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Analysis of Potential Causes of Safety Failure of New Energy Vehicle Power Batteries

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Abstract: The aim of this paper is to analyze the potential reasons for the safety failure of batteries for new-energy vehicles. Firstly, the importance and popularization of new energy batteries are introduced, and the importance of safety failure issues is drawn out. Then, the composition and working principle of the battery is explained in detail, which provides the basis for the subsequent analysis. Then, the potential impacts of factors such as overcharge and over-discharge, high and low temperature environments, internal faults, and external shocks and vibrations on the safety of the batteries are analyzed. Finally, some common safety measures and solutions are proposed to improve the safety of new energy batteries, in hopes of improving the safety of batteries for new-energy vehicle.

Keywords: New-energy vehicle; Power battery; Safety failure; Potential cause; Analysis and research

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1. Introduction

As the world pays more and more attention to environmental issues, new energy vehicles, as an environmentally friendly and sustainable means of transportation, are gradually replacing traditional fuel vehicles. The battery as one of the core components of new energy vehicles has become particularly important for the safety of the vehicle. However, safety accidents have occurred in recent years and have raise concerns about the safety of new energy vehicles. Therefore, an in-depth analysis of the potential reasons for the safety failure of new energy vehicle power batteries is of great significance to ensure the safety of new energy vehicles. This article will start with the composition and working principle of the power battery, followed by exploring the potential causes of safety failures of the power battery. Specifically, we, the impact of factors such as overcharging and over-discharging, high and low temperature environments, internal failures, and external shock and vibration on the safety of power batteries are analyzed. Subsequently, some common safety measures and solutions are proposed to improve the safety of batteries for new-energy vehicles. We hope to provide some guidance and reference for the safety of new energy vehicle power batteries and promote the sustainable development of the new energy vehicle industry through this paper.

2. The importance of batteries for new energy vehicles

First of all, the battery is the main source of energy of new energy vehicles. Electrical energy is stored and released by the battery when needed to power electric vehicles. Compared to traditional fuel vehicles, new-energy vehicle batteries can convert energy more efficiently and provide a greater power output. The battery of a new energy vehicle uses electric energy; thus, it does not produce exhaust emissions and achieves zero-

emission driving. This is of great significance for reducing air pollution and improving environmental quality, and helps in dealing with climate change and other environmental issues. Thirdly, compared to traditional fuel vehicles, the energy utilization efficiency of new energy vehicle batteries is higher. Batteries for new energy vehicles can store electrical energy and release energy when needed, thus reducing energy waste. This helps to reduce dependence on non-renewable energy and improve energy efficiency [1]. The electric energy used by the batteries of the fourth-generation electric vehicles can be charged by renewable energy, such as solar energy and wind energy. The use of renewable energy helps reduce dependence on traditional energy sources and promote sustainable development. Besides, the recycling and reuse of batteries also help reduce resource consumption and environmental impact. The development of the fifth-generation new energy vehicle batteries has promoted the innovation and progress of battery technology. Scientists and engineers have been conducting research and development to improve the performance, safety, and life of the batteries, which promotes the advancement of battery technology [2]. This technological innovation also helps drive the development of the entire new energy vehicle industry.

3. Composition and working principle of power battery

3.1. Basic components of a battery for new energy vehicles

(i) Positive electrode

The positive electrode of the battery is usually made of a lithium compound, such as lithium iron phosphate lithium (LiFePO4) or lithium nickel manganese cobalt oxide (NMC). The positive electrode is responsible for storing and releasing ions.

(ii) Negative electrode

The negative electrode of the battery is usually made of carbon, such as graphite. The negative electrode is responsible for storing and releasing negative ions [3].

(iii) Electrolyte

The electrolyte of the power battery is usually a liquid or solid conductive medium, which is used for ion conduction between the positive and negative electrodes.

(iv) Diaphragm

The diaphragm of the battery is located between the positive and negative electrodes, and it prevents the electrolyte from mixing while allowing the conduction of ions.

(v) Housing and connectors

The housing and connectors of the battery serve to protect the internal components of the battery and provide connection and installation of the battery.

3.2. Working principle of the battery

The working principle of the battery is based on the movement and chemical reaction of ions between the positive and negative electrodes. The basic steps of how a power battery works is described below (**Figure 1**).

(i) Charging process

During the charging process, electrical energy is supplied by an external source to move the lithium ions (Li^+) from the positive electrode material to the negative electrode material through the electrolyte. At the same time, the carbon in the negative electrode material will absorb and store lithium ions [4].

(ii) Discharging process

During the discharging process, when energy is released from the battery, the stored lithium ions in the negative electrode will move to the positive electrode through the electrolyte. At the same time, the lithium ions in the positive electrode material will react with the oxide layer, releasing electrons and oxygen.

