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Research on Functional Requirements of Automotive Power Battery Shells and Application of Carbon Fiber Composites

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Abstract. The mandatory national standard Safety Requirements for Traction Batteries for Electric Vehicles (GB38031-2025) will take effect on July 1, 2026. The stringent requirements of this new standard are bound to drive qualitative changes in the industry. As a core component of new energy vehicles (NEVs), power batteries are subject to paramount safety demands. The power battery shell, which houses all components of the battery pack, is a key focus for further enhancing safety standards. By comparing carbon fiber composites with traditional metal materials, this paper demonstrates that the former—boasting higher strength, lighter weight, and superior corrosion resistance—is more suitable for manufacturing power battery shells. It better meets the safety and lightweight requirements of power batteries, making it the preferred material for shell production.Although China currently faces shortcomings in the R&D, application, and recycling of high-quality carbon fiber materials, the immense market prospects necessitate intensified efforts to achieve systematic breakthroughs in the carbon fiber composite industry.Vigorously promoting the use of carbon fiber composites in battery shell manufacturing, as well as in the production of other automotive components, represents a key development direction in the materials field. Therefore, strengthening research to overcome technical bottlenecks and expand the application of carbon fiber composites is not only essential for achieving "corner overtaking" in the NEV sector but also a strategic imperative for national development.

Keywords: New energy vehicles, Power battery shells, Carbon fiber composites

1. Introduction

In recent years, the NEV industry has maintained robust growth. However, behind this prosperity, accidents such as fires and spontaneous combustion cannot be overlooked. Fundamentally, most safety incidents involving NEVs stem from "thermal runaway" of power batteries [1]. As electrochemical carriers, batteries undergo constant state changes during operation, meaning thermal runaway risks persist at all times. Thus, improving safety performance and safety protection technologies remains an ongoing priority. As an integral part of safety protection, battery shells must also meet corresponding safety standards. NEVs have become a primary driver of the global automotive industry's transformation and a critical engine for global economic growth [2]. Ensuring safety entails striking a new balance between lightweight design, high safety performance, and manufacturing feasibility—this is a guarantee for consumers' safety and a new strategy for "Made in

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China".This paper focuses on the functional requirements of automotive power battery shells and the properties of carbon fiber composites. By highlighting that carbon fiber composites outperform metal materials and better align with the functional needs of battery shells, coupled with their potential for larger market scale, this paper argues for increased research and applications of such composites.

2. Performance requirements of NEVs for power battery systems

With the rapid development of China's NEV industry, more urgent demands have been placed on the R&D of power battery technologies. Approximately 80% of NEV failures originate from power battery malfunctions [3]. When batteries are subjected to external impacts, overcharging/discharging, or heat accumulation, issues such as electrolyte leakage, local short circuits, and insulation damage may occur—ultimately leading to fires and endangering the safety of the vehicle and its occupants. Additionally, gaps still exist between China and developed countries, particularly in power battery technology [4]. Clearly, as the automotive industry expands and matures, it is crucial to continuously enhance product performance: while improving ride comfort, ensuring vehicle safety remains a top priority. Power batteries are the core focus of NEV technology. During operation, electrical energy primarily powers the vehicle's own weight; therefore, reducing vehicle weight is an indispensable technical path to save energy and extend driving range. Importantly, a lightweight design must not compromise safety (e.g., shock resistance and impact resistance); instead, it requires balancing safety improvements with constraints such as manufacturing processes and costs. In 2025, the Ministry of Industry and Information Technology released the mandatory national standard Safety Requirements for Traction Batteries for Electric Vehicles (GB38031-2025), which will take effect on July 1, 2026 [5]. This revision further clarifies requirements for test battery temperature, power-on/off states, observation duration, and vehicle test conditions. Technical standards have been upgraded: previously, systems only needed to issue a thermal event alarm 5 minutes before a fire or explosion; now, they must prevent fires and explosions (while still requiring alarms), and smoke must not harm occupants. Additionally, new tests have been added, including a bottom impact test (to assess protection after underbody collisions) and a post-fast-charging-cycle safety test (requiring no fire or explosion in external short-circuit tests after 300 fast-charging cycles). This standard compels battery systems to achieve significant technological breakthroughs in core battery shell functions, including structural stability, battery protection (anti-collision, anti-vibration, waterproofing, dustproofing, corrosion resistance), and thermal runaway mitigation.

3. Domestic and international research status of NEV power batteries

For a long time, steel and aluminum alloys have been the primary materials for manufacturing automotive power battery shells. However, the inherent limitations of metals hinder technological advancement: first, steel is heavy, and while aluminum alloy is lighter than steel, it still significantly reduces the energy density and range of the entire battery pack; second, steel is prone to rust, and aluminum faces risks of electrochemical corrosion; third, strict manufacturing requirements restrict design flexibility, making it difficult to meet the needs of high-performance vehicle models. Thus, finding alternative materials is inevitable.

