the electrolyte inside the battery increases significantly, resulting in a significant decrease in the rate of movement of the conductive ions. As a result, many of the battery's performance features, such as charging and discharging capacity, discharge voltage platforms, and output power, can be significantly reduced. In addition, low-temperature environment is more likely to promote the formation of lithium dendrites, leading to short-circuit inside the battery, seriously affecting the battery life, and even affecting the safety of use. As the temperature increases, the fluidity of the electrolyte inside the battery increases, the rate of ion movement

Table 2: Comparison of performance parameters of different types of power batteries.

	Lead-acid batteries	NiMH batteries	Lithium-ion battery	Nickel-cadmium batteries
Volume-specific energy	80	100-200	200-320	70-140
Mass-specific energy	35-40	75-80	140-200	40-50
Cell voltage	2	1.2	2.5-4.5	1.2
Operating temperature	-20-60	20-60	-20-60	-20-60
Power density	50	160-230	>300	190
Self-discharge rate	4-5	<35	<5	<35
Cycle life	500-800	>1000	>1000	>1000

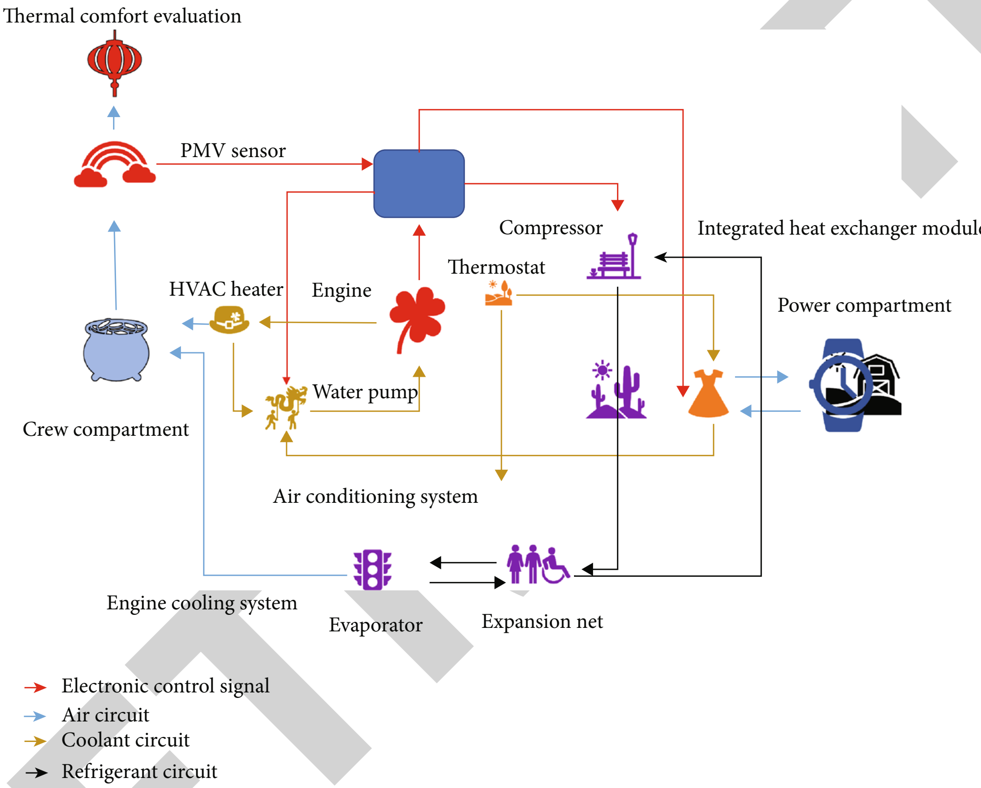

Figure 2: Architecture block diagram of integrated thermal management system for new energy vehicles.

increases, and the rate of chemical reaction increases, which also ensures the safety of use.

However, if the temperature of the battery is too high, it will not only fail to improve and reduce all functions but also lead to short circuit inside and outside the battery, or self-heating generated in the rapid discharge process. At the same time, because its active material loses the protection of SEI thin film, it generates exothermic heat with the active material in the electrode, making its temperature rise to 150 degrees Celsius. At about degrees Celsius, violent new exothermic heat occurs, such as the large rupture of the electrolyte.

3. Methodology

3.1. Integrated Thermal Management Model of New Energy Vehicles. The basic architecture of the integrated thermal management system for new energy vehicles includes engine cooling system, air conditioning system, HVAC heater, passenger compartment, power compartment, and ECU controller, as shown in Figure 2.

