Study on Low Temperature Characteristics and Heating Method of Lithium Battery for Vehicle

Hao Luo1,*

1Wuhan Business University, Wuhan, Hubei, China, 430056

*Corresponding author e-mail: 3534577@wbu.edu.cn

Abstract. In the process of electric vehicle promotion, the range, charging time and safety are mainly restricted by the characteristics of power battery. The characteristics of lithium ion power battery are significantly affected by ambient temperature, especially in low temperature environment, its available energy and power attenuation is more serious, and long-term low temperature environment will accelerate the aging of power battery and shorten service life. The development of lithium battery has entered a slow growth period in recent years after a rapid period. For high energy density lithium batteries, it should be used very carefully. A little carelessness, light will affect life, heavy may explode fire. Of all the conditions of use, voltage and temperature are the two most important related conditions. The use of lithium batteries at low temperature has poor performance, whether charging or discharging, and may have an impact on life. Under low temperature conditions, the performance of lithium battery will decline, such as prolonged charging time, reduced charge and discharge, smaller battery capacity and faster power loss, which will affect the driving mileage of new energy vehicles[1]. The working temperature of conventional lithium ion battery is between -20°C~60°C, but the performance of lithium battery will decrease and the discharge capacity will decrease after generally less than 0°C, so the working temperature of lithium ion battery performance is 0~40°C. If the temperature drops to a certain extent, the lithium battery will even be unable to charge and discharge.

Keywords: The Lithium Battery, Low Temperature, Heating, Automotive

1. Low temperature characteristics of lithium batteries

To understand the low temperature performance of lithium ion, it can be analyzed by testing the low temperature characteristics of power battery. The low temperature characteristics of power battery can be tested with different specifications and different materials, including low temperature discharge, charging and AC impedance. At the beginning of power battery charging, the voltage at the end of the battery rises instantly, and the lower the temperature, the higher the initial voltage of power battery charging. At low temperature, the terminal voltage rises faster and will soon reach the cutoff voltage and enter the constant voltage charging stage. With the decrease of temperature, the constant current charging time of power battery will be shortened, while the charging time of constant voltage stage
will be prolonged, and the total charging time will become longer. So, with the same amount of charge, the power battery will require a lot of time to charge.

In different temperature environments, the test results of power battery charging are divided into constant current stage and constant voltage stage. Set the same charge cutoff condition for the same battery, with the decrease of temperature, the total charge of power battery decreases. When the battery is in too low temperature environment, the viscosity of electrolyte increases and the movement of Li ions is blocked. Some Li ions deposited on the negative electrode surface cause lithium evolution, resulting in loss of battery capacity; When the battery is in the environment of too high temperature, the activity of electrolyte and active substance is great, the side reaction and the decomposition of electrolyte will occur inside the battery, on the one hand, the capacity loss is caused. On the other hand, the battery swells because of the side reaction[2].

![Lithium Ion Cell Operating Window](image)

**Figure 1.** Influence of voltage temperature on lithium battery.

The electrolyte viscosity of lithium battery increases under low temperature environment, the migration speed of lithium ion becomes slower, the discharge capacity will be relatively reduced at low temperature with large current, and the capacity of lithium battery will be the same as above in high temperature environment. Loss of capacity due to side reactions and possible gas bulging. Similarly, the reference test temperature of lithium battery is 23±5℃, and the result of higher or lower temperature test will be a little deviated. Due to the existence of high melting point solvent in the mixed solvent of electrolyte, the viscosity of lithium battery electrolyte increases at low temperature, and the solidification phenomenon of electrolyte occurs when the temperature is too low, which leads to the decrease of lithium ion transmission rate in electrolyte.

