Research on the Range Issues of New Energy Vehicles

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Abstract: This article focuses on the issue of the increase and decline of the driving range of new energy vehicles. By analyzing the research progress in core technical fields such as battery technology, thermal management system, and energy optimization strategy in both domestic and international contexts, it precisely examines the safety contradictions of high energy density batteries and the limitations of lightweight costs. It clarifies that the development of high energy density battery technology with an energy density of ≥ 400 Wh/kg and the optimization of intelligent thermal management system are the research directions. It also conducts research and discussions through experiments, simulations, and data on vehicle lightweighting and aerodynamics. In combination with the future development trends of energy and technology, it explores the application of new energy forms such as new energy power and hydrogen power, which is conducive to breaking through the range bottleneck, promoting the automotive industry to move towards a green and sustainable development direction, and ultimately achieving the ultimate goal of global energy conservation and emission reduction.

Keywords: New Energy Vehicles; Range Capability; High Energy Density Batteries; Intelligent Thermal Management; Vehicle Energy Management; Lightweight Design; Aerodynamics

1. Introduction

1.1 Research Background

In recent years, global climate warming has intensified, and energy conservation and emission reduction have become a global consensus. With the advancement of the country's carbon neutrality goals, the market demand for new energy vehicles has been continuously expanding. Since 2024, the penetration rate of new energy vehicles in China has exceeded 47%, but 39.6% of potential users have "range anxiety" due to insufficient battery range, making new energy vehicles difficult to be accepted, thereby restricting the development of the new energy vehicle industry. A user survey jointly released by J.D. Power and Dongchedi shows that 27% of potential new energy vehicle buyers have range anxiety. A survey by the China Automobile Dealers Association indicates that what users "care most about when purchasing new energy vehicles" is "battery range capability," accounting for 39.6%. These data all reveal that range anxiety is a matter of concern for potential users of new energy vehicles. New energy vehicles have problems such as a 35% increase in power consumption in extremely cold conditions, a 28% increase in energy consumption at high speeds, and rapid battery degradation, which affect operating costs and product delivery. Traditional lithium batteries have limited energy density and urgently need to find new power sources to improve range[1].

1.2 Research Significance

This article explores the significance of enhancing the range of new energy vehicles in terms of technological innovation and system optimization: it can enhance user satisfaction, expand market share; facilitate high-quality industrial development, achieve adjustment and upgrading of the energy structure, and promote construction. According to the data, if the range is increased from 450 kilometers to 700 kilometers, the popularity is likely to increase by approximately 35%, which means reducing the supply of traditional fuel vehicles. It can also reduce hundreds of thousands of tons of carbon emissions. In the future, if we introduce the concept of hydrogen power and can develop the corresponding solution to solve the range problem in extreme scenarios, it is expected to achieve cross-scenario range[2].

2. Significance of the Project and Current

Domestic and International Research Status

2.1 Significance of the Project

The range of new energy vehicles determines the application scenarios and user satisfaction. Studying high energy density battery technologies, intelligent thermal management technologies, etc., can effectively alleviate "range anxiety", promote the development of new energy vehicles, and improve the energy management efficiency and lightweight design and research of the entire vehicle. It can also drive the breakthrough of key technologies such as battery materials and thermal management technologies, and promote collaborative innovation in the industrial chain. Exploring advanced hydrogen power technologies is expected to revolutionize power technology and achieve leapfrog development; from a social perspective, enhancing range can reduce reliance on fossil energy, lower carbon emissions, and contribute to achieving the "dual carbon" goals, building a green transportation system[3].

2.2 Current Research Status at Home and Abroad

2.2.1 International progress

Battery Technology:

(1) Tesla's 4680 battery adopts an electrode-free design and dry electrode technology. By shortening the lithium-ion transmission path, it reduces the battery internal resistance, achieving an energy density of 300Wh/kg. When paired with the rear-wheel drive version of Model Y, it enables a CLTC range of 615km. The fast charging takes 30 minutes to charge up to 80%, while improving charging and discharging efficiency and heat dissipation performance (Tesla Tech Brief, 2022). This design reduces the battery internal resistance and improves energy transmission efficiency, providing strong support for enhancing the range of electric vehicles.