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3.1. Application status of carbon fiber composites in automotive structural components

The State Council's Made in China 2025 identifies carbon fiber and its composites as key materials for automotive energy conservation and NEV development. Through research and technological breakthroughs, carbon fiber composites are widely used in manufacturing automotive wheels, transmission components, braking systems, engine parts, interior trim, and outer shells [6]. Carbon fiber wheels reduce weight and rotational inertia: a 1kg reduction in unsprung mass equals a 6kg reduction in sprung mass, improving vehicle handling. Carbon fiber brake discs have exceptional high-temperature resistance—withstanding 2500°C while maintaining stable performance, as seen in the Porsche 918 Spyder’s brake discs that decelerate from 300km/h to 50km/h within 50 meters. Carbon fiber drive shafts reduce weight by over 40% with excellent durability: the Toyota 86's carbon fiber drive shaft weighs 5.5kg, a 50% reduction vs mainstream steel drive shafts [6]. However, high application costs and long production cycles constrain the automotive industry's reliance on CFRP composites, limiting them to high-end automotive manufacturing [7]. With technological advancement, carbon fiber composites are seeing expanding research and application as modern automotive design moves toward higher performance and lighter weight.

3.2. Key technical challenges of carbon fiber composite battery shells

The introduction of the new national standard Safety Requirements for Traction Batteries for Electric Vehicles (GB38031-2025) raises the bar for battery safety [8]. Compared to GB38031-2020, the new standard adds tests for "bottom impact", "thermal propagation", and "post-fast-charging safety" while tightening requirements for existing tests. Thermal propagation, bottom impacts, and fast-charging safety are currently the three most prominent safety risks for NEV power batteries—and the new standard addresses each of these risks proactively. This indicates that battery shells now require higher-performance materials, forcing enterprises and research institutions to accelerate new material R&D, enhance material properties and structural strength, optimize manufacturing processes, reduce weight, and lower costs to improve competitiveness and meet consumers' evolving performance demands. As a key candidate material for battery shells, carbon fiber composites urgently require technological upgrading.

3.3. Existing research gaps in carbon fiber composites

Currently, safety standards for power battery shells are primarily based on Safety Requirements for Traction Batteries for Electric Vehicles (GB38031-2020), with indicators inherited from previous-generation metal manufacturing processes [8]. There is an urgent need to establish a more scientific safety evaluation system for carbon fiber composite battery shells—particularly updating research on the unique failure modes and safety hazards of carbon fiber composites. For instance, during vehicle operation, carbon fiber composite battery shells are exposed to combined environmental stressors (mechanical vibration, temperature/humidity fluctuations, and chemical corrosion), which degrade material performance and compromise battery system safety and reliability. Thus, the durability of carbon fiber composite battery shells must be clearly defined as a key safety indicator.

Although China has made significant progress in manufacturing high-performance carbon fiber composites in recent years—with improvements in key technologies, equipment, and applications—gaps remain between China and leading countries such as the United States, Japan, and Germany. Key challenges include high impurity content in domestic raw fibers, unstable product quality, high production costs, and heavy reliance on imports for high-end products. However, China's booming

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NEV industry presents unprecedented opportunities for carbon fiber composite development. Based on independent innovation, China must accelerate the development of a complete carbon fiber industrial chain—advancing raw material technology, production processes, and application integration to achieve breakthroughs.

4. Functional and performance requirements of NEV battery shells

As a load-bearing component, the power battery shell protects battery modules and is critical to NEV safety. The rigidity of the battery pack shell is particularly important: it must remain intact when subjected to external collisions or compression during accidents. Power batteries consist of high-voltage cells, electronic components, sensors, and connectors—thus, the shell must also prevent water seepage under complex road conditions (to keep internal components dry) and resist high temperatures, corrosion, and aging to ensure the vehicle's service life and overall safety. In terms of design, multi-functional integration is an optimized approach for carbon fiber composite battery shells. However, this introduces an inherent conflict between mechanical and electrochemical properties: carbon fiber composites in batteries must act as both electrode materials and structural reinforcements, requiring them to simultaneously ensure mechanical stability and enable efficient energy storage and transfer—placing higher demands on material technology.