2. **The main factors affecting the low temperature of lithium batteries**

2.1. **Positive electrode materials**

From the micro point of view, the low temperature characteristics of lithium ion power battery are mainly restricted by the low ionic conductivity of the electrolyte in the battery at low temperature, the decrease of the electrochemical reaction rate of the battery electrode at low temperature, the decrease of the conductivity of the SEI film on the surface of the negative graphite particles of the battery at low temperature, and the low solid phase diffusion coefficient of lithium ion in the negative graphite
particles of the battery at low temperature. Therefore, the performance of lithium ion power battery at low temperature is first related to the battery electrolyte. Electrolyte solvent of power cell not only directly affects the temperature range of liquid phase line of electrolyte, but also directly participates in the reaction of forming SEI film\[3\]. The conductivity of electrolyte decreases at low temperature, and the lithium metal precipitated by low temperature charging is easy to react with electrolyte, which leads to the further deterioration of low temperature performance of lithium ion power battery. There are many kinds of cathode materials used in lithium ion batteries. The difference of cathode materials is one of the fundamental reasons for the difference of low temperature performance of batteries. At -20°C, the discharge capacity of lithium iron phosphate battery can only reach 67.38 at room temperature, the nickel cobalt manganese ternary battery can reach 70.1, and the lithium manganese oxide battery can reach 83% of the normal temperature capacity. It can be seen that the low temperature performance of lithium manganese oxide battery is the best, while that of lithium iron phosphate battery is poor.

![Figure 2. Lithium battery structure.](image)

2.2. **Diaphragm**

The size of diaphragm aperture has a direct effect on the performance of lithium battery. Too small aperture will increase the internal resistance of the battery, and too large aperture will easily make the positive and negative electrode contact directly or be easily pierced by lithium dendrite to cause short circuit of the battery. The suitable porosity plays an important role in the performance of the diaphragm and lithium battery: if the porosity of the diaphragm is too small, the permeability of the electrolyte is weak, the conductivity is low, and the porosity is too high. Although the permeability and electrolyte adsorption ability are obviously improved, the corresponding shrinkage and puncture resistance become worse, the performance of lithium-ion batteries is greatly affected by the kinetic characteristics. Since Li+ need to be first desolvation when embedded into graphite materials, this requires a certain amount of energy, which hinders the Li+ diffusion into the graphite interior. On the contrary Li+ when the graphite material is removed into the solution, the solvation process will first occur, and the solvation process does not need to consume energy, Li+ the graphite can be removed quickly. Therefore, the charging acceptance ability of graphite material is obviously worse than that of discharge acceptance\[4\]. The attenuation of energy and power characteristics of lithium ion power battery is serious in low temperature use. Macroscopically, the low temperature performance of lithium ion power battery is that with the decrease of temperature, the impedance of power battery increases, the discharge voltage platform decreases, and the terminal voltage of the battery decreases faster. The available capacity and power are greatly attenuated.

The ratio of AC voltage to current signal varies with frequency is measured. This method can obtain more electrode interface structure and kinetic information than other conventional
electrochemical methods, so it is widely used to study the internal mechanism of lithium ion batteries. With the decrease of temperature, the ohmic impedance of high frequency increases, and the impedance of high frequency and medium frequency increases with the decrease of temperature.

3. How to heat
In order to ensure the heating stage, the battery pack is not filled with current, divided into constant current, constant voltage two charging modes. Constant current charging mode, request charging voltage for battery pack maximum allowable voltage, request charging current for heating demand current. The DCDC working power is not constant, which may lead to small electric flow to battery pack charging due to the delay of BMS and charging pile response time. In addition, if the request current is relatively small, some DC charging piles on the market can not respond to the small current charging, and can only be heated by the energy in the battery pack[5].

![Figure 3. Lithium battery production process.](image)

3.1. Reduce heating frequency
I believe that a good thermal insulation design for power batteries can effectively reduce the burden of heating devices and reduce the frequency of forced heating. Once there is a need for heating, the energy for the rapid heating of the battery mainly comes from two aspects, the battery itself and the external equipment. By using these energies to heat, such as heating membranes and PTC Coefficient. The heating film belongs to the constant resistance heating element and can always be maintained in a certain range of heating power output. As the name implies, the PTC value is positively correlated with the temperature. With the increase of temperature, the resistance is also increasing, so the constant temperature heating can be realized, and the safety is better.