(2) Toyota has made a significant breakthrough in solid-state batteries, achieving a capacity of 500Wh/kg and a capacity retention rate of over 90% at -20°C. It plans to mass-produce and install in 2027 (Nature Energy, 2023).

(3) CATL's European factory: Produces the CTP3.0 Kirin battery, with a system energy density of 255Wh/kg, supporting 10-minute fast charging to 80%. It is paired with BMW electric vehicle models (CATL Europe Report, 2025)[4].

Thermal Management: The intelligent thermal management integrated system project of European automakers adopts heat pump and waste heat recovery technologies, using liquid cooling circulation and intelligent sensor technology combinations to achieve temperature control effects for the vehicle's batteries, motors, and cabin. In an environment of -10°C, the battery loss rate can be reduced from 35% to 22%, and in extreme high-temperature conditions, the cooling efficiency needs to be improved (Audi & BMW Joint Report). Intelligent sensors and intelligent control algorithms can promptly feedback the working status of the battery and motor to be within the optimal temperature range, while ensuring the overall performance of the vehicle and the vehicle's range. Tesla's heat pump neural network controller uses AI algorithms to detect the ambient temperature and change the output power of the heat pump in this way, which can increase the winter range of Model 3 by 15% (Tesla AI White Paper)[5].

New power exploration: Hydrogen fuel cell vehicles, such as those from Toyota and Hyundai, have achieved commercial production, with a range of 600-800 kilometers. However, due to the high cost of hydrogen storage and transportation, as well as the limitations of hydrogen refueling station construction, they cannot be widely used and promoted.

2.2.2 Domestic updates

Battery Innovation: (1) The Kirin Battery (CTP3.0) developed by CATL features an all-in-one module-free structure, optimizing the arrangement of battery cells and cooling systems, achieving a volume utilization rate of 72%. When paired with the Zeke 001 model, it can reach a range of 1032km (CLTC) within 8 minutes (CATL Whitepaper, 2023). (2) The graphene-based fast-charging battery developed by Guangzhou EVAN is capable of charging 80% in 8 minutes (SAE Technical Paper 2023-01-0156). This battery incorporates graphene into the electrodes to enhance the conductivity of the electrode materials and the speed of ion transmission, thereby solving the problem of long charging times. (3) Huawei's 1.5MW ultra-fast charging technology: It can provide 20km of range after 1 minute of charging. The fully liquid-cooled ultra-fast charging stations have been put into operation in cities such as Xi'an and Shenzhen, and the ultra-fast charging stations serve over 1,400 vehicle trips daily (Huawei Digital Energy

Report, 2025)[6].

Energy Management: The team from Beihang University combined model predictive control (MPC) with reinforcement learning to develop a vehicle dynamic energy management system. Under NEDC conditions, it reduced energy consumption by 12.7% (Automotive Engineering, 2022). It can intelligently allocate battery energy, optimize the output of the power system, and recover braking energy, among other goals. The BMS 3.0 of NIO uses over 200 sensors to monitor the battery cells, with the prediction error of battery cell health < 3%, and the accuracy of range estimation reaches 95% (NIO Technology White Paper, 2024)[7].

New Power Research: China continues to increase its investment in hydrogen fuel cell vehicles, having established numerous demonstration operation projects of hydrogen fuel cell vehicles in places like Shanghai and Guangdong, and has put them into use in various types of vehicles such as buses, logistics vehicles, and passenger cars; however, bottlenecks in hydrogen production, transportation, and refueling still need to be overcome.

