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Analysis of the memory effect of lithium iron phosphate batteries charged with stage constant current

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Abstract. Lithium iron phosphate batteries are widely used in various fields and have long been considered to have no memory effect. It is not until recent years that the memory effect of lithium iron phosphate batteries has been discovered and studied. In engineering applications, electric vehicles are usually charged with stage constant current. Here, we first briefly explain the process of memory effect generation. Make the battery have a memory effect under different charging methods. Compare and analyze the characteristics of memory effect under each charging method for optimization ideas of development ChaoJi and other high-power and high-current charging technologies.

Keywords: Lithium iron phosphate battery, Memory effect, stage constant current, high-current charging.

1. Introduction

With the frequent occurrence of electric vehicle safety accidents, the safety of power batteries has attracted widespread attention from the society. In May 2020, GB 38021-2020 "Electric vehicles traction battery safety requirements" was released, which puts forward higher requirements for the safety of power batteries; In July, BYD Han EV was launched. The safety of its lithium iron phosphate blade battery has been further improved, and it will not catch fire even under harsh conditions such as acupuncture. At the same time, by improving the space utilization rate, the vehicle's battery loading capacity has been increased. From the perspective of environmental protection, cost, and safety, lithium iron phosphate batteries are undoubtedly the most promising power battery.

For a long time, lithium-ion batteries were considered to have no memory effect. Until 2013, Sasaki [1] discovered the memory effect of lithium iron phosphate cathode material and used models [2, 3] to explain the reasons for the memory effect of lithium iron phosphate materials. The memory effect of a lithium battery is different from that of a nickel-chromium battery. The memory effect of a nickel-chromium battery is that the battery cannot be fully charged and discharged after a long-term incomplete charging and discharging of the battery, and the battery capacity is degraded and difficult to recover [4, 5]; For lithium iron phosphate batteries, an incomplete charge and discharge will cause the battery to produce a memory effect, causing a jump of voltage during the memory-releasing cycle. And this memory effect can be erased after the battery is fully charged and discharged. The memory effect of lithium iron phosphate cathode material is affected by active particles, relaxation time,



charge-discharge depth, charge-discharge rate, etc.[6, 7]. The essence of memory effect is that the delay of voltage overshoot causes the battery terminal voltage to jump, which effect the estimation of battery SOC, polarization voltage, etc. Literature [8] analyzed the memory effect of A123 lithium iron phosphate in different charging cycles and the impact of DOD on the battery terminal voltage and SOC estimation. Literature [6] found that the memory effect of lithium iron phosphate depends on the size of the particles, especially after a long period of relaxation.

With the rapid growth of the number of electric vehicles, the number of charging piles has also increased substantially, but still does not meet the increasing demand for charging. Electric vehicles are often unable to be fully charged. Therefore, under the background of the rapid development of high-current charging technology strategies, research the memory effect of incomplete charging of lithium iron phosphate batteries at a large rate is very necessary. This paper compares and analyzes the memory effect characteristics of stages constant current charging in different situations, and provides optimized ideas for the development of ChaoJi and other high-power and high-current charging technologies.

2. Memory effect of lithium iron phosphate battery

The memory effect of the positive electrode material will increase the voltage at the charging of the lithium iron phosphate battery. As shown in Figure 1, the voltage curve of the memory effect when the battery is not fully charged to 70% SOC. The charging curve of a normal full charge and discharge is the black curve. After the battery has undergone an incomplete charge and full discharge of 70% SOC, when the memory effect is erased (red curve), the charging voltage curve is abnormal. There is a jump in the battery voltage near 70% SOC, and the voltage rises, which was consistent with Sasaki et al.'s results of the voltage increase of the memory effect of the cathode material.

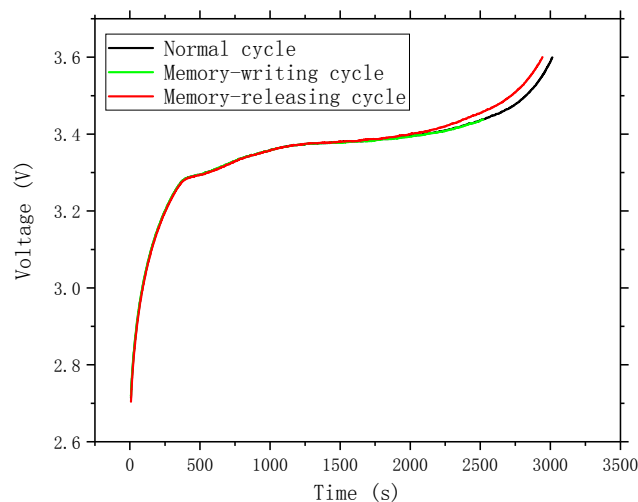


Figure 1. Charging voltage cure of $\text{LiFePO}_4/\text{Graphite}$ battery under memory-effect conditions at 25°C and 1C.