3.1.1. Mathematical Model of Engine Cooling System. The basic theories of heat production, heat transfer, flow, etc. of each component of the engine cooling system and related test data establish the internal heat production model, the radiator heat transfer model, and the external circulation model and build the overall framework of the engine cooling system on this basis, which is used to describe the thermodynamic state and flow state of the engine cooling process system. Figure 3 shows the temperature characteristic curve of the thermostat opening degree with respect to the engine outlet water temperature. The thermostat model constructed in this paper is a wax type thermostat, which is characterized by a nonuniform valve body opening temperature characteristic curve in flow regulation, and there is an obvious time lag between the heating and cooling processes of the thermostat. Phenomenon.

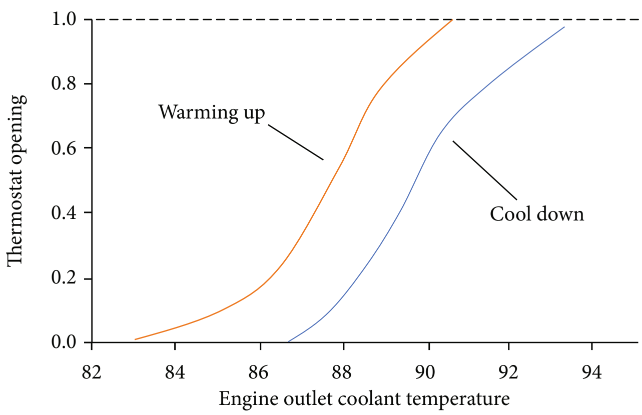

Figure 3: Thermostat opening temperature characteristic curve.

The calculation of engine effective power and mean effective pressure is shown in

$$P_e = \frac{T_{tq} \cdot N_e}{9550}, \quad P_{me} = \frac{30 P_e \cdot \tau}{V_s \cdot N_e \cdot i}, \tag{1}$$

where P_{me} is the engine mean effective pressure, τ is the number of engine strokes, and i is the number of engine cylinders.

Determine the fuel consumption rate B_e per unit power of the engine through the interpolation of the MAP map of the universal characteristics of the engine and calculate the fuel consumption B_e of the engine:

$$B_e = \frac{P_e \cdot b_e}{1000}, \tag{2}$$

where b_e is the engine fuel consumption rate per unit power and B_e is the hourly fuel consumption of the engine.

Water jacket coolant energy balance equation:

$$\dot{Q}_{wc} + \dot{m}_c \cdot c_c \cdot (T_{c,e,\text{in}} - T_{c,e,\text{out}}) - \dot{Q}_{eb} = m_{c,e} \cdot c_c \cdot \frac{dT_{c,e}}{dt}. \tag{3}$$

Engine case energy balance equation:

$$\dot{Q}_{eb} + \dot{Q}_f - \dot{Q}_a = m_{eb} \cdot c_{eb} \cdot \frac{dT_{eb}}{dt}. \tag{4}$$

3.1.2. Analysis of Heat Generation Mechanism of Lithium-Ion Battery. The internal structure and chemical reactions of lithium-ion batteries are complex. Understanding the heating mechanism of batteries can not only accurately derive the most important parameters in the thermal model, i.e., the heating rate of batteries, but also help to analyze the simulation results and test data of the model. A more reasonable analysis and evaluation of the differences is an important basis for accurately predicting the battery temperature and rationally designing the thermal management system.

The research shows that the heat generation source of the power battery is mainly composed of four parts: Joule heat Q_j, reaction heat Q_r, polarization heat Q_p, and side reaction heat Q_s. The total heat generation of the battery is

$$Q = Q_j + Q_r + Q_p + Q_s. \tag{5}$$

Among them, Q_j is the heat generated by the Ohmic resistance of the battery, Q_r is the heat generated by the internal chemical reaction of the battery, Q_p is the heat generated by the polarization reaction of the battery, and Q_s is the heat generated by the side reaction of the battery.

3.2. Establishment of Calculation Model of Battery Pack and Cooling Structure. In the battery cooling system, the heat is transferred from the battery to the cooling flat tube and then taken away by the cooling liquid when it flows in the flat tube. Mathematical models are used to express the continuity equation, momentum conservation equation, and energy conservation equation of the entire cooling system.

