The Application of Industrial CT Detection Technology in Defects inspection of lithium Ion Battery

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Abstract. Industrial CT can intuitively display the internal structure, material composition and defect status of the tested object in the form of two-dimensional sectional image or three-dimensional image without damaging the structure of the tested object. It is widely used in the location, size, density change and distribution of internal defects of composite materials. It is the best nondestructive testing technology for internal micro size structure. Compared with the traditional detection technology, the defect detection of lithium-ion battery using industrial CT detection technology has many advantages, including component measurement of complex battery internal structure through high-density information in a non-contact and non-destructive manner. This paper introduces a series of defects of lithium ion battery scanned by industrial CT, analyzes the causes and how to improve the process.

1. Introduction

With the rapid development of science and technology, the public consumption level is constantly improving, the concept of green and environmental protection is deeply rooted in the hearts of the people, and all industries and fields pay more and more attention to the utilization and development of clean new energy. As is well known, cars mainly use internal combustion engines to burn gasoline to provide power, in the process of consuming a lot of non-renewable energy, but also discharge a lot of exhaust gas to the environment and air pollution[1]. In order to protect the environment and alleviate the problem of energy shortages, new energy vehicles have rapidly developed and occupied a certain market in the automobile industry due to their low-carbon, environmental protection and energy saving. Therefore, strengthening the development of new energy vehicles can promote the better development of the automobile industry.

In the development of new energy vehicles, the most important link is the power battery technology of vehicles. At present, the battery types used in new energy vehicles include lead-acid batteries, nickel-hydrogen batteries, fuel cells and lithium-ion batteries. Among them, lithium-ion batteries occupy a huge market in the electric vehicle industry with their high voltage, high energy density and good cycle stability. For electric vehicles, the quality and performance of power batteries have a huge impact on the overall quality of the vehicle. It is the core part of new energy vehicles. The detection mode and automation level in the production process will have a direct impact on the production efficiency,
product quality and product consistency [2]. Therefore, the accurate and reliable detection of the structure inside the battery is crucial to controlling the quality of the battery and the overall performance of the electric vehicle. Because the lithium-ion batteries are in a sealed environment after being assembled, water and oxygen in the air can damage the lithium-ion battery materials, so we cannot detect the defects in the presence of the battery by dismantling [3]. However, for the internal changes during the battery operation and whether the battery pack is qualified, it is particularly important to choose the appropriate detection means to visually detect the internal structure and defects of the battery.

At present, the information of battery internal defects is mainly obtained through ultrasonic detection method, penetration detection method and radiation irradiation method, but the detection results of these methods show inaccurate, and can only detect defects on the surface or near the surface. This study uses industrial computed tomography (industrial CT) technology to detect the defects of the internal battery. Industrial CT intuitively displays the internal structure, material composition and defect condition of the detected object in the form of two-dimensional fault image without damaging the detected object structure. It is widely used in the internal defect position, size, density change and distribution of the composite materials, and is the best nondestructive detection technology of the internal microsize structure [4, 5].

2. The Principle of the Industrial CT
The imaging principle of industrial CT is to produce a fan high energy X-ray in a controlled state using a ray beam with some energy, which decay after the X-ray penetrates the workpiece to be inspected, and varying degrees of attenuation reflect the internal information. The detectors and subsequent systems receive X-rays to convert them into digital signals. During the scanning process, the projection data is obtained from multiple angles. According to the obtained projection data, using a specific reconstruction algorithm, the internal structure, composition, material and defect situation are presented in a two-dimensional or three-dimensional image.

The scanning cycle of the industrial CT usually includes scanning time, data processing and recovery time of the data acquisition system, scanning device relocation time, etc., and controlling the scanning time by setting the scanning degree and the number of scanning pictures, so as to detect the commercial or large number of samples [6].

