International Journal on Engineering Technologies and Informatics

Damage Analysis Regarding the Cycling of a Traction Battery by Ultrasonic Scanning

Research Article

Volume 3 Issue 2- 2022

Author Details

Tianyi Ma[1,2], Xiaoqian Dai[1,2], Zhipeng Sun[1,2], Haishuo Ma[1,2], Weijian Hao[2] and Yue Xu[1,2]*

[1]CATARC New Energy Vehicle Test Center (Tianjin) Co.,Ltd., China

[2]China Automotive Technology and Research Center Co.,Ltd., China

*Corresponding author

Tianyi Ma CATARC New Energy Vehicle Test Center (Tianjin) Co.,Ltd., Tianjin 300300,China

Article History

Received: July 20, 2022 Accepted: July 26, 2022 Published: July 27, 2022

Abstract

How to effectively detect the status of the internal structure of a traction battery is an important topic that ultimately affects its wide application space and long service life, and how to use non-destructive methods to quickly detect the various types of damage, such as gas generation and electrolyte dewetting is a great challenge. In this paper, throughout long-term cycling, the deterioration of the internal structure of a traction battery is analyzed by ultrasonic scanning and shown to be an effective method for the detection of the internal defects of batteries.

Introduction

With the large-scale application of lithium ion traction batteries, there are still many practical challenges and problems to be solved [1,2]. As more electric vehicles are placing higher demands on the safety, endurance, environmental adaptability and cost of traction batteries, testing and verification technologies must also be improved, namely, for the rapid detection of the internal structure and defects [3,4].

Traction batteries are completely covered by metal, aluminum, or plastic film, for isolation from air and moisture, so the interior of a battery is similar to a "black box". We cannot directly see the small defects inside the battery, and it is difficult to infer the hidden damages of the battery, so the macro performance of the battery will not immediately fluctuate [5,6]. At present, we usually test the internal resistance, maximum discharge current or discharge time and cycle life of batteries, which takes a lot of time and also affects the subsequent use of the battery to a certain extent, causing damage to the batteries. Therefore, it is of great significance to find a traction battery detection method with high efficiency, convenient operation, accurate detection results, and non-destructiveness to the battery samples [7-9].

Ultrasonic scanning testing is one of the most common non-destructive testing methods, and has been widely used in steel industry. It is a technology that can check the macro defects of the sample or measure the characteristics of it without damaging the sample. However, ultrasonic testing technology still has limitations. Even if there are defects in the area close to the detection, it is difficult to be reflected, due to the blind area. To prevent the sample surface from scattering the ultrasonic waves, high surface roughness is needed through the use of couplants [10-13]. It is difficult to make an intuitive and convenient quantitative analysis of defects, and it is quite difficult to detect samples with complex shapes and structures. On the other hand, with the development of mathematics, numerical methods such as finite difference, finite element, and boundary element have also been applied to ultrasonic testing technology. Through numerical simulation, the research cycle is shorter, the cost is lower, and it is more flexible and convenient. Over time, these limitations have been greatly improved [14-15].

In this paper, ultrasonic scanning technology is used to analyze the damage to the internal structure of a traction battery in the cycling process. The results show that the ultrasonic scanning technology can effectively detect and analyze the phenomena of electrolyte drying, gas production, and uneven current density in the internal structure of the battery with respect to the actual use conditions.

Experimental Section

Ultrasonic scanning testing of a traction battery produces an ultrasonic field with a certain frequency and energy. According to the reflection theorem, ultrasonic waves will reflect or refract at the interface of two media with different acoustic impedance, resulting in local changes in the ultrasonic field, which will be collected and displayed by the receiving instrument. The ultrasonic transmitter transmits pulse signals to the inside of the sample to be tested. When the ultrasonic signal encounters defects with different acoustic impedance in the propagation process, such as cracks, the defect will reflect the ultrasonic signal to the detection instrument, which can be processed and analyzed. According to the characteristics of the received ultrasonic waves, the collected signals are presented in an easily-understood way after the algorithmic processing of the background computer software. Finally, the sample is checked for defects and then the defects are characterized.

The main equipment parameters of the ultrasonic scanning system used in this experiment are as follows: scanning area 600 mm x 300 mm, in-plane resolution 1 mm, repeat positioning accuracy 0.05 mm, peak emission voltage 400 V, and minimum detection spacing 0.1 mm.