2.2.3 Current challenges

There is a contradiction between the safety and performance of high-energy-density batteries. Most high-energy-density batteries use high-nickel cathodes, and during the charging process, they are prone to phase changes and thermal runaway, which affects battery safety. Taking a certain brand's 811 lithium-ion battery model as an example, it operates normally during normal driving, but during sudden acceleration and braking, it undergoes frequent high-rate charging and discharging, resulting in extremely high temperatures. The cooling system malfunctions, and after a certain period of charging and discharging, the battery will experience high-temperature overheating and combustion, demonstrating the uncontrollable risks inherent in the high-nickel cathode material. During the charging and discharging process of high-nickel lithium-ion materials, the crystal structure is prone to change, causing the ignition point of the electrolyte to be mostly below 200°C. Under high-voltage platforms (800V), the electrochemical reaction is intense, and the liquid electrolyte cannot meet the safety requirements of the battery. That is, while increasing the energy density, battery safety also needs to be taken into account. This is a challenge faced at the present stage: lightweight material costs and process limitations. Carbon fibers, although capable of reducing weight by 40%, have a cost that is 5 to 10 times that of steel and cannot meet the requirements for large-scale molding, thus not being widely applied (Li et al., Materials Today, 2022). A certain domestic vehicle, due to the use of carbon fiber body panels, increased the cost of each vehicle by 32,000 yuan, losing its competitiveness in the industry. The qualified rate of magnesium alloy die-casting is lower than 75%, with poor corrosion resistance, requiring coating treatment, and the manufacturing of complex materials results in significant waste. In addition, factors such as high production temperatures, high pressures, and high costs of carbon fiber production are not conducive to its widespread application in large-scale production of automobiles. In terms of battery performance, the viscosity of the electrolyte increases at low temperatures, the internal resistance increases, and the range degradation can reach 30%; high temperatures can cause self-discharge and degradation of electrode materials. To solve these problems, breakthroughs are needed in lightweight materials and battery technology, as well as in thermal management technology[8].

The development of new energy is constrained by both technology and infrastructure. Hydrogen power faces problems such as difficult hydrogen storage, high transportation costs, and a shortage of hydrogen refueling stations. In terms of charging infrastructure, the proportion of ultra-fast charging stations is low and their distribution is uneven. There are few charging facilities in old residential areas, and private cars have long queues for charging.

3. Research Objectives, Contents and Key Issues

3.1 Research Objectives

1. Battery Technology: Develop high-energy-density batteries with an energy density of ≥ 400 Wh/kg. Through material modification and structural optimization, balance battery safety and cycle life. Break through the existing bottleneck of battery energy density and significantly increase the range of new energy vehicles.
2. Thermal Management: Optimize the intelligent thermal management system to

achieve a temperature difference of ≤ 3℃ between the battery and the motor. At the same time, reduce the energy consumption of the thermal management system by 30% to ensure that the battery and motor are always within the optimal working temperature range, thereby improving their performance and lifespan.

3. Energy Management: Through optimizing energy distribution and recovery strategies, achieve a 15% reduction in vehicle energy consumption under NEDC conditions, further improving the energy utilization efficiency of new energy vehicles.

4. Lightweighting and Design: Use lightweight materials such as carbon fiber to optimize the vehicle body structure, combined with aerodynamic design, to reduce the drag coefficient to ≤ 0.25. Reduce the air resistance during vehicle operation, decrease energy consumption, and enhance the range.

5. Research on Hydrogen Power: Investigate the feasibility of hydrogen power in automotive applications, propose technical implementation plans, and provide theoretical basis for the upgrade of future new energy vehicle power systems.

3.2 Research Contents

3.2.1 Battery technology research

Material system optimization: Conduct integrated application research on high-nickel ternary positive electrodes (NCM811), silicon-based negative electrodes (Si@C), and solid-state batteries. Improve the structural stability and cycle life of high-nickel ternary positive electrodes, solve the volume expansion problem of silicon-based negative electrodes during charging and discharging through porous carbon coating technology, and further enhance their initial charging and discharging efficiency and cycle stability performance; carry out the construction of solid-state battery production lines and optimize process parameters to achieve breakthroughs in high-energy battery technology[9].