4.1. Carbon fiber composites outperform alternatives in key properties

Carbon fiber composites offer the following advantages: (1) Low density and high specific strength: The density of CFRP is only 1/5 that of steel and 1/3 that of titanium alloy. Its specific strength is approximately 4 times that of high-strength steel, super-hard aluminum, and titanium alloy, and twice that of fiberglass-reinforced plastic (FRP)—while its specific modulus is three times that of these materials [9]. Excellent fatigue resistance: Under static conditions, steel can only withstand approximately 50% of its ultimate strength; in contrast, CFRP can withstand up to 90% of its ultimate strength even after over 100 stress cycles [9]. (3) Superior wear resistance, pressure resistance, water resistance, and corrosion resistance [9]. (4) Near-zero thermal expansion coefficient, coupled with good electrical conductivity and electromagnetic shielding performance [9]. These properties enhance resistance to accidental collisions and align with the operational requirements of power battery shells.

Fires in NEVs typically occur in five scenarios: spontaneous combustion during normal driving, collision-induced combustion, spontaneous combustion when stationary, combustion during charging, and water immersion-induced combustion (extreme environments) [10]. Carbon fiber composites furnish a more robust safety barrier against these risks by virtue of their compliance with the physical performance requirements of power battery shells.

With a density of 1.5-2.0g/cm^3 (compared to 2.7g/cm^3 for aluminum alloy), carbon fiber composites facilitate significant weight reduction for battery shells, thereby reducing energy consumption throughout the vehicle's service life. In summary, carbon fiber composites represent a preferred material for battery shells owing to their superior mechanical properties, physical performance, and lightweight characteristics.

4.2. Requirements for manufacturing processes and costs

Despite the significant advantages of carbon fiber composites in power battery shell applications, technological innovations in power batteries (e.g., increased battery space utilization, higher battery

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system energy density, and optimized integration schemes) require concurrent advancements in manufacturing processes [7]. Technical breakthroughs are still needed in production consistency control, defect management, and key bonding technologies.

Cost remains a major barrier to the adoption of carbon fiber composites for battery shells. The cost of carbon fiber raw materials and composite manufacturing processes is generally higher than that of traditional metals. While carbon fiber composites deliver long-term weight reduction and efficiency gains, high initial investment makes it difficult for manufacturers to balance performance requirements with cost reduction, hindering widespread application.

Nevertheless, the technical development of carbon fiber composite battery shells is moving toward low-cost production, multi-functional integration, and environmental sustainability. Developing new technologies to improve the bonding performance between carbon fibers and matrices is a key challenge that must be addressed.

5. Comprehensive analysis of carbon fiber composite properties

Carbon fiber composites offer four key advantages for battery shells: (1) Exceptional tensile strength: Enhances impact and vibration resistance, improving safety; (2) Low density: At approximately 2/3 the density of aluminum alloy, it reduces shell weight and extends driving range; (3) Corrosion resistance: Resists acid and alkali corrosion, prolonging service life; (4) High thermal conductivity: Facilitates heat dissipation from internal components, improving battery performance and safety. These properties directly address the performance requirements of power batteries.

5.1. Comparison of carbon fiber types

Carbon fibers exhibit diverse properties when combined with different matrix materials, enabling optimization of mechanical, thermal, and electromagnetic performance. Based on matrix materials (resin, metal, ceramic, etc.), carbon fiber composites can be categorized into resin matrix composites, carbon/carbon composites, metal matrix composites, ceramic matrix composites, and rubber matrix composites [11]. Resin matrix composites dominate the global carbon fiber composite market, accounting for approximately 80% of consumption [11]. The properties of high-performance carbon fiber composites vary by matrix:

Resin matrix composites: Thermosetting resins (epoxy, phenolic, and bismaleimide) offer high strength and stiffness; thermoplastic resins (polycarbonate, polyphenylene sulfide, and polyether ether ketone) provide good moisture resistance, toughness, and processability [11].

Metal matrix composites (based on copper, aluminum, nickel, or actinium): Deliver high specific strength, high specific modulus, and excellent fatigue strength [11].

Ceramic matrix composites: Improve toughness and enhance resistance to mechanical and thermal shock [11].

Rubber matrix composites: Enhance thermal fatigue resistance and extend service life [11].

Carbon/carbon composites (reinforced with carbon fibers and carbon cloth): Feature low density, ablation resistance, and thermal shock resistance [11]. Notably, high-performance carbon fiber composites can be optimized for specific needs (e.g., fiber orientation), and material selection for battery shells must match functional requirements.

