# Research on Adaptability of Temperature Characteristic for Electric Vehicle Power Battery

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**Abstract.** The operating temperature of power lithium-ion batteries in different application scenarios and working conditions not only relates to the economic cost and power performance of the energy system, but also directly affects its life. Therefore, based on the vehicle-mounted power battery, a comprehensive battery test platform was built to carry out charge and discharge tests, and the relationship between capacity and temperature was studied. In the temperature range of -30~50℃, a temperature gradient of 20℃ was used to obtain the charge/discharge curves at different temperatures, and the temperature characteristics of the power LFP batteries were analyzed in terms of charging and discharging.Based on data analysis, the conclusions of the study provide numerical references for the control of temperature thresholds for power battery applications.

**Keywords:** Lithium-ion battery; ambient temperature; charging and discharging performance; capacity.

## 1. Introduction

In recent years, with the rapid development of the economy and society, as well as the demand for sustainable development and the concept of green environmental protection continue to put forward and implement, all industries have embarked on the road of green development one after another, which is represented by the automotive industry, new energy vehicle sales continue to rise.

Due to the advantages of high operating voltage, high energy density, long cycle life, small self-discharge rate, no memory effect, etc., lithium-ion batteries with lithium iron phosphate as the anode combination (also known as LFP lithium-ion batteries) have gradually occupied a large share of the battery market for electric vehicles[1,2]. In addition, the high charge/discharge rate, good stability and high energy density of LFP Li-ion batteries also make them good energy storage candidates for grid peak shaving and frequency regulation [3,4]. However, the performance degradation of lithium-ion batteries limits their application in many fields. Therefore, quantitatively analyzing the effect of temperature, an important factor on battery performance, is crucial for controlling the temperature threshold and enhancing battery life.

At present, many scholars study the performance of lithium batteries in terms of temperature, multiplication rate, internal resistance and other parameters. [5,6]. J. Jaguemon [7] found that the voltage of Li-ion ternary batteries decreases significantly at low temperatures, and the discharge time decreases as the ambient temperature decreases. Wang [8] investigated the charging process of lithium-ion batteries at low temperatures and found that the rate of battery capacity decline after 5 cycles at temperatures less than -15°C was linearly increasing. Shen[9,10] analyzed the effect of current characteristics on the performance of lithium-ion batteries in terms of step current or step discharge frequency,Xiong [11] studied the battery heat production and temperature rise of lithium-ion batteries with different health states under multiple test conditions from the study of aging state, and explored the effects of different temperatures, different multiplicities and other key acceleration factors on battery life.

In this paper, it analyzes the effect of temperature on battery capacity during charging and discharging from the key accelerating factor of temperature, and systematically compares and evaluates the changes of discharging capacity at different temperatures, aiming to conduct a comprehensive comparative study on the temperature characteristics of LFP series batteries. Through the comparative tests of different temperature factors under charging and discharging conditions, the effects of temperature characteristics on the changes of battery charging and discharging capacity, charging and discharging time and temperature rise were found.

## 2. Material and Methods

### 2.1 Power cell

Considering the working performance and experimental requirements of different types of lithium-ion batteries, a commercial lithium iron phosphate blade battery with mass 2631g and model 3.2V138Ah LiFePO4 is selected as the research object, which has high capacity, low internal resistance, good safety, and also has an operating range of -20~55°C, which can well meet the experimental requirements, and its main parameters are shown in Table 1.

Table 1. 138Ah LFP prismatic battery main parameters.

| Parameters | Value |
|---|---|
| Nominal capacity (Ah) | 138 |
| Nominal voltage (V) | 3.20 |
| Charging voltage (V) | 3.65 |
| Discharge cut-off voltage (V) | 2.00 |
| Internal Resistance | ≤1.8mΩ |
| Operating temperature (°C) | Charging:-10-55°C |
| | Discharge:-20-55°C |
| Dimension (mm) | 960*90*12 |
| Quality (g) | 2631 |
| Nominal capacity (Ah) | 138 |

### 2.2 Laboratory equipment

The cell-level lithium-ion power battery test platform used in this paper consists of a battery charging and discharging device, a high and low temperature test chamber (including the battery under test), a temperature acquisition device and a host computer. The battery is tested using the Digatron battery testing system, which is a comprehensive battery tester that can realize charge/discharge tests with different functions, such as constant current, constant voltage, constant power and pulse charge/discharge, as well as perform the above tests under auxiliary different temperature conditions. The influence of the working temperature on the battery charging and discharging performance is crucial for its application under actual working conditions, which can be tested by integrating the high and low temperature environment box, and the upper computer is mainly used for the control of the test process and the recording and storing of the data, and its actual construction is shown in Figure 1.