Solid-state battery integration: Explore the interface matching between sulfide solid-state electrolytes and high-nickel positive electrodes, silicon-based negative electrodes, through surface modification and composite electrolyte design to reduce impedance, and promote the implementation of pilot production.

3.2.2 Intelligent thermal management system design

Design an intelligent temperature control system based on deep learning (LSTM), combined with liquid cooling - PCM (phase change material) hybrid cooling scheme. Use the LSTM algorithm to conduct real-time analysis and prediction of the temperature data of batteries and motors, and intelligently control the working state of the liquid cooling system and PCM (phase change material) cooling system based on the prediction results, achieving precise temperature control of batteries and motors. Through experiments and simulations, optimize the design of liquid cooling channels to improve heat dissipation efficiency, reduce energy consumption, and enhance the real-time response capability of the thermal management system in extreme temperatures.

3.2.3 Energy management

Develop multi-objective optimization algorithms for the dynamic allocation of battery energy and efficient recovery of braking energy. Optimize the output and energy recovery based on factors such as vehicle driving conditions, battery state, and motor load, maximizing energy utilization efficiency, and analyze the coordination methods between the energy management system and the battery management system and the thermal management system during their coordinated operation[10].

3.2.4 Lightweighting and design

Optimize the design of carbon fiber body panels, using methods such as finite element analysis, to minimize material usage while ensuring the strength and safety of the body and minimizing the body weight; conduct wind tunnel tests to verify aerodynamic performance, optimize the body design, and minimize the drag coefficient of the body to increase the stability and range of the vehicle.

3.2.5 Hydrogen power research

Hydrogen power system: Study the feasibility of applying high-pressure gaseous, low-temperature liquid, and solid-state hydrogen storage technologies in vehicles, optimize the design of hydrogen fuel cell stacks, improve energy conversion efficiency; explore on-board hydrogen production technology to reduce dependence on hydrogen refueling stations; analyze the overall integration scheme of hydrogen-powered vehicles to solve problems such as hydrogen supply, fuel cell heat dissipation, and safety protection[11].

3.3 Key Issues

Stability problem of high-nickel ternary materials: During high-voltage charging and discharging of high-nickel cathode materials, the surface SEI film is prone to failure, leading to battery capacity degradation and the risk of thermal runaway. Solution direction: Through doping modification and surface coating techniques, balance energy density, structural stability, and cycle life.

Extreme temperature thermal management challenge: For intelligent thermal management systems, quickly control temperature in extremely cold environments of -30℃ to high-temperature environments of 50℃; the reliability of liquid cooling and PCM materials is insufficient in extreme temperatures. Goal: Improve the real-time and reliability of the thermal management system in extreme conditions. This is also the future development direction[12].

Bottleneck in mass production of lightweight materials: The cost of carbon fiber is high, and its prepreg material has a complex molding process and a long preparation cycle, making it impossible to be mass-produced. Breakthrough: Develop low-cost and high-efficiency carbon fiber preparation and molding processes to reduce the production cost.

Bottleneck of hydrogen power technology: Low efficiency in hydrogen storage and transportation (high-pressure hydrogen storage tanks are heavy and large, affecting range); High cost and short lifespan of fuel cells; Insufficient hydrogen refueling station infrastructure, making it impossible to ensure their commercial application.

4. Research Methods, Technical Route and Feasibility Analysis

4.1 Research Methods

4.1.1 Experimental research

Battery material synthesis: Utilize the co-precipitation method to synthesize high-nickel ternary cathode precursors. Adjust the reaction temperature, pH value, and metal ion molar ratio to improve the morphology and particle size distribution of the precursors; use the chemical vapor deposition (CVD) technology to coat a porous carbon layer on the surface of silicon nanoparticles, and study the effects of deposition temperature, time, and gas flow rate on the structure and performance of the carbon layer.

Thermal management system bench test: Establish a test bench for the thermal management system and integrate liquid cooling circulation, heat pump system, and PCM heat dissipation module. Use PID control algorithm to control the temperature and flow rate of liquid cooling, and use the LSTM model to predict and verify the effectiveness of the intelligent temperature control algorithm for the changes in battery temperature.

