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# Study on Temperature Change of LiFePO<sub>4</sub>/C Battery Thermal Runaway under Overcharge Condition

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**Abstract.** In this paper, thermal runaway test of lithium iron phosphate battery (LiFePO<sub>4</sub>/C) under overcharge condition was carried out. The temperature and its rise rate of three types of LiFePO<sub>4</sub>/C batteries (25 Ah, 60 Ah and 200 Ah) in the process of thermal runaway were compared and analyzed. The research shows that under the condition of 1C-rate overcharge, the starting temperature of the LiFePO<sub>4</sub>/C battery thermal runaway is about 116 °C - 131 °C, and its temperature rise rate of thermal runaway is about 3.01 °C/s - 5.82 °C/s. The highest temperature reached by thermal runaway has nothing to do with the battery capacity.

**Key words:** LiFePO<sub>4</sub>; thermal runaway; overcharge; temperature.

## 1. Introduction

Lithium ion batteries have the advantages of high energy density and long cycle life, and are widely used in many fields. Lithium ion batteries have a variety of material systems, such as lithium cobaltate batteries, lithium manganate batteries, ternary batteries and lithium iron phosphate (LiFePO<sub>4</sub>/C) batteries, of which the LiFePO<sub>4</sub>/C batteries are relatively safe and are mainly used for energy storage in electric vehicles and power grids.

In recent years, safety accidents of the LiFePO<sub>4</sub>/C batteries have occurred from time to time. A great deal of research has been carried out. Anup Barai et al. [1] studied the transportation safety of LiFePO<sub>4</sub>/C batteries, and the results show that 8 Ah LiFePO<sub>4</sub>/C pouch batteries at higher voltages exhibited sparks, fumes and fire. Ahmed Abaza et al. [2] studied the internal and external short circuits of commercial automotive pouch Lithium ion batteries, and the results show that the battery electrical and thermal response were determined by the shorting resistance. Qingfeng Yuan et al. [3] took the 32 Ah lithium ion battery as the research object, it is found that when the battery thermal runaway occurs, the internal temperature of the battery is much higher than the surface temperature of the battery. Zhang J Y. et al. [4] studied the overcharge characteristics of LiFePO<sub>4</sub>/C batteries, it is believed that overcharge of LiFePO<sub>4</sub>/C batteries will lead to a sharp drop in battery capacity and safety problems.

In order to reduce the safety risk of Lithium ion battery application, it is necessary to monitor the battery state in real time, such as voltage, temperature, state of charge, etc. Temperature monitoring is a



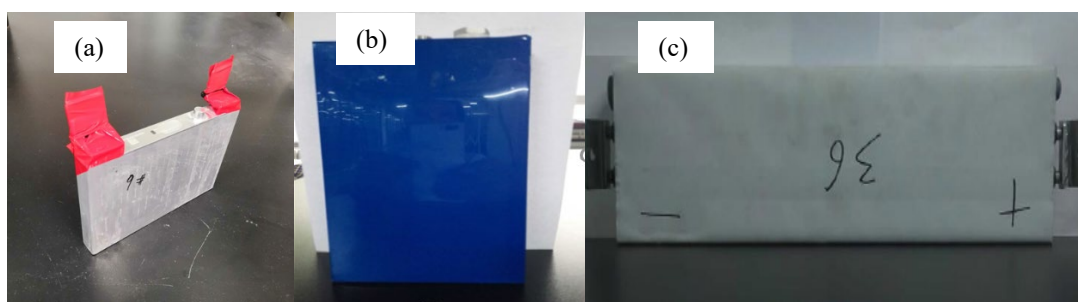
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more effective way, because thermal runaway of batteries will generate a large amount of heat, which can cause significant changes in battery temperature. In this paper, the temperature changes of  $\text{LiFePO}_4$  batteries with 20, 60, and 200 Ah during thermal runaway under overcharge conditions are analyzed. The work will contribute to the design of temperature detection and early warning of batteries.

## 2. Experiment

### 2.1. Battery Samples

Three kinds of  $\text{LiFePO}_4/\text{C}$  batteries with 25Ah, 60Ah and 200Ah were taken as research objects, which are shown in Figure 1. The rated voltage of all batteries is 3.2V.