Kondo [9] summarized the three conditions for the memory effect: orderly charging/discharging cycle, short rest before charging/discharging, and long rest before discharging/charging. Take the memory generated during charging as an example. As shown in Figure 2, it is the process of the memory effect of the lithium iron phosphate battery. In first cycle, the lithium iron phosphate battery is not fully charged, and it is discharged after rest for a period of time. The next cycle, it is fully charged after a period of rest, and the battery voltage will be abnormal during the memory-releasing

cycle. At the same time, fully charge will erase the memory effect and make the battery voltage normal during subsequent cycles.

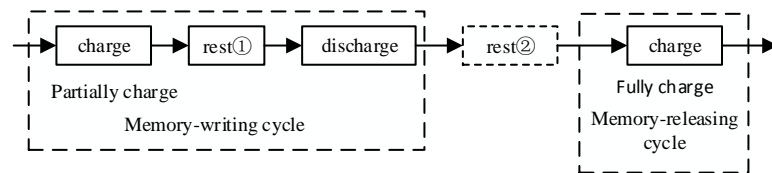


Figure 2. The process of memory effect of LiFePO₄ material.

The two period of rest in the process of the memory effect are the key to the memory effect. Long-term rest in the memory-writing cycle ① will strengthen the memory effect and make the charging voltage jump more obvious when the memory effect is released. If the period of rest is cancelled, the voltage jump will be weakened [7]. Long rest time between memory-writing and memory-releasing cycle may cause the memory effect to disappear [4]. Therefore, the memory effect observed is more obvious when the first time is left rest for a long time, and the second time is left for a short time.

3. Memory effect of stage constant current charging

3.1. Experiment content

The experiment of staged constant current charging to produce the memory effect is shown in Figure 3. Before the stage constant current charging, which produces the memory effect, the battery is fully charged and discharged at a rate of 0.5C to obtain the voltage curve, marked as a, during normal charging; when the memory effect is written in the cycle, the battery is charged with stage constant current and constant current discharge once or 5 times, the first stage is charged to point A at a rate of 4C, the SOC value of the battery at point A is SOCA, and in the second stage, the battery is charged to point B at a rate of n*C, and the SOC at point B is 70%, and the memory effect is obtained. The voltage curve is marked as b. When the memory effect is erased, the memory effect erase voltage curve, marked as c, is obtained by fully charging at 0.5C.

The lithium iron phosphate battery adopts the charge and discharge termination voltage of 3.6V and 2V specified by the manufacturer. Fully discharge, the battery is discharged at a certain rate until the battery terminal voltage is less than 2V, and the discharge is stopped. Fully charge, the battery is charged at a certain rate until the battery terminal voltage is 3.6V, and then charge at a constant voltage of 3.6V until the current is less than 1 / 20C.

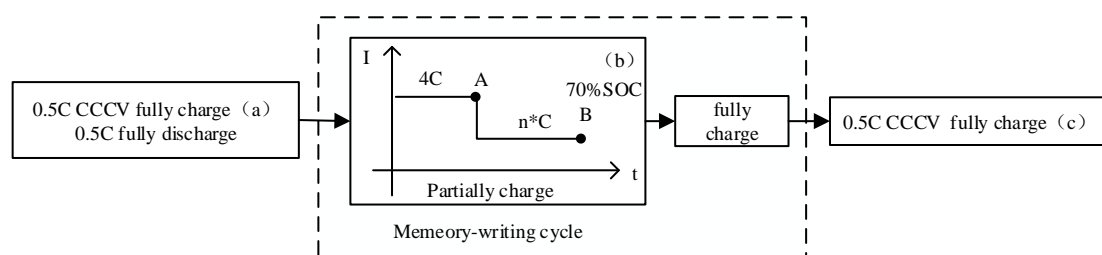


Figure 3. The experimental procedure for producing the memory effect of staged constant current charging

The memory effect experiment was performed on the battery under multiple groups of SOCA and n values. The SOCA and n groupings are shown in Table-1.

Table 1. SOCA, n grouping table .

SOCA	n
	0.5C
50%	1C
	2C
40%	0.5C
60%	0.5C

3.2. Memory effect analysis

Figure 4 shows the voltage curves of memory-releasing after one memory-writing cycle, type I, and the voltage rise curves by comparison the charging voltage between memory-writing and memory-releasing cycle. The first stage is constant current charging to 50% SOC, and the second stage uses different current rate to charge. In the second stage, when charging at different rates, the memory effect is produced, but the voltage curve during memory-releasing cycle is obviously different, and the memory effect is more obvious with stage constant current charging than the non-staged charging.