Results and Discussion

Figure 1 shows the charge-discharge characteristic curve of the traction battery sample. This electrochemical curve is typical of $LiFePO_4$-graphite chemistry, with a significant charging platform at about 3.4 V, which is formed by the stripping of lithium ions from $LiFePO_4$ and their embedding in the graphite anode. There is a significant discharge platform at about 3.2 V, which is the electrochemical process of lithium ion stripping from the graphite and its return to $LiFePO_4$. In a charge-discharge cycle, the charging capacity and discharge capacity are close to 40 Ah, indicating that the battery sample has qualified coulombic efficiency.

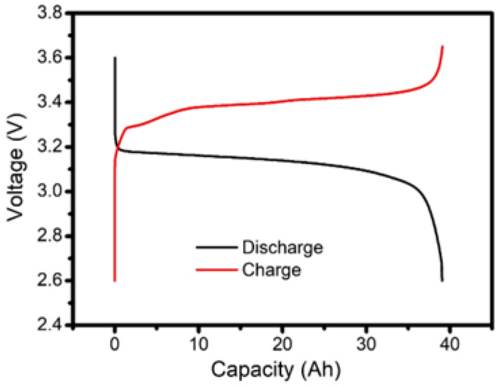


Figure 1: Charge-discharge characteristic curve of the traction battery sample.

Figure 2 shows the cycle performance of the battery sample. We use a 1 C rate to charge and discharge the battery. The capacity retention rate of the first 200 cycles of this cell is 98.8%, and the capacity retention rate of the first 500 cycles is 96.9%. When the battery is cycled to about the 800th cycle, the capacity decreases significantly. After the 1000th cycle, the capacity decreases to 34.8 Ah, and the capacity retention rate is 87.9%.

To further analyze the damage of the battery sample during cycling, we carried out ultrasonic scanning tests before and after the cycle of the sample, including flaw detection testing and uniformity analysis under different SOC (State of Charge) states. Figure 3 shows the defect scanning results before and after the cycle, and Figure 4 shows the details of the area marked in Figure 3 & Figure 4.

In general, the battery is in good physical condition prior to cycling, and there are no obvious areas of poor packaging. In terms of details, it can be seen that trace gases are sealed between the two layers in a small part of the aluminum-plastic film hot pressing process (light blue part). Although trace gases are sealed at the edge, they do not connect the outside with the cell. Compared with that prior to cycling, the quality of the edge banding of the sample after the cycle has decreased significantly due to more gas existing between the edge banding areas (the blue is darker). Although these areas are not connected with the external environment, they will still reduce the electrochemical activity of the surrounding areas. Especially in area 5, there is a risk of liquid leakage due to the connection between the inner and outer extension of the battery and the path indicated by the arrow.

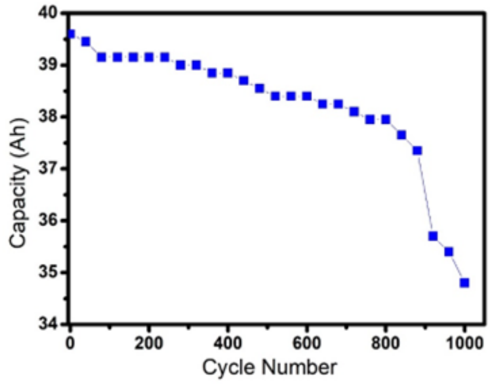
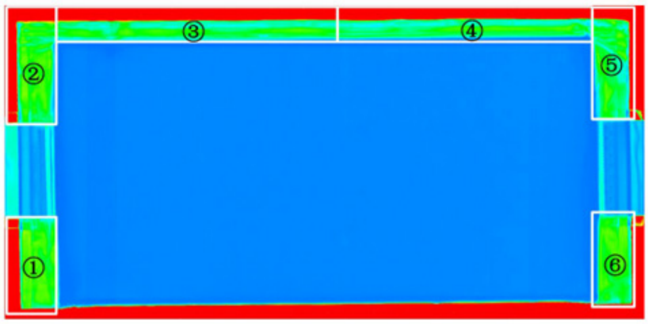
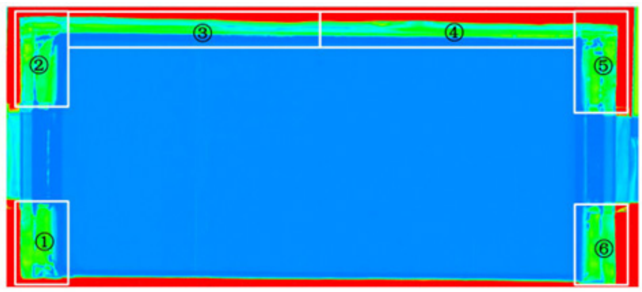


Figure 2: Cycle performance of the battery sample.