(1) Hydrogen power experiment: Establish a hydrogen fuel cell test bench to detect the electrical performance, thermal performance, and durability of the fuel cell; conduct pressure tests, air tightness tests, and safety performance tests for hydrogen storage containers, complete the development of a hydrogen production device for small-scale trials, and explore new and efficient hydrogen production processes.

(2) Improve infrastructure: Promote the construction of hydrogen refueling stations, formulate planning and subsidy policies, simplify approval procedures, and attract capital.

(3) Industrial synergy: Strengthen the collaborative cooperation among upstream and downstream enterprises in the hydrogen-powered vehicle industry chain to form a complete industrial ecosystem, reduce costs, and enhance competitiveness.

(4) Policy support and public awareness enhancement: The government introduces purchase subsidies, tax incentives, etc., strengthens public awareness campaigns, raises public awareness of the safety and environmental protection of hydrogen-powered vehicles, and promotes market promotion.

4.1.2 Simulation analysis

1D-3D Combined Simulation: Optimize the design of the liquid cooling channel, simulate the heat dissipation effect under different channel structures and coolant flow rates to improve the heat dissipation efficiency. Simulate the wind resistance coefficient of the vehicle under different driving conditions, optimize the body shape design.

COMSOL Multi-Physics Simulation: Based on the COMSOL Multiphysics platform, establish a coupling model of battery-thermal management system to study the influence of internal heat transfer, mass transfer, and synergy on the heat pipe heat dissipation and PCM phase change characteristics.

Hydrogen Power: Build a hydrogen-powered vehicle system model using MATLAB/Simulink to analyze the dynamic characteristics of hydrogen supply, fuel cell power generation, and vehicle power output; use ANSYS to simulate the structural strength and fatigue life of the hydrogen storage container.

4.1.3 Data-driven

Data collection: Collaborate with vehicle manufacturers to obtain standard operating conditions (such as NEDC and WLTC) and actual road test data (vehicle speed, acceleration, battery voltage, current, temperature, etc.) as well as driving behaviors of drivers under different driving styles and usage scenarios collected through user surveys and on-board sensors.

Data Analysis and Modeling: Utilize tools such as Python and Matlab to complete the cleaning, preprocessing, and feature extraction of collected data. Employ machine learning algorithms to establish a driving mode recognition model and an energy management strategy optimization model. Through data training and verification, improve the accuracy and applicability of the algorithms. At the same time, collect technical parameters related to hydrogen power and nuclear power, and analyze the feasibility and performance of the related technologies.

4.2 Technical Route

4.2.1 Materials research phase

The high-nickel cathode materials were doped and modified. Experimental investigations were conducted on the structural stability and electrochemical performance of the materials before and after doping, and the optimal doping scheme was obtained. The porous carbon coating process for silicon-based anodes was studied. Using CVD technology, a porous carbon layer was prepared on the surface of the silicon-based anode, and the performance of the coated layer was improved by adjusting the coating process parameters.

While conducting pilot production of solid-state batteries, a solid-state battery laboratory production line was established, and the preparation process of solid-state electrolytes, electrode-electrolyte interface and other key process technologies were studied. Laboratory small-scale trial production of solid-state batteries was completed.

4.2.2 System integration phase

Design a liquid cooling - PCM hybrid heat dissipation structure and develop the hardware for the thermal management system; embed the LSTM algorithm into the vehicle's electronic control unit (ECU) to achieve intelligent temperature control functionality. Design and optimize the structure of the carbon fiber body, verify its strength and stiffness through finite element analysis, and conduct lightweight verification. At the same time, develop multi-objective optimization algorithms to achieve the optimization control of the vehicle's energy management system.

Conduct lightweight verification of the carbon fiber body, optimize the design of the carbon fiber body structure through finite element analysis, manufacture carbon fiber body samples and conduct strength tests to verify the lightweight effect.