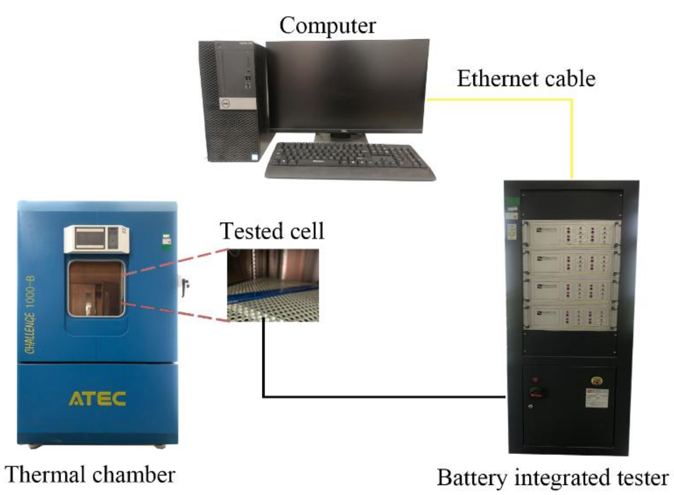

Fig. 1 Key equipment of battery test bench.

### 2.3 Experimental methods

For different charging and discharging strategies, this paper chooses the strategy of constant current and constant voltage (CC-CV)) charging and constant current discharging to carry out the test, a complete charging and discharging test is carried out by the battery testing system according to the preset program, and the relevant data during the test is recorded by the computer. A typical charge/discharge test is performed on the prepared batteries respectively.

Discharge performance test first battery charging, constant current and constant voltage mode with 1/3C constant current charging current to the cut-off voltage of 3.60V, and then turn to constant voltage (3.60V) charging, current reduced to 0.05V cut-off. The discharge process is to place the battery in the environmental chamber at -30, -10, 10, 30 and 50°C, respectively, and discharge at 1/3C multiplication rate with constant current and discharge cut-off voltage of 2.00V, while collecting the surface temperature of the battery.

According to different performance requirements, the working temperature test parameters are adjusted to complete the entire series of experiments for temperature performance testing. Table 2 shows the detailed charge and discharge procedure.

Table 2. Charge and discharge test steps

| | Charge | | | Discharge | | |
|---|---|---|---|---|---|---|
| Step no. | Type | Rate | End condition | Type | Rate | End condition |
| 1 | Rest | 0 | T=30min | Rest | 0 | T=30min |
| 2 | Discharge | 1/3C | V≤2.00V | Charge | 1/3C | V=3.60V |
| 3 | Rest | 0 | T=30min | Charge | 3.60V | I =0.05C |
| 4 | Charge | 1/2C | V=3.60V | Rest | 0 | T = 30min |
| 5 | Charge | 3.60V | I =0.05C | Discharge | 1/3C | V≤2.00V |

## 3. Results and Discussions

### 3.1 Charging characteristics

As the temperature decreases, the constant current charging time of the power battery is shortened, while the constant voltage stage charging time is extended, and the total charging time becomes longer. Therefore, the charging time required for the power battery will be greatly increased under charging the same amount of power, as shown in Figure 2.

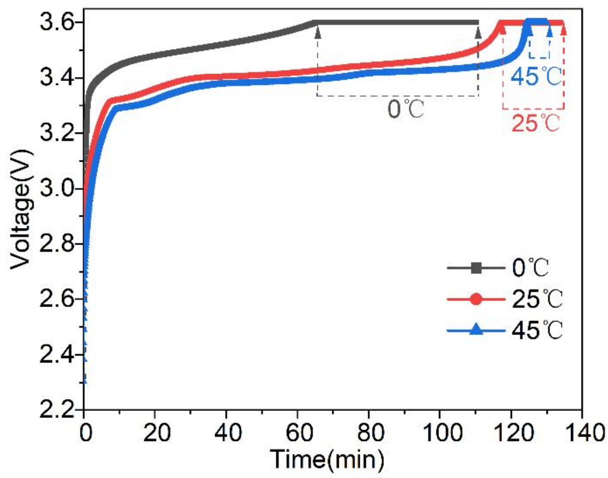


Fig. 2 CC-CV charging at various temperatures

### 3.2 Discharge characteristics

In this test, the samples were charged at room temperature with 1/3C constant current, the cutoff voltage was 3.60V for constant current charging, and the cutoff charging current was 0. 05C for constant voltage charging; then the batteries were placed in constant current discharge in the temperature set to -30°C, -10°C, 10°C, 25°C, 30°C, and 50°C temperature chambers, respectively, and the test results are shown in Table 3. As the ambient temperature increases, the energy efficiency of the power battery increases.

Table 3. C/3 discharge capacity and energy at different temperatures.

| Temperature /℃ | -30 | -10 | 10 | 25 | 30 | 50 |
|---|---|---|---|---|---|---|
| Discharge capacity /Ah | 70.47 | 102.83 | 130.57 | 138.60 | 137.42 | 137.31 |
| Retention/% | 50.85 | 74.20 | 94.21 | 100.00 | 99.16 | 99.08 |
| Discharge energy/Wh | 177.12 | 287.25 | 396.76 | 437.30 | 437.87 | 440.93 |
| Retention/% | 40.50 | 65.69 | 90.73 | 100.00 | 100.13 | 100.83 |

As shown in Figure.3, the lower the ambient temperature, the more drastic the temperature change generated by the discharge, and as the ambient temperature increases, the internal temperature of the power battery rises and the rate of temperature change gradually decreases.