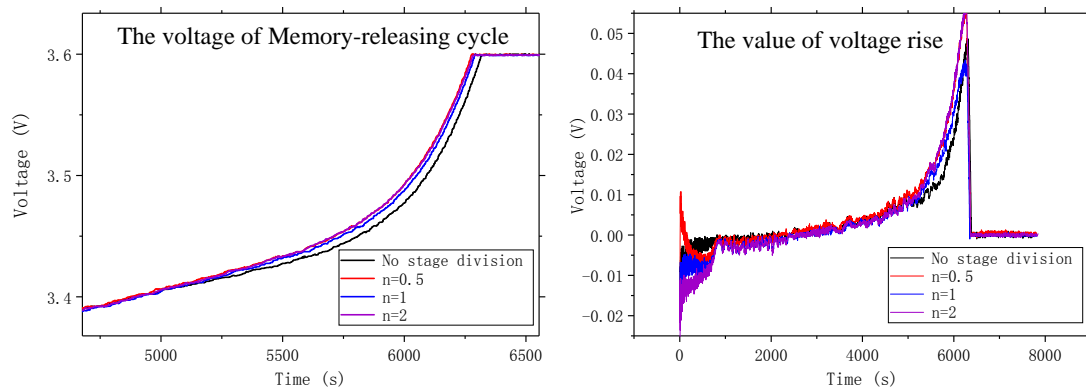


Figure 4. The memory-releasing voltage curve when charging to 50% SOC in the first stage and charging at different rates in the second stage

Figure 5 shows the voltage curves of memory-releasing after one memory-writing cycle, type I, and the voltage rise curves by comparison the charging voltage between memory-writing and memory-releasing cycle. The first stage is constant current charging to different SOC, and the second stage uses 0.5C rate to charge the memory effect erase voltage curve. The first stage of charging to different SOC produced a memory effect, but the voltage erasing curve for memory-releasing cycle is obviously different, and the memory effect is more obvious with stage constant current charging than the non-staged charging.

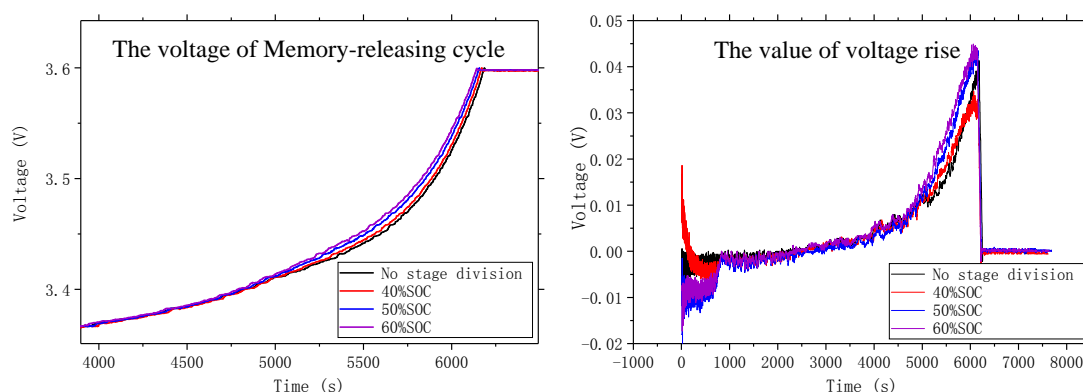


Figure 5. The memory-releasing voltage curve charged to different SOC in first stage, and the second stage is charged at a rate of 0.5C the memory-releasing voltage curve

The memory effect is written once, type I, the voltage rise of the curve is small. However, due to the voltage of the lithium iron phosphate battery has a plateau, the slight voltage rise is enough to affect the battery SOC estimation. It is complicated and when the memory effect is written for many cycles. The memory effect is more obvious, and long-term incomplete charging will cause a serious decrease in the accuracy of battery SOC estimation.

As shown in Figure 6, the memory-writing voltage curve during the first stage charging to 50% SOC and the second stage 0.5C rate charging. With the increase of the number of cycles, the voltage increases significantly under the same charging time. The essence of the memory effect of the lithium iron phosphate battery is the difference in the lithium content of the active particles in the positive electrode material before charging [9,10], that is the particles are not uniform, and the long-term incomplete charging of the battery may affect the life of the battery.