**Figure 1.** Battery picture, (a) 25Ah, (b) 60Ah, (c) 200Ah

### 2.2. Experimental Step

Firstly, batteries were charged to a fully charged state according to the recommended procedure of the battery manufacturer, and left on hold for 12 h. Secondly, the thermocouples were tightly attached to the middle position of the sides of batteries. Thirdly, batteries were overcharged at a rate of 1 C. The highest charging voltage was set to 35 V. When the thermal runaway of batteries occurred, the charging stopped. During the experiment, the battery surface temperature was recorded.

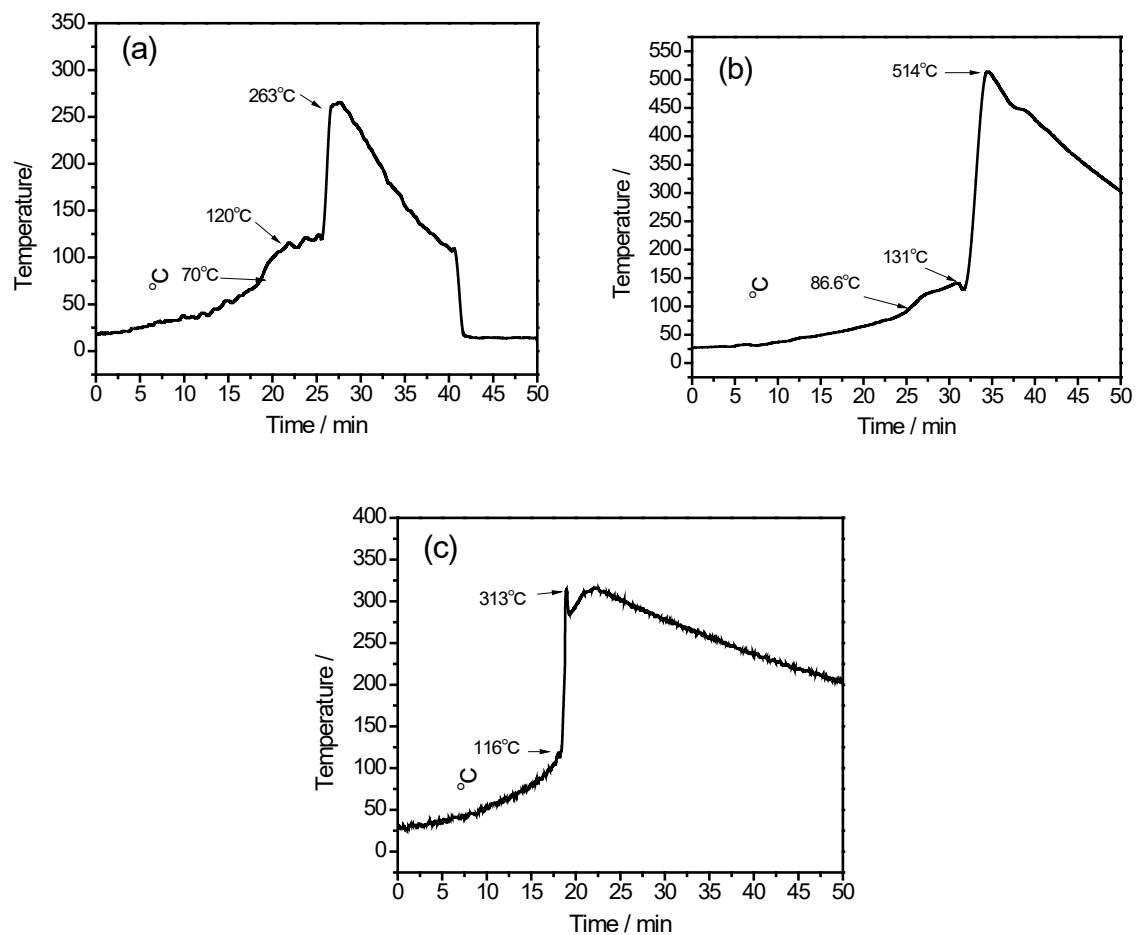
## 3. Analysis

As shown in Figure 2, under overcharge condition,  $\text{LiFePO}_4/\text{C}$  battery undergoes thermal runaway reaction, and its temperature change is roughly divided into three stages. The first stage is a slowly rising stage, the battery temperature gradually rises from room temperature to the starting temperature of thermal runaway. In this stage, the temperature changes of the three batteries with different capacities are different. Batteries with 25 Ah and 60 Ah are basically the same, which temperature rise rate suddenly increases after it exceeds 70 °C (25 Ah) and 86.6 °C (60 Ah), and then gradually flattens out, while the temperature rise of the battery with 200 Ah always shows a gradually increasing trend.

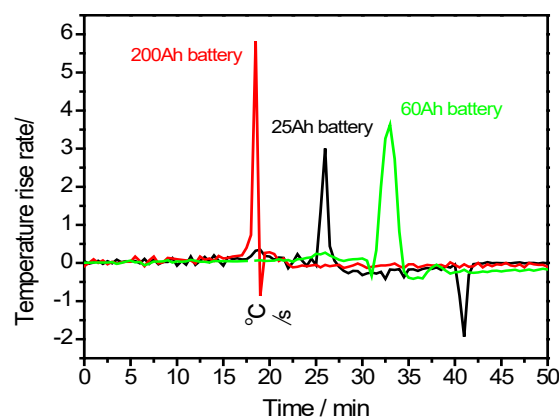
The second stage is the thermal runaway stage. All battery temperatures are rising rapidly. The starting temperatures of thermal runaway are 120 °C (25 Ah), 131 °C (60 Ah) and 116 °C (200 Ah). The highest temperatures reached by thermal runaway are 263 °C (25 Ah), 514 °C (60 Ah) and 313 °C (200 Ah), respectively. It can be seen that the highest temperature of battery thermal runaway has nothing to do with battery capacity.

The last stage is the cooling stage. After reaching the maximum temperature of thermal runaway, the battery temperature starts to decrease rapidly. In addition, the sudden temperature drop after 40 min in Figure 2(a) is caused by the thermocouple falling off during the test.