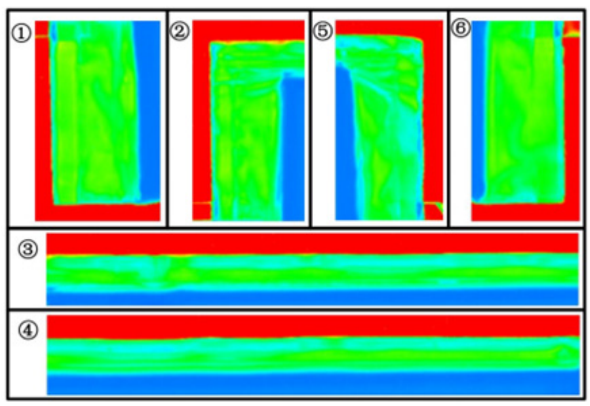


Before Cycle



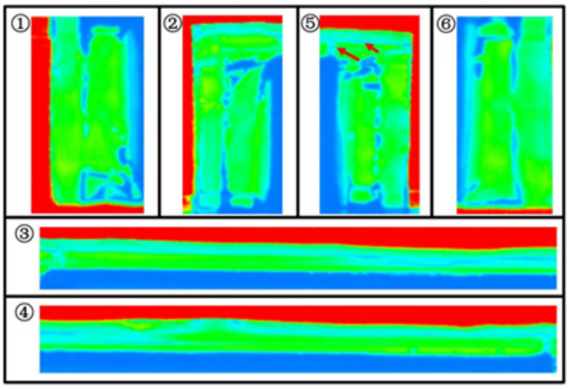
After Cycle

Figure 3: defect scanning results before and after the cycle.



Before Cycle

Citation: Tianyi M, Xiaoqian D, Zhipeng S, et al. Damage Analysis Regarding the Cycling of a Traction Battery by Ultrasonic Scanning. *Int J Eng Tech & Inf.* 2022;3(2):1–4. DOI: 10.51626/ijeti.2022.03.00034



After Cycle

Figure 4: details of the area marked in Figure 3.

Further, we analyze the uniformity of the SOC of the samples before and after the cycle. The working conditions are as follows:

1. Discharge the battery at a constant current of 20 A to 2.5 V, and define the SOC of the battery in this state as 0%;
2. On the basis of step 1, charge the battery at a constant current of 20 A for 20 min, and then set aside for 20 min;
3. Use ultrasonic testing equipment for the scanning test, and repeat step 2 until the battery reaches the charging cut-off voltage;
4. Through the collected ultrasonic data, the SOC distribution inside the battery can be analyzed.

As shown in the figure, the image color represents the actual SOC distribution in the battery obtained by ultrasonic scanning detection. The standard deviation describes the distance that each data point deviates from the average value, and the value range is 0-1. Figure 5 shows the SOC uniformity change of fresh battery during charging. We can see that the standard deviation of SOC distribution shows a trend of first increasing and then decreasing during charging. Specifically, in the process of SOC charging from 0 to 16%, the standard deviation increases, while in the process of continuous charging, the standard deviation decreases, and finally after the battery is fully charged (SOC 100%), the standard deviation decreases to 0.03, which is the lowest value in the whole process. Figure 6 shows the SOC uniformity change of the battery during charging after cycling. We can see that the overall standard deviation is greater than that of the fresh battery, and the trend of the standard deviation is close to that of the fresh battery. At the end of the charging cycle, the standard deviation of SOC distribution is 0.08, which is significantly greater than that of the fresh battery. Via a comparison between Figure 5 & Figure 6, we can find that the SOC uniformity of the battery after cycling is significantly lower than that of the fresh battery, which is caused by the instability of the internal interface of the battery.

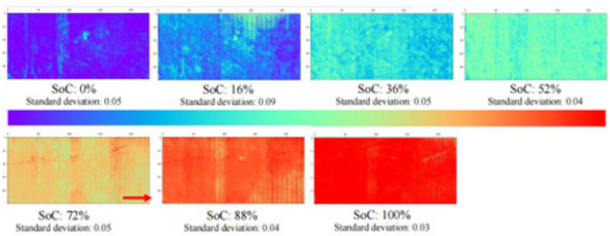


Figure 5: SOC uniformity change of fresh battery during charging.