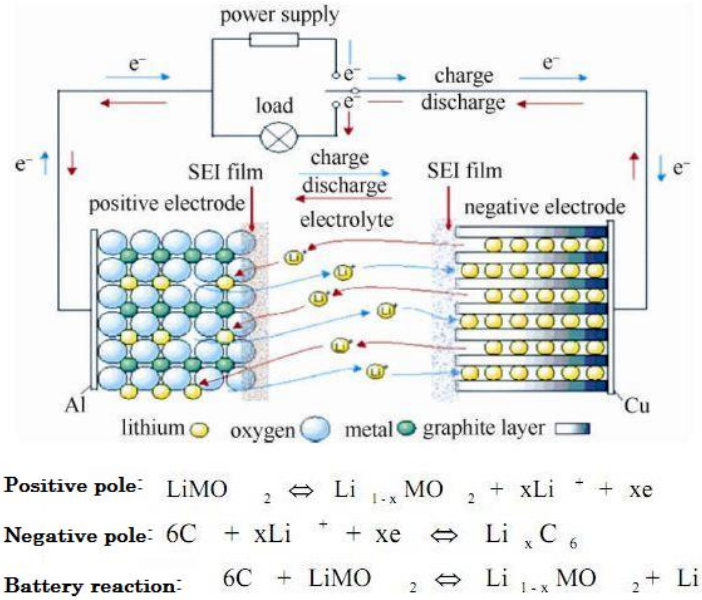

Figure 1. Schematic diagram of the working principle of lithium-ion batteries

3.3. Flow of electrons

During discharge, the released electrons flow through an external circuit, providing power to the external device. While charging, electrical energy from an external source causes electrons to flow back into the battery to store electrical energy.

Charging and discharging are achieved through the movements and chemical reactions of ions between the positive and negative electrodes, thereby generating electrical energy to move the vehicle. This working principle makes the battery a key energy storage and release device for new energy vehicles.

4. Overcharge and over-discharge

4.1. Concepts of overcharge and overdischarge

Overcharge and overdischarge refers to the situation where the battery voltage or power exceeds the designed range during the charging or discharging process. Overcharge is when the battery is charged beyond its designed voltage or capacity. Overcharge occurs when a battery continues to receive power even when the voltage or charge exceeds its designed range [5]. Overcharge will cause the internal reaction of the battery to run out of control, causing abnormal chemical reactions inside the battery, which may lead to safety problems such as heating, gas release, and electrolyte leakage. Over-discharge is when the battery is discharged beyond its design voltage or capacity. Excessive discharge will lead to incomplete internal chemical reaction of the battery, reduction of the performance and lifespan of the battery, and may cause safety problems such as damage of the internal structure of the battery and low battery voltage. Both overcharge and over-discharge will have a negative impact on the safety of the battery. Therefore, it is very important to control the charging and discharging process to ensure that the voltage and power of the battery work within the designed range to ensure the safety and performance of the battery.

4.2. Analysis of the impact of overcharge and overdischarge on the safety of power batteries

The potential causes of safety failure of new energy vehicle power batteries is summarized in **Figure 2.**

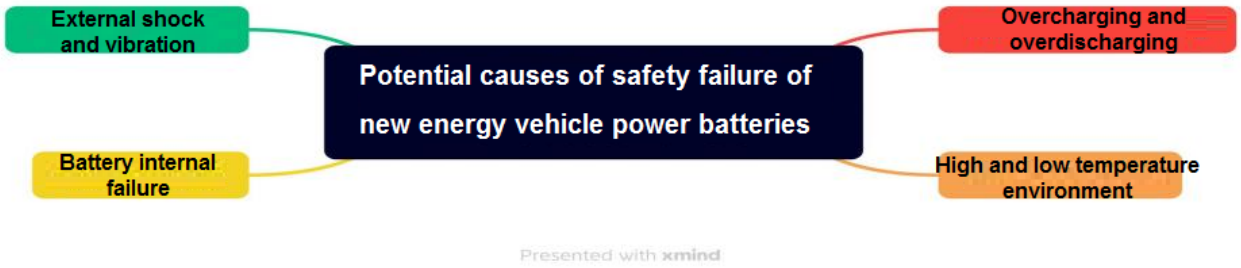

Figure 2. Potential causes of safety failure of new energy vehicle power batteries

(i) Overcharge

When the battery is overcharged, the chemical reaction inside the battery will become unstable, causing its internal temperature to rise. This can trigger a thermal runaway, causing the battery to overheat, burn, and even explode. Overcharging may also lead to the precipitation of lithium metal inside the battery, forming lithium dendrites, increasing the risk of short circuit and further exacerbating potential safety hazards.