The continuity equation can be expressed as

$$\begin{aligned} &\frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho v)}{\partial v} + \frac{\partial(\rho w)}{\partial w} = 0, \\ &\text{div}\left(\rho u \vec{u}\right) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \tau_{zx}}{\partial x} + F_x, \\ &\text{div}\left(\rho v \vec{v}\right) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + F_y, \\ &\text{div}\left(\rho w \vec{u}\right) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z} + F_z. \end{aligned} \tag{6}$$

Among them, ρ represents the coolant density and u, v, and w represent the components of the velocity vector in the x, y, and z directions, respectively.

In the formula, p is the pressure acting on the calculation area and F_x, F_y, and F_z, respectively, represent the forces along the x, y, and z directions of the microunit in the calculation area.

The flow model can be expressed as

$$R_e = \frac{vl}{\nu}, \tag{7}$$

where v is the fluid velocity (m/s), l is the effective length of the flat tube (m), and u is the kinematic viscosity of the fluid medium. Since the essence of CFD (Computational Fluid Dynamics) software is to solve differential equations, the accuracy of iteration depends on the difference between the previous calculation result and the next calculation result. When the difference between the two is 0, it indicates that the algorithm has high precision, but it cannot achieve the ideal precision in the actual test. Therefore, when judging the convergence of the algorithm according to the residual value, in order to obtain the most accurate calculation result under the allowable conditions, the residual value of the fluid velocity, temperature, pressure, and other related factors is set to 10^4.

Table 3: Thermal parameters of each component of the battery.

Component	Thermal conductivity	Total thickness	Specific heat capacity	Density
Case	170.00	1.00	875	2770
Cathode coating	1.53	9.29	1017	3100
Aluminum foil	238.00	1.15	903	2702
PP diaphragm	0.33	4.61	1978	659
Anode coating	1.04	7.67	1437	1550
Copper foil	398.00	0.66	385	8933
Electrolyte	0.60	10.00	1715	1179

Table 4: The total internal resistance of each SOC of the battery when discharged at different rates at 25°C.

R (mΩ)	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0
1C	2.5	2.8	3.3	3.5	3.0	2.9	3.1	3.3	3.0	3.1	4.4
2C	2.1	2.6	2.9	2.9	2.6	2.6	2.8	2.9	2.7	2.9	4.3
3C	1.9	2.4	2.7	2.7	2.5	2.6	2.8	2.8	2.8	3.0	5.1

3.3. Design of Lithium Battery Thermal Management System. In new energy electric vehicles, although the liquid cooling structure is more complex than air cooling structure, the cooling effect is much higher than air cooling. In addition, a liquid heating device can be designed in a liquid cooling system to ensure that the performance of lithium batteries is not affected at low temperatures. Liquid cooling is a method of using liquid materials as cooling media through direct or indirect contact with heat sources. The battery can be cooled by placing cooling plates around the battery or by immersing the battery module in a well-insulated liquid material. For safety reasons, researchers prefer indirect contact cooling. The thermal structure of the battery pack uses a miniature cooling flat tube. The top is a cooling flat tube located at the bottom of the battery pack. By adding flat tubes, the coolant cools the battery pack by taking away the heat generated by the battery pack during operation.

Because of the large number of components in lithium batteries, heat and heat transfer are more complex. When building a thermal model, it is usually necessary to make some assumptions about the physical properties of the material inside the battery: (1) The material inside the battery is evenly distributed, and the thermal physical parameters, thermal conductivity, and density are isotropic. (2) The thermophysical parameters of the materials inside the battery do not change with the change of temperature and charging state. (3) The current density in each area of the battery is evenly distributed during operation.

The accuracy of the thermal model depends not only on the correct theory and reasonable assumptions but also on the accurate acquisition of the physical parameters of the material. Through the data provided by the battery manufacturer and the review of relevant literature, the relevant parameters of each component of the battery are summarized in Table 3.

The internal heat source of the battery is mainly composed of three parts: the core, the positive and negative ears, and the positive and negative electrodes, among which the core is the most important heating part. The heat consumption for each part is calculated as follows.

Table 5: Experimental battery parameters.

Performance	Parameter value
Rated capacity	17 Ah
Standard	3.7 V
Standard charging time	5-6 h
Fast charging time	2-3 h
Recommended discharge current	0.2-1.5C
Charge cut-off voltage	4.2 V
Discharge cut-off voltage	3 V
Internal resistance	<3 mΩ
Size	115 × 70 × 27 mm
Cycle life	>1500
Ambient temperature	Standard charge: 0-45°C Fast charging: 5-40°C Discharge: -20-60°C Store: -40-60°C

From the differential equation of the internal thermal conductivity of batteries, it can be seen that the core heating rate of batteries has a significant impact on the temperature of batteries, and its calculation accuracy will directly affect the accuracy of the thermal model of batteries. Therefore, exploring a more accurate core heat model, linear battery heat model, is the focus of related research work.