Figure 3 is the battery temperature rise rate during overcharge test. From Figure 3, it can be seen that the temperature rise rate of 200 Ah battery is 5.82 °C/s, followed by 3.62 °C/s for 60 Ah battery and 3.01 °C/s for 25 Ah battery. In addition, since the temperature sampling interval in the test is set to 0.2 s, the temperature change in the early stage of thermal runaway in Figure 3 is not obvious, and the curve part is scattered.



**Figure 2.** Temperature of batteries, (a) 25 Ah, (b) 60 Ah, (c) 200 Ah



**Figure 3.** Temperature rise rate of batteries

As can be seen from Figure 2 and Figure 3, under the same overcharge rate, the 200 Ah battery is the first to generate thermal runaway, and its thermal runaway temperature rise rate is also relatively maximum. This may be due to the fact that the 200 Ah battery has the largest capacity and the largest scale of side reactions caused by overcharge condition, so its temperature rise rate is relatively maximum.

during overcharge and its thermal runaway occurs at the earliest. However, For the 200 Ah battery, the highest temperature of thermal runaway is only 313 °C, which is lower than 514 °C of the 60 Ah battery. This may be due to the fact that the surface area of the 200Ah battery is significantly larger than that of 60 Ah batteries, so the 200 Ah battery has better heat dissipation effect and reduces the heat accumulation inside the battery.

#### 4. Conclusion

In this paper, the temperature change during thermal runaway of the LiFePO<sub>4</sub>/C battery was studied. The analysis shows that the starting temperature of LiFePO<sub>4</sub>/C battery thermal runaway is 120 °C (25 Ah), 131 °C (60 Ah), 116 °C (200 Ah) at 1C charging rate. The temperature rise rate of 200 Ah battery thermal runaway is 5.82 °C/s, but the highest temperature of thermal runaway (313 °C) is lower than that of 60 Ah battery thermal runaway (514 °C).

In the safety management of the battery system, a reasonable temperature monitoring scheme should be formulated including the battery temperature and temperature rise rate, especially the sudden change of temperature rise rate.

#### Acknowledgments

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