Carry out hydrogen power system integration design, including the layout and matching of hydrogen fuel cells, hydrogen storage devices, and on-board hydrogen generation equipment, determine the type, structure, and energy conversion scheme.

4.3 Verification and Optimization Phase

Conduct bench tests for the thermal management system, and perform performance tests on the optimized thermal management system to verify its temperature control effect and energy consumption reduction under different operating conditions.

Carry out real vehicle road tests in extreme weather conditions to test the integrated optimized new energy vehicle, collect vehicle performance data, including range, energy consumption, battery status, etc.

Based on the test results, update the algorithm iteratively to further optimize the thermal management system, energy management system, and body design, and improve the comprehensive performance of the new energy vehicle.

3.4. Conduct bench tests and real vehicle tests for the hydrogen power system, optimize the performance of the fuel cell and the hydrogen supply system.

4.3 Feasibility Analysis

4.3.1 Material technology foundation

Technical Foundation: Ningde Time has experience in the research and production of high energy density batteries, and Kirin Battery technology has also been introduced in this research; the dynamic energy management algorithm and thermal management technology of the Beihang team can be applied or improved in this research topic; the research on solid-state batteries and carbon fiber materials conducted by domestic universities and research institutions is the theoretical and technical foundation of this thesis; in the hydrogen power field, the commercial exploration of hydrogen-powered vehicles by Toyota, Hyundai, etc. provides reference for subsequent technical research.

4.3.2 Simulation tool support

Professional simulation software such as COMSOL and ANSYS have strong multi-physics coupling functions. In this project, we can use professional simulation software to conduct precise simulation analysis of the battery thermal management system and aerodynamic performance, saving the cost of experimental trial and error and shortening the research and development cycle; for new power systems, professional and hydrogen power system simulation tools can complete the implementation of project research work.

4.3.3 User data acquisition

Car companies have NEDC/WLTC operating condition data and real driving condition data from users. Cooperation with car companies can obtain a large amount of real data for training and verifying energy management algorithms; the research results in the hydrogen-related field of domestic research institutions can be used as an important reference basis for the technical feasibility and performance evaluation of this project.

5. Innovation

5.1 Technological Integration Innovation

For the first time, the deep learning method (LSTM) and the liquid cooling-PCM hybrid cooling system were combined into the thermal management system. Based on the real-time temperature information of the battery and the motor, the LSTM algorithm was used to predict the temperature trend in the future period, and accordingly, it was determined how to make the liquid cooling and PCM cooling systems work more compatibly, so as to make the thermal management system better meet the requirements in different working conditions and external environments, and better achieve the purposes of temperature control, regulation of heat dissipation rate, and energy saving and consumption reduction. New approaches and methods for combining hydrogen power with existing battery technologies and thermal management systems were explored to develop new power systems for new energy vehicles.

5.2 Materials and Design Synergy

Optimize the matching relationship between high-nickel ternary cathodes, silicon-based anodes, and traditional graphite anodes, breaking through the energy density bottleneck of traditional graphite anodes; explore the synergy mechanism of different positive and negative electrode materials, develop electrode preparation processes and battery assembly technologies suitable for their matching, and achieve an increase in battery energy density. In combination with carbon fiber body and wind tunnel tests, balance lightweighting and structural strength, and improve the overall performance of the vehicle. In hydrogen power, pay attention to the coordination of materials and systems, allowing new materials to exert greater efficacy and ensuring the safety and reliability of new technologies.

5.3 User Demand Oriented Approach

Develop dynamic energy management strategies based on various massive driving behavior data. By analyzing the actual driving behaviors of users and their energy demands, the energy management system can adjust the battery's optimal working state according to the current operating conditions. This enables efficient energy utilization and effectively alleviates users' concerns about mileage. At the same time, by analyzing the current hydrogen-powered and new energy vehicle models available in the market, and understanding the purchasing needs and acceptance levels of users for these vehicles, it provides certain data support for the research and promotion of the technology.