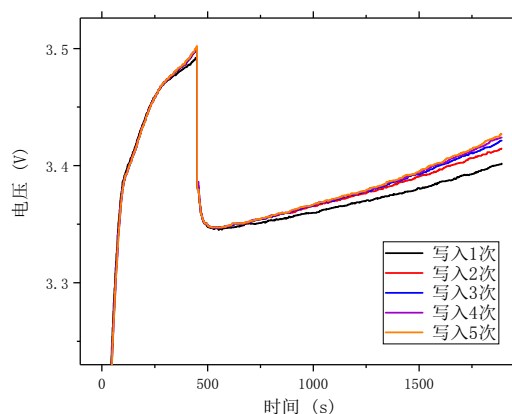


Figure 6. The memory-writing voltage curve when charging to 50% SOC in the first stage and charging at a rate of 0.5C in the second stage.

As shown in Figure 7, when charging to the same SOC in the first stage, and charging at different rates in the second stage, the voltage rises comparing charging voltage between memory-writing and memory-releasing cycle. for one memory-writing cycle and five memory-writing cycles. Although the

SOC of the first stage is different, the memory-writing cycle five times has a higher voltage rise than the one writing cycle, and the voltage rise of the five cycles can reach up to 100mV. The long-term incomplete charging has a greater impact on the battery terminal voltage.

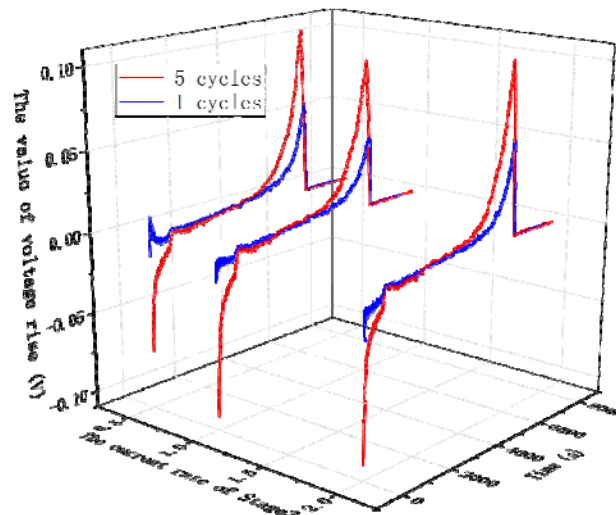


Fig 7. The voltage rise curves of different times during writing cycle when charging to 50% SOC in the first stage and charging at different rates in the second stage.

As shown in Figure 8, when the first stage is charged to a different SOC, and the second stage is charged at a rate of 0.5C, the voltage curve rises for one writing cycle and five cycles. Although the SOC in the first stage is different, the voltage rise of the memory effect writing cycle five times is higher than that of the one writing cycle.

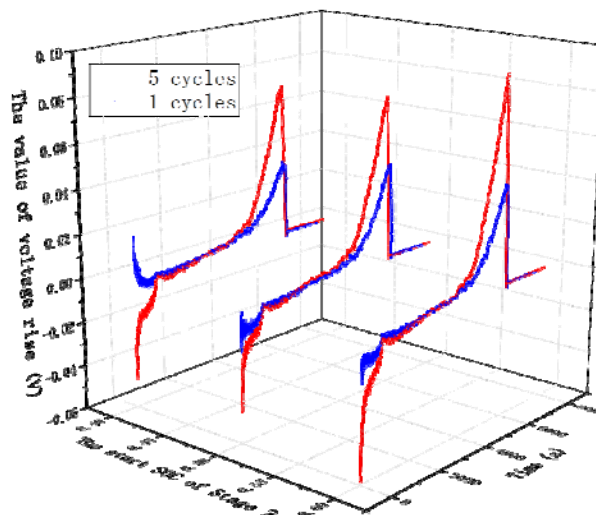


Figure 8. The voltage rise curves of different times during writing cycle when charging to different SOC in the first stage and 0.5C rate charging in the second stage.

4. Conclusions

This article first conduct multiple memory effect experiments on lithium iron phosphate batterie charged with stage constant current. Compares the memory effect characteristics in different types of stage constant current. The memory effect generated by the stage constant current is more obvious than the memory effect generated by the no-stage constant current. The uplift of former is obvious, and the long-term phased constant current incomplete charging has an extended impact on the battery voltage, and the voltage increase can reach up to 100mV. Therefore, several points should be paid attention to when developing electric vehicles powered by lithium iron phosphate batteries:

When managing the system, the impact of the memory effect of the lithium iron phosphate battery should be considered, and the error of the SOC estimation should be considered.

Develop charging technology, and when formulating a charging strategy, you can appropriately charge at a high rate to reduce the charging time and avoid incomplete charging of electric vehicles.

For users of electric vehicles, lithium iron phosphate electric vehicles that have been incompletely charged for a long time should be regularly SOC corrected.

Acknowledgments

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