(ii) Overdischarge

When the battery is overdischarged, the voltage of the battery will drop to a low level, which may cause the battery to not work properly. Excessive discharge will cause the chemical reaction inside the battery to be unstable, which may trigger a thermal runaway inside the battery, causing the battery to overheat, burn, or even explode. In addition, excessive discharge may also cause damage to the lithium ions inside the battery, reducing the capacity and performance of the battery [6].

5. Safety failures caused by low or high temperature environments

5.1. Potential risks of high temperature environments

A high temperature environment will cause the internal temperature of the battery to rise, which may cause overheating and thermal runaway, increasing the risk burning and explosion. High temperatures speed up the rate of chemical reactions inside the battery, resulting in shorter battery life, which means less battery capacity. Under a high temperature environment, the lithium metal inside the battery may precipitate and form lithium dendrites, which increases the risk of short circuit and further aggravates the potential safety hazard.

5.2. Potential risks of low temperature environment

Low temperatures cause the chemical reactions inside the battery to slow down, reducing the battery's discharge capacity and power output. This will result in reduced battery life and battery capacity. In a low temperature environment, the charging speed of the battery may be limited, because the internal chemical reaction of the battery will slow down at a low temperature, and the charging current cannot be absorbed effectively. In a low temperature environment, the internal resistance of the battery will increase, resulting in a decrease in the output power of the battery, which may cause difficulty in starting the engine if the vehicle or malfunction [7].

These potential risks may lead to reduced performance, shortened battery life, and reduced safety of batteries. To reduce these risks, manufacturers take measures to manage the environment temperature, such as temperature sensors and cooling or heating systems. In addition, users should also follow relevant usage guidelines when using electric vehicles and avoid using or storing electric vehicles under extreme temperature conditions to reduce safety risks.

6. Internal battery failure and external shock and vibration

6.1. Internal failure

(i) Thermal runaway and overheating

Internal battery failures may cause thermal runaway of the battery, increasing its internal temperature. Overly high temperatures will accelerate the chemical reaction inside the battery, further increasing the battery temperature, forming a vicious circle. This may cause the battery to overheat, burn, or even explode, posing a serious threat to the vehicle and passengers [8].

(ii) Short circuit and fire

Internal failure of the battery may lead to the precipitation of metallic lithium inside the battery, forming lithium dendrites. These lithium dendrites can penetrate the separator and cause short circuit, which causes the battery to overheat, burn, or explode. A short circuit could also start a fire inside the battery, further compounding the safety risk.

(iii) Decrease in capacity and performance

Internal battery failures may lead to damage and aging of battery materials, which in turn lead to battery capacity fading and performance degradation. This will affect the cruising range and performance of the electric vehicle, and reduce the reliability and experience of the vehicle.

(iv) Shortened battery life

Internal battery failures may accelerate the aging process of the battery, resulting in shortened battery life. This means batteries need to be replaced more frequently, increasing maintenance costs and inconvenience.

(v) Radiation of safety hazards

An internal failure of the battery may cause damage to one unit of the battery module or battery pack, which in turn causes failure of adjacent units, forming a chain reaction. This may affect the safety of the entire battery pack, increasing the risk of accidents [9].

The internal failure of the battery has a serious impact on the safety of the battery. To reduce these risks, manufacturers usually implement strict quality control measures to ensure the quality and reliability of the manufacturing process. In addition, the use of battery management system (BMS) can also monitor and control the working status of the battery and identify and deal with potential failures in time [10]. Users should follow the usage guidelines when using electric vehicles, regularly service the battery, and avoid excessive charging and discharging and physical damage to reduce the risk of internal battery failure.

6.2. External shock and vibration

(i) Risk of fire and explosion

External shocks and vibrations may cause a short circuit or damage inside the battery, causing overheating of the battery, rapid release of electrical energy, or uncontrolled chemical reactions inside the battery, resulting in fire or explosion.

(ii) Degradation of battery performance

External shocks and vibrations may cause damage to the battery casing or internal components, thereby reducing the performance and lifespan of the battery. This can lead to reduced battery capacity and energy density and slower charging and discharging rates [11].

(iii) Battery failure

External shocks and vibrations can damage the components in the battery or cause the internal connections to loosen, resulting in the battery not functioning properly or failing completely. This will affect the vehicle's power output and range.

(iv) Safety hazard

External shocks and vibrations may damage the battery case, exposing the chemicals and electrolyte inside the battery. This can be dangerous to personnel and the environment as the electrolyte is corrosive and toxic [12].