6. Plan Progress and Expected Outcomes

6.1 Plan Progress

The first stage involves conducting a comprehensive investigation of the current research status both domestically and internationally, grasping the development trend of related technologies, identifying deficiencies and making up for them, and clarifying the specific research plan; collecting data from various sources such as NEDC, WLTC operating conditions, and diverse driving behaviors of users as important reference materials for subsequent work; completing the construction and debugging of the test platform for the thermal management system, enabling the test equipment to realistically simulate various working conditions; collecting and preliminarily analyzing hydrogen power technology materials.

The second stage involves conducting high-nickel ternary positive material doping experiments to understand the influence patterns of different doping elements and doping processes on performance; exploring and optimizing the process of silicon-based negative electrode with porous carbon coating; completing the design of a liquid cooling-PCM hybrid heat dissipation structure and establishing an initial draft of an intelligent temperature control system based on LSTM algorithm; initiating the design of carbon fiber body structure, conducting preliminary optimization using finite element analysis methods; conducting research on hydrogen fuel cell stacks and hydrogen storage technology, and developing a concept design for miniaturized nuclear reactors.

Expected Outcomes: The expected results of the research on the range of new energy vehicles are significant, covering technical, academic, and application fields. Technically, solving issues such as battery and resistance is the key to improving range; academically, producing papers and patents to promote communication; application-wise, forming solutions, promoting cooperation and demonstrations, and facilitating industry development.

Technical Achievements: Through material optimization and pilot production of solid-state batteries, the energy density of the battery pack reaches 350Wh/kg, with a range exceeding 960 kilometers; the thermal management system utilizes intelligent algorithms and mixed cooling to precisely control temperature, ensuring stable range in extreme climates; the energy management algorithm for the entire vehicle reduces energy consumption and improves range in complex road conditions; lightweighting and aerodynamics design reduces vehicle weight and reduces wind resistance, reducing energy consumption; hydrogen power enhances the performance of fuel cells, laying the foundation for future power development.

Academic Achievements: Plans to publish papers in core journals at home and abroad to share innovative results; applying for patents to protect core technologies; participating in international academic conferences to enhance international influence, promoting technical cooperation and academic exchanges.

Application Achievements: Forming a complete technical solution to provide reference for automakers; collaborating with automakers to enhance the competitiveness of product range; promoting hydrogen power demonstration operations to accumulate experience and improve the industry chain; assisting in formulating hydrogen power standards and specifications to lay the foundation for future applications.

Research shows that to improve the range of new energy vehicles, breakthroughs need to be made from multiple dimensions:

Battery Technology: Develop high-nickel ternary / solid-state batteries with an energy density of ≥ 400Wh/kg, simultaneously addressing material stability and safety issues;

Thermal Management: Optimize the intelligent temperature control system to achieve rapid temperature regulation of the battery within -30℃ to 50℃ environments, reducing energy consumption by 30%.

System Synergy: Through energy management strategies, lightweight design, and aerodynamics optimization, improve energy utilization efficiency.

6.2 Future Outlook

Exploration of New Power Technologies: Hydrogen power is being explored. Toyota and Hyundai's hydrogen fuel cell vehicles can travel up to 600-800 kilometers, but the high cost of hydrogen storage and the insufficient construction of hydrogen refueling stations have hindered its widespread adoption; on-board hydrogen production technology may become a key solution.

Integration of technologies and industrial collaboration promote the combination of LSTM algorithms and liquid cooling - PCM hybrid cooling technology to achieve precise thermal management.

Strengthening industry collaboration, reducing the cost of lightweight materials such as carbon fiber, and improving charging/hydrogen refueling infrastructure (in China, only 12% of public charging piles are fast chargers in 2025, and the layout in third- and fourth-tier cities needs to be accelerated).

Policy and market-driven: The government needs to introduce subsidy policies to support hydrogen-powered demonstration operations and nuclear power technology research and development; enhancing public awareness of new power technologies, such as the potential for zero carbon emissions, to help achieve the "dual carbon" goals.

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