The influence factors of internal resistance of ternary batteries have been studied. It is shown that the change of internal resistance temperature has little influence at high temperature (above 25°C). Therefore, this paper chooses to measure the total internal resistance of batteries by pulse current discharge method, taking into account the effect of power ratio and SOC on the internal resistance. The total internal resistance measured when discharging at various rates at 25°C, the measured total internal resistance values of the used batteries at different SOCs are shown in Table 4.

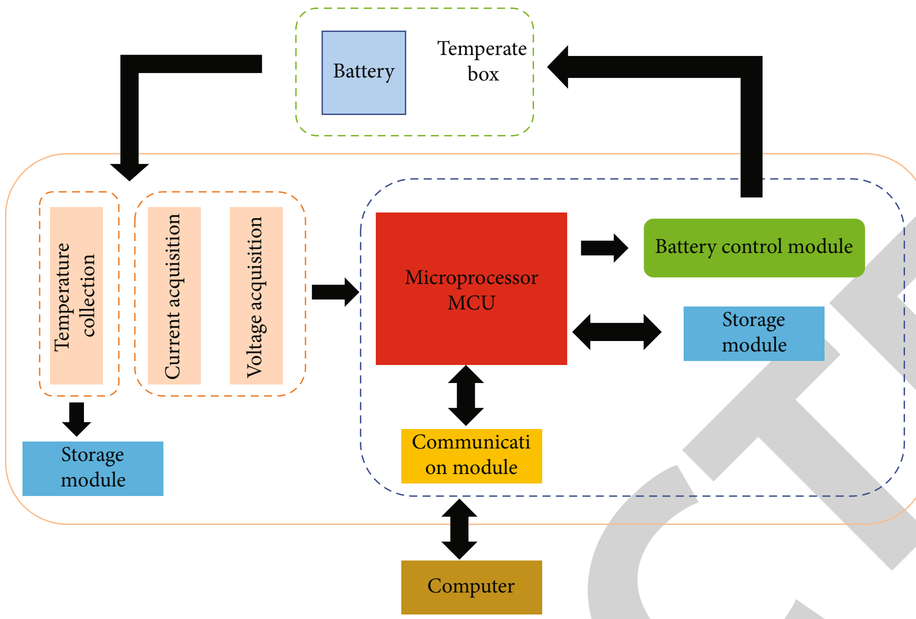

FIGURE 4: Test framework and schematic diagram.

4. Result Analysis and Discussion

4.1. Experimental Setup. Based on the road test of new energy vehicles, this section verifies the confidence of the results of the integrated thermal management 1D/3D coupling calculation method and checks and evaluates the heat transfer design performance and economy of the thermal management system. The thermal rheological analysis of the system is carried out according to the influence of the system performance indicators on the coupling effect of the integrated system, the intake state of the heat exchanger, the cooling liquid flow, and the refrigerant flow. According to the differences in thermal rheological characteristics of the system performance indicators on the structural characteristics of the power cabin, the thermal structure characteristics of the system are analyzed, and the matching speed of the fan and the matching displacement of the compressor for different structural schemes are determined to realize the quantitative evaluation of the optimization effect of the thermal management system.

The test battery is a ternary lithium-ion square aluminum shell battery produced by a company. Since part of the test involves the collection of battery temperature, four thermal sensors are placed on the surface of the battery, which are, respectively, arranged on the front, side, and center of the bottom surface of the battery core, and the front is close to the negative ear with a higher heat generation rate. Table 5 shows the experimental parameters.

The test involves the interaction among battery capacity, voltage, discharge rate, internal resistance, SOC, and temperature, including the following four aspects:

(1) The charge discharge capacity of the battery and the change of the voltage at various ambient temperatures (that is, the initial temperature of the battery) are studied to obtain the optimal operating temperature of the battery

(2) The correlation between the internal resistance of each cell and SOC at each discharge speed is discussed, which lays a foundation for the thermal modeling in Section 3

(3) Explore the temperature rise of the battery during charging and discharging under different ambient temperatures to provide a reference for the selection of simulated ambient temperature

(4) Explore the temperature rise of the battery under different discharge rates, and compare the experimental data with the simulation data to verify the battery thermal model

Experimental framework and testing principle are as follows.