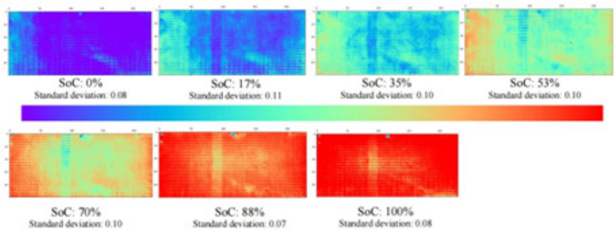


Figure 6: SOC uniformity change of cycled battery during charging.

Conclusion

In this paper, the damage to the internal structure of a power battery sample in use is analyzed by means of ultrasonic flaw detection. The results show that over 1000 cycles of the power battery and with decreasing capacity, the internal interface of the battery is significantly degraded due to gas production, electrolyte dewetting, seal deterioration, and other reasons, and this degradation process leads to a decrease of the uniformity of the internal SOC of the battery sample during the charging process, which further affects the performance of the battery and the stability of the internal structure.

Acknowledgment

The authors appreciate financial supports from National Key R&D Program of China (2021YFB2501500), Young Elite Scientists Sponsorship Program by CAST (2021QNRC001)

References

1. Wang Y, Liu B, Li Q, Cartmell S, Ferrara S, et al. (2015) Lithium and lithium ion batteries for applications in microelectronic devices: A review. J Power Sources 286: 330-345.
2. Tarascon JM, Armand M (2011) Issues and challenges facing rechargeable lithium batteries. Nature 414: 171-179.
3. Marom R, Amalraj SF, Leifer N, Jacob D, Aurbach D (2011) A review of advanced and practical lithium battery materials J Mater Chem 21: 9938-9954.
4. Etacheri V, Marom R, Elazari R, Salitra G, Aurbach D (2011) Challenges in the development of advanced Li-ion batteries: a review. Energ Environ Sci 4: 3243-3262.
5. Liu S, Xiong C (2014) Long cycle life lithium ion battery with lithium nickel cobalt manganese oxide (NCM) cathode. J Power Sources 261: 285-291.
6. Nitta N, Wu F, Lee JT, Yushin G (2015) Li-ion battery materials: present and future. Mater Today 18: 252-264.
7. Balogun M, Qiu W, Luo Y, Meng H, Mai W, et al. (2016) A review of the development of full cell lithium-ion batteries: The impact of nanostructured anode materials. Nano Res 9: 2823-2851.
8. Wen J, Yu Y, Chen C (2012) A review on lithium-ion batteries safety issues: existing problems and possible solutions. Mater Express 2: 197-212.
9. Tsujikawa T, Yabuta K, Arakawa M, Hayashi K (2013) Safety of large-capacity lithium-ion battery and evaluation of battery system for telecommunications. J Power Sources 244: 11-16.
10. Martinez-Laserna E, Sarasketa-Zabala E, Villarreal I, Stroe DI, Swierczynski M, et al. (2018) Technical viability of battery second life: a study from the ageing perspective. IEEE T Ind Appl 54: 2703-2713.
11. Heymans C, Walker SB, Young SB, Fowler M (2014) Economic analysis of second use electric vehicle batteries for residential energy storage and load-levelling, Energ. Policy 71: 22-30.

Citation: Tianyi M, Xiaoqian D, Zhipeng S, et al. Damage Analysis Regarding the Cycling of a Traction Battery by Ultrasonic Scanning. *Int J Eng Tech & Inf.* 2022;3(2):1–4. DOI: 10.51626/ijeti.2022.03.00034

12. Wang W, Li Y, Lin C, Su Y, Yang S (2019) State of charge-dependent failure prediction model for cylindrical lithium-ion batteries under mechanical abuse. Appl Energ 251: 113365.

13. Li J, Sun D, Jin X, Shi W, Sun Chao (2019) Lithium-ion battery overcharging thermal characteristics analysis and an impedance-based electro-thermal coupled model simulation. Appl Energ 254: 113574.

14. Arora S, Shen W, Kapoor A (2016) Review of mechanical design and strategic placement technique of a robust battery pack for electric vehicles. Renew Sust Energ Rev 60: 1319-1331.

15. Murai Y, Tasaka Y, Nambu Y, Takeda Y, Gonzalez S (2010) Ultrasonic detection of moving interfaces in gas–liquid two-phase flow. Flow Measurement and Instrumentation 21(3): 356–366.

Citation: Tianyi M, Xiaoqian D, Zhipeng S, et al. Damage Analysis Regarding the Cycling of a Traction Battery by Ultrasonic Scanning. *Int J Eng Tech & Inf*. 2022;3(2):1–4. DOI: 10.51626/ijeti.2022.03.00034