3.2. Increase power consumption
If we want to shorten the charging time in winter, we can increase the power consumption of the car on the way to the charging station, such as turning on the motion mode, turning on the warm air and so on, and heating the power battery by high power discharge. When you reach the charging station, the temperature of the power battery may reach a working state that allows high current charging, which can also save some charging time.
In this age of efficiency, people or things who can only cope with one job face severe challenges. For electric vehicles, thermistors that can only heat work clearly have the potential to improve. At this time, the liquid cooling temperature control system which can take into account preheating and refrigeration has got a wider stage. Specifically, it can be cooled at high temperature and heated at low temperature according to the overall heat management requirements of power battery pack. The liquid cooling temperature control system mainly includes the cold and heat exchanger, the heating device, the coolant circulation pipeline and the liquid circulation power source several parts. It uses cold and heat exchanger or heating device to control the temperature of power battery to increase or decrease. Taking this system as an example, the complexity of liquid cooling temperature control system is high. Therefore, after preheating, the effect is more lasting than that of thermistor heating. Generally speaking, the liquid cooling temperature control system can ensure that the whole temperature reaches the set range after the electric vehicle is driving, and no or a small amount of power battery is used to provide energy for the temperature control system.

Both lithium iron phosphate battery and ternary lithium battery are in low temperature environment, which will be affected by the decrease of positive and negative electrode material activity and electrolyte conductivity. As a result, the charging time will increase accordingly, and the power is more difficult to fill. During use, the power battery pack "power down" speed will be significantly accelerated. Therefore, in order to solve the problem, the engineer developed battery preheating system and heat management system. Reduce the impact of ambient temperature on battery pack by adjusting battery pack temperature.

4. Conclusion

When lithium battery is charged at low temperature, it is easy to analyze lithium and form lithium dendrite, which leads to short circuit in battery, which has hidden danger of safety. Therefore, battery manufacturers generally provide battery allowable charging temperature range, taking Carnegie 36 Ah battery as an example, the allowable charging temperature is 0–45 °C. Therefore, when the lithium battery is charged in a low temperature environment, it is necessary to start the heat management system first, heat the battery, and wait for the battery temperature to rise to the allowable charging range before turning on the charging function back to the beginning of the problem. There are two common ideas for solving this problem, one is the preheating and heating methods we discussed earlier, the other is to improve the battery's ability to withstand cold, preferably a battery that is not afraid of cold or heat⁶. Hainan can also withstand Harbin. If you can do like Apple, one or two individual products, the benefits must be the best. If you think along this line, the best solution is to
work on the battery itself. To improve battery performance, the main method is to add additives to electrolyte to improve low temperature performance, or to change electrode materials and test other technical routes. In particular, the latter, once can achieve mass production, is indeed a qualitative leap. these are efforts in the electrochemical direction.

Acknowledgments
Guiding Project of the Scientific Research Plan of the Hubei Provincial Department of Education in 2019, No: B2019248.

References
[1] Zhao Shixi, GUO Shuangtao, ZHAO Jianwei, Song Yu, Nan Cewen, research progress of lithium ion battery at low temperature. Acta Silicate.
[2] Lei Zhi-ju, ZHANG Cheng-ning, Li Jun-qiu, et al. Low temperature performance of lithium-ion batteries for electric vehicles.
[3] Sun, F.; Xiong, R.; He, H. A systematic state-of-charge estimation framework for multi-cell battery pack in electric vehicles using bias correction technique. Appl. Energy 2016, 162, 1399–1409.
[4] Cho, H.; Choi, W.; Go, J.; Bae, S.; Shin, H. A study on time-dependent low temperature power performance of a lithium-ion battery. J Power Sources 2012, 198, 273–280.
[5] Zhang, C.N.; Lei, Z.G.; Dong, Y.G. Method for Heating Low-Temperature Lithium Battery in Electric Vehicle. Trans. Beijing Inst. Technol. 2012, 32, 921–925.
[6] Liu, C.; Zhang, H. Research on heating method at low temperature of electric vehicle battery. Chin. J. Power Sources 2015, 39, 1645–1647, 1701.