Industrial CT can detect the stack alignment of stacked power cells, the winding battery winding alignment, measure the negative layer beyond the positive length and find the maximum minimum and average. You can also detect the winding alignment of the cylinder battery, shell depth, roll size and other data, as well as the inner structure of the cylinder battery stage ear and the positive and negative electrode sheet, detect the alignment of the square soft pack battery electrode positive and negative electrode plate and the angle of negative bending. Check the open circuit of battery electrode ear welding, dislocation ratio of core positive and negative electrode, measurement of positive and negative electrode distance, welding and leakage of protection plate and positive and negative electrode. To ensure the quality detection of the battery at the same time, it can also directly distinguish inferior batteries, curb the circulation of unsafe and non-friendly batteries to the market from the source, and reduce quality risks.

3. Preparation process of the lithium-ion battery
As an excellent energy storage equipment, the lithium-ion battery is mainly composed of the cathode material, the negative electrode material, the electrolyte and the diaphragm. Among them, the positive and negative electrode material can ensure that the lithium ions are reversible embedded and detached in order to achieve the purpose of storing and releasing energy. Electrolytes should have high lithium ion conductivity and extremely low electron conductivity, ensuring that lithium ions can conduct rapidly in the electrolyte and reduce self-discharge. The diaphragm is in the middle of the positive and negative electrode material, avoiding the short circuit of the battery due to the direct contact of the two electrodes, and better infiltrating the electrolyte, which can form a migration channel of lithium ions.
The process requirements of power lithium-ion battery are very strict and complex. The preparation process is shown in Figure 1, and the main process is pulp making coating, assembly, etc.

**Fig 1. Battery preparation process**

Pulping: with special solvent and paste respectively mixed with powder positive and negative electrode active substances, after high speed mixing, make slurry positive and negative electrode material. The viscosity of the slurry is then tested, and the unqualified slurry shall be reworked. The raw material density and particle size of the slurry are different, and it is solid-liquid phase mixed, it is difficult to stir, generally adopts the planetary vacuum high-speed mixer to achieve.

Apply: Apply the slurry evenly to the collector surface, dry the solvent, and make positive and negative plates. Lithium-ion batteries usually feature extrusion coating, transfer copy coating, and scraper coating.

Assembly: put the positive plate, diaphragm, negative plate and diaphragm in top to bottom order, roll it into the battery core, cover the steel shell on the outer layer of the battery core, spot welding on the bottom, inject electrolyte, and then through the laser point pole ear and sealing, i.e. to complete the module assembly process of the battery. Connect the module assembly to the module and then check the resistance to the module electrodes. After the inspection, put the module into the housing and install BMS, PDC, charging control module fan and water pipe. Finally, the air tightness, differential pressure, charge and discharge, temperature and capacity are tested.

4. **Defects formed in batteries are detected using industrial CT technology**

The complex system composition, preparation process and application environment of lithium batteries are the causes of failure[7-8]At present, the common failure mechanism mode of power lithium battery is caused by uneven distribution of electrolyte, active particles, poor positive and negative electrode alignment, poor sheet alignment, diaphragm damage and assembly and manufacturing defects. We judge the type of defects using the results obtained by industrial CT three-dimensional scans, and the specific results are shown below.

4.1. **Improper distribution or deterioration of the electrolyte**

Lithium lithium ion battery electrolyte is divided into liquid electrolyte and solid-state electrolyte. As one of the important components of lithium ion batteries, it plays the role of transmitting lithium ions between positive and negative electrodes. At present, commercial lithium-ion batteries use liquid electrolyte, but the liquid electrolyte solvents are flammable and have safety risks. And with the increase of battery charge and discharge times, the electrode oxidation corrosion will consume part of the electrolyte leading to the electrolyte reduction or deterioration, and the electrode plate can not be completely infiltrated into the electrolyte, which will make the electrochemical reaction incomplete and damage the battery life.
The CT scanning image of the cross-section of the lithium-ion battery is shown in FIG. 2, which can clearly see an obvious difference in the gray scale of the electrolyte, which shows the uneven distribution of the electrolyte. This phenomenon may be caused by the enrichment of the electrolyte in some areas, and the electrode oxidation corrosion reduces the electrolyte and has no safe infiltration electrode sheet[9]By improving the injection process, inject liquid under vacuum conditions, extend the static time or inject electrolyte in batches, reduce the resistance to the electrode pad; add electrolyte infiltration agent, reduce the surface tension of the liquid, and observe that the injection speed is significantly improved.