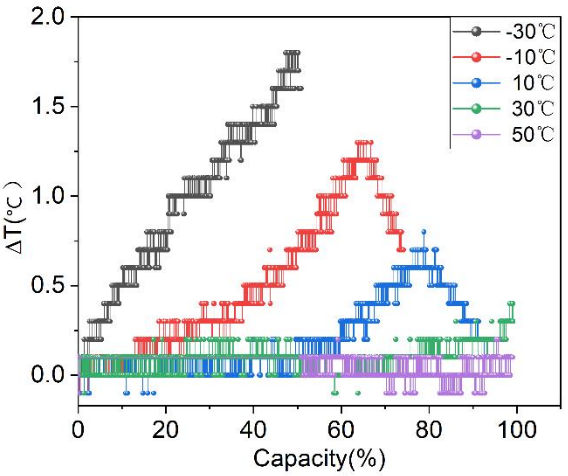


Fig. 3 Discharge temperature variation

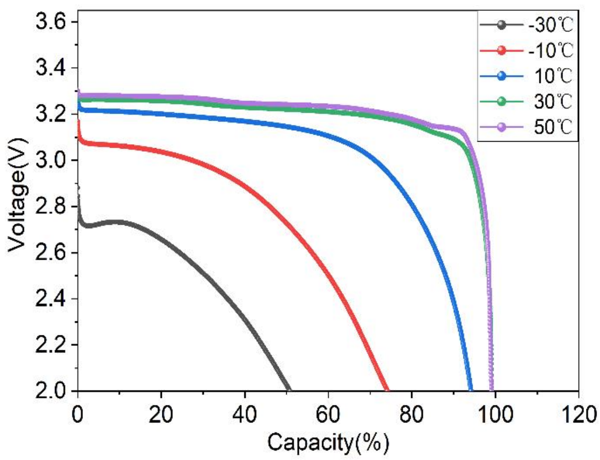


Fig. 4 Variation of discharge voltage at different temperatures

As shown in Figure 4, changes in temperature directly affect the discharge performance and discharge capacity of lithium-ion batteries. The lower the temperature, the greater the initial terminal voltage drop of the power battery, the lower the battery discharge capacity and discharge platform, and the voltage gap is more pronounced under different ambient temperature conditions. As the temperature decreases, the impedance of the power battery increases, resulting in an increase in the partial voltage of the internal resistance of the battery, so the terminal voltage of the battery decreases.

In particular, it can be found in the figure that under the environmental conditions of -30℃, due to the heat generated by the chemical reaction inside the battery at the early stage of the battery discharge, and then there is a phenomenon that the terminal voltage of the power battery at the early stage of the low-temperature discharge has been rebounded.

Discharge at different ambient temperatures (-30 ~ 50℃) at 1/3C times the current, get relative to 25 ℃ when the energy efficiency can be equated to the discharge efficiency of the characteristics of the discharge efficiency, that is, with the increase in ambient temperature, the discharge efficiency increases; temperature over a certain point, will destroy the chemical balance within the battery, high temperature rechargeable battery materials will degrade the performance of the battery, discharged battery capacity is reduced, the results is shown in Figure 5.

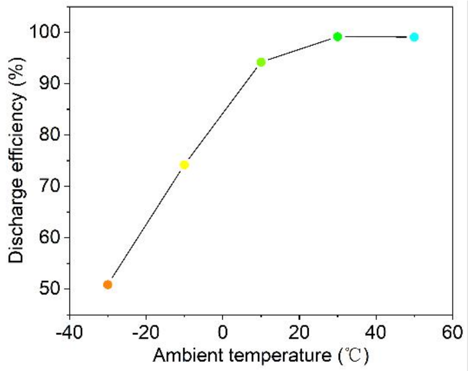


Fig.5 Efficenecy of discharge energy

## 4. Conclusions

This paper carries out charging and discharging experiments on LFP power battery under different ambient temperatures and analyzes the influence of temperature on the charging and discharging performance of power battery. The results show that the lower the ambient temperature is, the shorter the constant current charging time of the battery under the same multiplicity, the longer the constant voltage stage time, the longer the total charging time; the temperature difference between the temperature rise and the initial terminal voltage drop in the discharge stage increase, and the discharge efficiency decreases; moreover, the discharge capacity under the condition of -30℃ at the multiplicity of 1/3C is attenuated to about 50% of that under the condition of 25℃. It provides reference value for the subsequent more comprehensive understanding of temperature on power battery power and capacity characteristics.

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