(v) The effect on vehicle stability

External shocks and vibrations may lead to loose battery connections or deformation of the battery structure, thereby affecting vehicle stability and performance [13].

To reduce these potential risks, manufacturers have taken various measures, such as using strong battery casings, designing shock-absorbing structures, optimizing the layout and connection methods of battery internal components, and implementing strict safety testing and certification standards [14]. In addition, the impact of external shock and vibration should also be considered in the design and manufacture of vehicles to ensure the safety performance and reliability of the battery [15].

7. Conclusion

The safety of power batteries is an important issue in the development of new energy vehicles. External shock and vibration are considered to be an important factor in the analysis of potential causes of safety failure of new energy vehicle batteries. External shocks and vibrations may cause battery damage, internal short circuits, loose connections, structural deformation, etc., resulting in potential risks such as fire, explosion, battery performance degradation, safety hazards, and reduced vehicle stability. In order to ensure the safety of the batteries, manufacturers have taken various measures, such as designing strong battery cases using shock-absorbing materials, optimizing the internal structure, and implementing strict safety testing and certification. In addition, the impact of external shock and vibration should be considered in the design and manufacture of the vehicle to ensure the safety performance and reliability of the battery. Although external shocks and vibrations may pose potential risks to the safety of power batteries, these risks can be minimized through proper design, manufacture, and use. Continuous research and technological innovation will be needed to further improve the safety of batteries and promote the sustainable development of the new energy vehicle industry.

Disclosure statement

The author declares no conflict of interest.

References

[1] Hu H, 2021, Difficulties and Countermeasures in the Capital Management of New Energy Vehicle Power Battery Companies. Finance and Economics, 2021(31): 101–103.

[2] Xin M, Wang J, Lu H, 2021, Analysis on the Development Status of New Energy Vehicle Power Battery Thermal Management Technology Based on Patent Analysis. Automobile Digest, 2021(11): 25–28.

[3] Ye C, Wang X, 2018, Overview of My Country's Pure Electric Vehicle Industry Development Bottleneck and Development Suggestions. Times Automobile, 2018(10): 66–68.

[4] Li K, Lu W, Liang C, 2020, Review and Prospect of China's New Energy Vehicle Power Batteries from the Perspective of Management. Science and Technology Management Research, 40(05): 173–177.

[5] Zhang S, Li T, 2019, Prediction and Countermeasures for the Amount of Scrapped Power Batteries of New Energy Vehicles in China - Calculation Based on Monte Carlo Simulation. Environment and

Sustainable Development, 44(06): 101–105.

[6] Yang H, 2021, The Application Dilemma and Improvement Path of the Extended Producer Responsibility System for the Recycling of New Energy Vehicle Power Batteries in My Country. Resource Regeneration, 2021(12): 39–42.

[7] Ministry of Industry and Information Technology, 2019, Notice on Carrying Out the Investigation of Potential Safety Risks of New Energy Vehicles, viewed May 10, 2023, http://www.miit-eidc.org.cn/art/2019/6/17/art_97_4052.html

[8] Ministry of Industry and Information Equipment Industry Development Center, Zhejiang Geely Holding Group Co., Ltd., 2021, Annual Report of China Automotive Industry and Technology Development – 2021, Publishing House of Electronics Industry, Beijing.

[9] Feng X, 2019, Research Report on Power Battery Safety in 2019, Sohu, viewed May 10, 2023, https://www.sohu.com/a/335679260_560178

[10] Wu C, 2023, Analysis and Solution of New Energy Vehicle Power Battery Safety Problems. Times Automobile, 2023(10): 100–102.

[11] Wang HB, Li Y, Wang QZ, et al., 2021, Mechanisms Causing Thermal Runaway-Related Electric Vehicle Accidents and Accident Investigation Strategies. Energy Storage Science and Technology, 10(2): 544–557.

[12] New Energy Vehicle Industry Technology Innovation Strategic Alliance, 2019, Annual Tracking Report on New Energy Vehicle Power Battery Technology, viewed May 10, 2023, https://xueqiu.com/1235427606/147429802

[13] Cao Y, Yan CQ, Wang YF, et al., 2018, The Technical Route Exploration of Lithium Ion Battery with High Safety and High Energy Density. Energy Storage Science and Technology, 7(3): 384–393.

[14] Chen XX, Li S, Hu YG, et al., 2019, Failure Mechanism of Li1+x(NCM)1−xO2 Layered Oxide Cathode Material During Capacity Degradation. Energy Storage Science and Technology, 8(6): 1003–1016.

[15] Wang F, Wang Z, Lin C, et al., 2022, Analysis of Potential Causes of Safety Failure of New Energy Vehicle Power Batteries. Energy Storage Science and Technology, 11(5): 1411–1418.