![Figure 2. CT scan image of lithium ion batteries with undistributed or deteriorated electrolyte](image)

4.2. The active particles are broken or detached
The positive and negative electrode material of the battery ensures that the lithium ions are reversible embedded and removed therein for the purpose of storing and releasing energy. During the charge and discharge process, both the positive and negative electrode material will lead to the crack and pulverization of the positive and negative electrode material particles, and the electric contact and ion conduction will deteriorate, so that the battery gradually fails.

FIG. 3 shows a CT scanning image of the battery cross section, where the electrode plates are thickened or thinner, and impurities appear in the electrolyte, resulting in a decrease in the battery capacity [10]. This phenomenon may be caused by the pulverization or shedding of active particles of positive or negative electrode materials. Can modify the positive material, such as cation doping can effectively stabilize the crystal structure, surface envelope can effectively reduce the contact area between the active material and the electrolyte, inhibit the occurrence of secondary reaction, thus stabilize the electrode and electrolyte interface, can also improve the crushing and shedding of the active particles by improving the compaction density.

![Figure 3. A CT scan image of a lithium-ion battery with broken or detached active particles](image)
4.3. Poor stack alignment and low positive and negative pole alignment ratio

The battery manufacturing process is an important factor affecting the performance of lithium-ion batteries. Reinding, sealing and other procedures during assembly. Although industrial production has been realized, it is inevitable that there will be extreme unalignment, offset and other problems [11].

![Figure 4. A CT scan image of a stacked unaligned lithium-ion battery](image)

A scanned image of the CT battery section, as shown in FIG. 4, shows a significant dark distribution near the pole plate, indicating that there is a gap between the pole plate and the cover steel shell, possibly making the battery internal resistance high or short circuit. The above phenomena may be errors in assembly that can improve stack alignment by improving the assembly process. Fine tune the assembly instrument parameters, improve its accuracy, strictly measure the size of the positive and negative polar plates and the diaphragm, reduce the error between the dimensions, and adjust the temperature and time of the electrode plate drying to reduce the water and gas produced in the subsequent assembly process, reduce the possibility of the polar plate deformation, and thus improve the stack alignment.

4.4. Broken diaphragm

The lithium-ion battery diaphragm plays an important role in isolating positive and negative poles and preventing internal short circuit, while allowing ionic charge carriers to transport rapidly between positive and negative poles. However, most diaphragm materials have problems such as low porosity, poor electrolyte wetting, and serious high temperature and thermal contraction, resulting in diaphragm damage, internal short circuit, and finally makes the battery explode under abnormal conditions [12-13].

The CT scan image of the cross-section of the lithium-ion battery, as shown in FIG. 5, shows a breakage of the diaphragm, which may cause a short circuit inside the battery to cause an explosion. The above phenomenon may be that the diaphragm is damaged by external force during the assembly process, or it may be due to the serious thermal contraction of the diaphragm causing cracks.

![Figure 5. A CT scan image of a lithium-ion battery with a broken diaphragm](image)
5. Conclusion
Compared to traditional measurement techniques, industrial CT has multiple advantages, including the ability to perform component measurements of complex internal battery interior structures through high-density information in a non-contact and non-destructive manner. This is particularly important in quality detection of lithium-ion batteries, since defects in the battery cannot be detected in a sealed environment after being assembled. This paper detects the internal structure of the battery on the basis of ensuring the overall structure of the battery, and analyzes the defect type from the scanning result, controls the quality of lithium-ion battery, finds inferior battery and reduce safety risks, on the other hand, improves the performance of lithium-ion battery, and has good application prospects in battery safety detection and failure analysis.

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