The connection relationship between the devices in the test and the working principle of the system is shown in Figure 4. Before the test, use the computer to set up the designed battery charging and discharging scheme and set up the control module of the test system. During the test, the test system loads the corresponding current and voltage for the battery according to the input scheme to achieve charging and discharging. During the test process, the test system continuously collects battery information through current, voltage, and temperature acquisition devices and stores it in the built-in memory module. Display and storage are realized on the computer.

4.2. Experimental Results and Analysis

4.2.1. Influence of Ambient Temperature on Battery Charge and Discharge Capacity and Voltage. The capacity-voltage curves of batteries charged and discharged at different

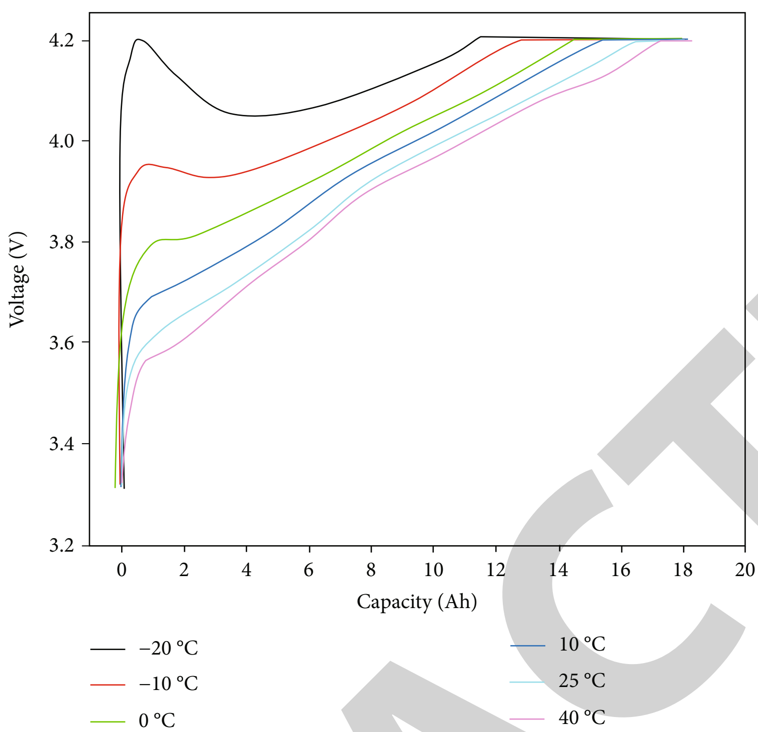

Figure 5: Battery charging capacity-voltage curves at different temperatures (1C).

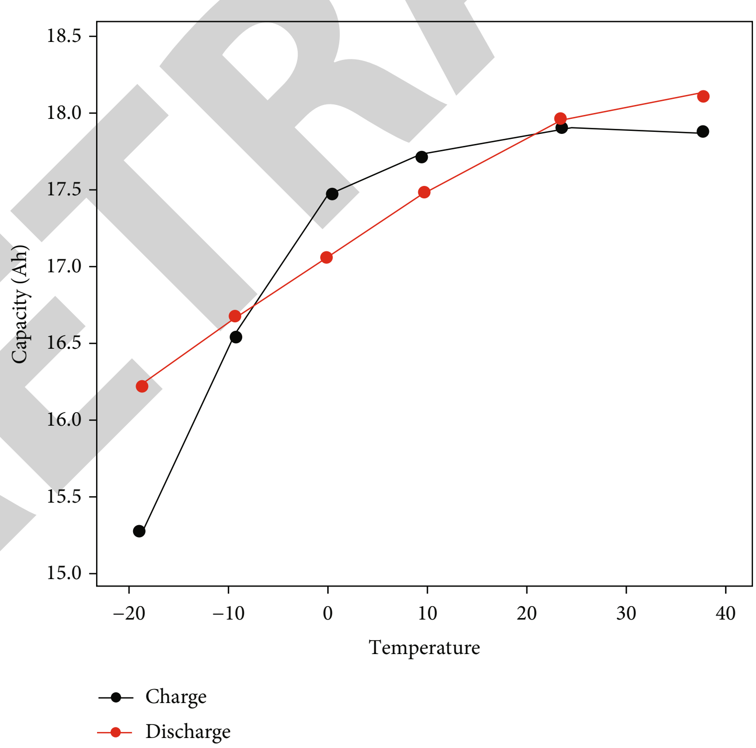

Figure 6: Change trend of charge and discharge capacity with ambient temperature.