5.2. Performance comparison between carbon fiber composites and metals

Currently, high-strength aluminum alloy, titanium alloy, and steel are the primary materials for automotive power battery shells [12]. Titanium alloy offers high strength and corrosion resistance but is costly; steel is low-cost and easy to process but heavy and corrosion-prone; high-strength aluminum alloy balances lightweight design, strength, and corrosion resistance—making it the most widely used material. According to the Chinese Society of Composite Materials, carbon fiber composites outperform metals in several key aspects [12]: (1) Weight and strength: Carbon fiber composites are lighter and offer higher specific strength and modulus; (2) Corrosion resistance: Carbon fiber undergoes graphitization at 2000-3000°C, forming a graphite-like microcrystalline structure with inherent corrosion resistance; (2) Fatigue resistance: Carbon fiber components excel in high-fatigue areas (e.g., automotive chassis); (4) Design flexibility: Using laminate theory, carbon fiber materials can be customized for stiffness and strength by adjusting layer angle, ratio, and sequence—unlike traditional metals, which rely solely on thickness increases. Given these advantages, carbon fiber composites for automotive power battery shells represent a cutting-edge direction for automotive lightweighting and the integration of new materials and technologies.

6. Conclusion

Compared with traditional metals, carbon fiber composites offer higher strength, lighter weight, and better corrosion resistance. With ongoing technological advancements, they are increasingly capable of meeting the diverse performance requirements of automotive power batteries—making them a key target for new material R&D. Today, the development of cutting-edge technologies such as artificial intelligence, cloud computing, and big data provides effective solutions to longstanding challenges in the NEV sector [13]. Consumer concerns including battery quality, range, charging efficiency and safety are gradually addressed, bringing unprecedented opportunities for the NEV industry. As technology advances and research deepens, existing challenges will be overcome, driving further industrial growth.

For the sustainable development of the NEV industry, the carbon fiber composite market (encompassing R&D, manufacturing, application, and recycling) must address four key technical challenges: (1) Reduce carbon fiber material costs to eliminate barriers to widespread adoption; (2) Strengthen research on mechanical properties and service life under different reinforcement materials to meet diverse needs; (3) Improve manufacturing processes and technical capabilities; (4) Expand the recycling of end-of-life power batteries to promote resource reuse and environmental protection. These steps will break bottlenecks in the application and production of carbon fiber composite shells. More importantly, to achieve leadership in the global NEV sector, China must adopt a strategic perspective: leveraging the accelerated growth of the NEV era to enhance top-level design and advance carbon fiber composite R&D and application through policy guidance, regulatory frameworks, and fiscal support.

References

[1] Yan, H. (2019). How to Address Power Battery Safety Challenges: Insights from This Technical Forum. Public Transport of the People, pp. 39.
[2] Fu, Z. (2021). Embracing New Energy for Sustainable Development. Journal of Beijing Petroleum Management Cadre College, pp. 9.
[3] Wang, Z. Q., Ma, C., Fan, J. F., Zhang, X. G., & Zhang, G. E. (2022). Development and Performance of Thermally Conductive Silicone Materials for Power Batteries. Materials Science, pp. 941.

DOI: 10.54254/2755-2721/2026.MH30661

[4] Cheng, Y., Feng, J., Liu, Z. P., Wen, H., & Huang, X. H. (2019). A Study on the Diversified Innovation Strategy for China's New Energy Vehicles. China Market, (28), 16.
[5] China Environmental News Network. (2025, April 16). New National Standard for Electric Vehicle Batteries to Take Effect on July 1, 2026. Retrieved from http: //www.cenews.com.cn/news.html?aid=1223295
[6] Li, C. X. (2019). Applications of Carbon Fiber and Its Composites in the Automotive Industry. New Material Industry, pp.7.
[7] Zhang, J. H. (2019). An Analysis of the Application Status of Carbon Fiber-Reinforced Polymer Composites. Building Materials & Decoration, (October), 63.
[8] Wu, P. (2025). A Study on Volkswagen's Marketing Strategy Under the New National Standard for Automotive Batteries. Electronic Commerce Review, pp. 1502.
[9] Sohu.com. (2021, March 15). An Introduction to Carbon Fiber-Reinforced Polymer Composites. Retrieved from https: //www.sohu.com/a/471456397_120246036
[10] Ruan, Y. L., & Wang, J. (2019). An Analysis of Fire Accidents in China's New Energy Vehicles and Countermeasures. Automotive Abstracts, (05), 40-41.
[11] Fan, X. (2019). Application Status and Development Trends of Carbon Fiber Composites. Chemical Industry, 37(4), 12.
[12] Chinese Society of Composite Materials. (2020, June 8). Performance Comparison Between Carbon Fiber Composites and Traditional Metals. Retrieved from https: //www.csfcm.org.cn/site/content/2410.html
[13] Yuan, Z., & Tan, Q. (2023). Long-Term and Short-Term Forecasting of New Energy Vehicle Sales in China. Advances in Applied Mathematics, pp. 2002.