temperatures are summarized as shown in Figure 5. From the point of view of the change of capacity with temperature, the trend of charge and discharge is consistent: with the decrease of environment temperature, the charge and discharge capacity decreases gradually. This is because the chemical activity of active materials in batteries decreases at low temperatures, and some electrolyte solvents are solidified, which results in a decrease in ionic conductivity, a

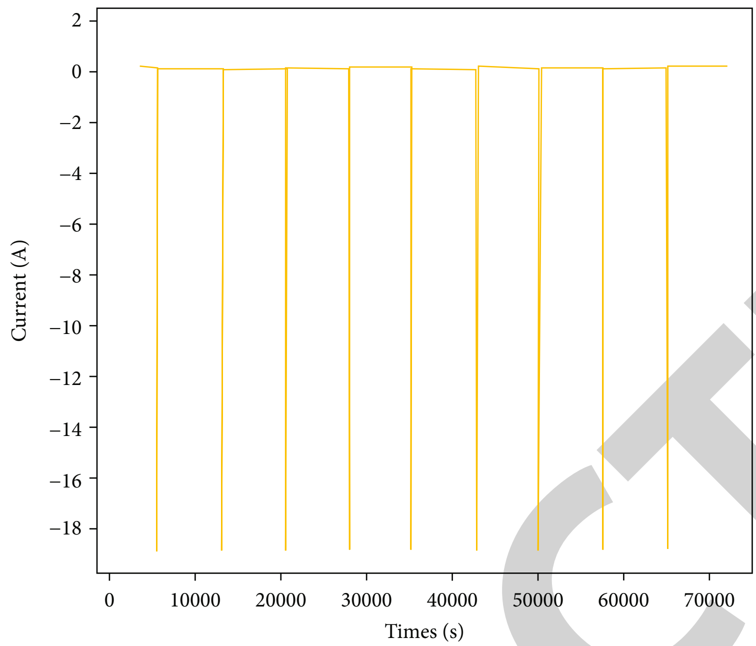

FIGURE 7: Input current curve.

decrease in light migration, and a decrease in capacity. As the reduced ionic conductivity increases with the decrease of temperature, the capacity decay increases with the increase of temperature.

Although the overall change trend of capacity with temperature is the same during charging and discharging, in order to further understand the difference between the two affected by temperature, the temperature-capacity curves during charging and discharging are now compared and analyzed, as shown in Figure 6.

It can be seen that the change of charge and discharge capacity with temperature is mainly that the rate of decay of discharge capacity with decreasing temperature is relatively stable, while the rate of charge capacity decay is faster and faster, indicating that low temperature has a greater impact on the charging performance of the battery than discharge.

4.2.2. Relationship between Internal Resistance, Discharge Rate, and SOC. The internal resistance value of the battery cannot be directly output by the test system, and it needs to be analyzed and calculated according to the response curve of the battery terminal voltage under pulse current excitation. Taking 1C as an example, the current loading situation is shown in Figure 7.

It can be seen that at the beginning of the battery discharge, there is an instantaneous current drop caused by the ohm resistance at the end flow, and then, the end current gradually drops to UL with the discharge. When the discharge stops, the end current rises instantly, and then, the end current is due to the polarization inside the battery. Rising slowly, while the polarization effect is gradually weakened, and the battery end current gradually stabilizes after 2 h of standing, this stability value is numerically equal to the open-circuit current AoC of the battery under the current SoC.

5. Conclusion

The battery as the power carrier of electric vehicle has a vital effect. The thermal management design of lithium-ion batteries is also an important guarantee for the safety performance of electric vehicles. On the basis of consulting the relevant literature of lithium-ion batteries at home and abroad, this paper has a thorough understanding of the main research contents and various technical routes of the thermal management system for lithium-ion batteries. Taking the square aluminum-shell ternary lithium power batteries as the research object, the thermal characteristics and thermal structure of the modules are analyzed. After a comprehensive discussion and analysis, the main contents are as follows: (1) Comprehensive comparison and analysis of the detailed classification of lithium-ion batteries. The performance differences of lithium-ion batteries with different material systems and different structure forms are compared, and the production technology and technical characteristics of lithium-ion batteries are analyzed in depth. The thermal safety and thermal balance of lithium-ion batteries were studied from three aspects: material, structure and manufacture. (2) Experiments were carried out to verify the correlation between the related performance parameters and temperature of lithium-ion batteries, and the single thermal model was validated by using the temperature data of lithium-ion batteries at 25°C at different discharge rates. The results show that the model has good performance.

Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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