

Study on internal resistance of Li-ion power battery

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Abstract

Purpose – The internal resistance of a single power lithium-ion battery is an important representation of its power characteristics. When the current flows through a single battery with high internal resistance, the amount of heat generated is relatively large, resulting in accelerated deterioration of the single power battery, further increasing the internal resistance, accelerating the deterioration of the single power battery with high internal resistance, and seriously affecting the endurance and safety performance of new energy vehicles. Therefore, this paper studies the mechanism and improvement plan of low internal resistance consistency of a single battery.

Design/methodology/approach – Addressing the issue of high internal resistance in lithium-ion batteries at the production site, we employed a full-factor analysis using a quality tree approach to examine raw materials, production equipment and processes. This enabled us to identify the root causes and subsequently improve the internal resistance of lithium-ion batteries through upgrades in equipment and process optimization.

Findings – Through the analysis and improvement of the internal resistance of power lithium-ion batteries, a comprehensive understanding of the internal resistance of the power lithium-ion battery has a comprehensive understanding of the influencing factors of power lithium-ion batteries. The use of power lithium-ion batteries on new energy vehicles has played a supporting role.

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Keywords Consistency, Internal resistance, Lithium-ion power battery

Paper type Research paper

1. Introduction

The internal resistance of a single power lithium-ion battery is an important representation of its power characteristics (Hong *et al.*, 2023). When the current flows through a single battery with high internal resistance, the amount of heat generated is relatively large, resulting in



accelerated deterioration of the single power battery, further increasing the internal resistance, accelerating the deterioration of the single power battery with high internal resistance, and seriously affecting the endurance and safety performance of new energy vehicles (Chen *et al.*, 2020). Therefore, this paper studies the mechanism and improvement plan of low internal resistance consistency of single battery.

2. Analysis of influencing factors of internal resistance

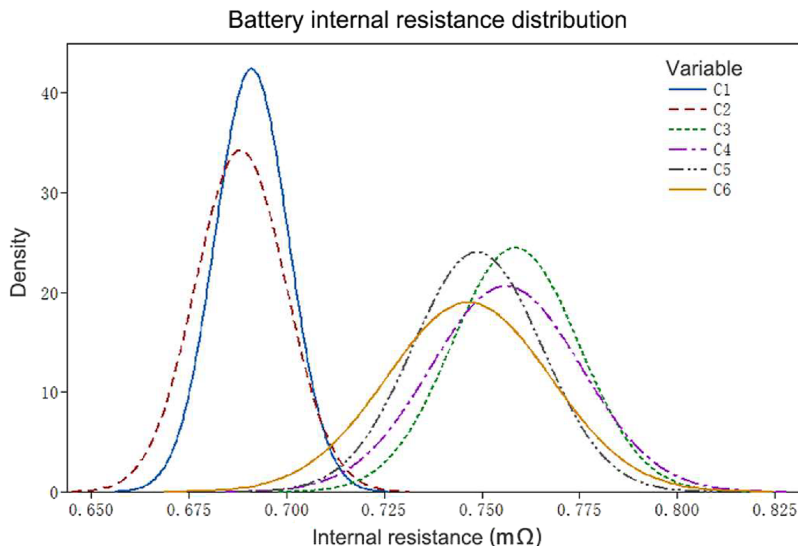
The internal resistance of a battery is the expression of the electrical characteristics displayed by the chemical reaction inside the battery (Du *et al.*, 2019). The internal resistance of the battery is related to the conductivity and concentration distribution of the electrolyte and collector inside the battery, the permeability of the diaphragm, and the resistance of the battery shell (Dai *et al.*, 2014). Extract different batches of batteries in production and test the internal resistance distribution as shown in Figure 1.

From the C3 batch, the internal resistance of the battery suddenly increased significantly, with an average increase of 0.07 m Ω , and the spread became larger. The abnormal fluctuation of battery internal resistance is analyzed as follows.

2.1 Influence analysis of battery internal resistance

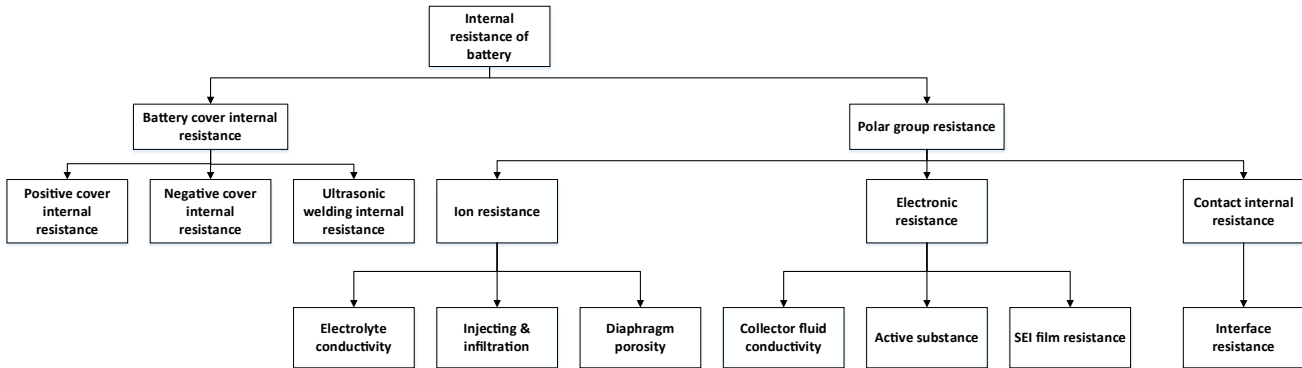
According to fault tree analysis (FTA), the internal resistance of the battery is analyzed as shown in Figure 2, which is mainly divided into the internal resistance of the battery cover and the internal resistance of the pole group, which mainly includes ionic resistance, electronic resistance and contact internal resistance (Li *et al.*, 2020). The internal resistance tests of different battery batches are shown in Table 1.

As can be seen from Table 1, from batch C4, the measured AC internal resistance of the battery increases by 0.07 m Ω , in which the internal resistance of the pole group increases by 0.09 m Ω and the internal resistance of the battery cover increases by 0.09 m Ω . The internal resistance of battery cover, electrolyte, diaphragm and pole plate was analyzed for the failed batch battery.



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Figure 1. Distribution diagram of battery internal resistance under different work orders



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Figure 2. Frame diagram for the analysis of inconsistent battery internal resistance

Table 1. Analysis of internal resistance of the battery Mo

Battery lot	Mean internal resistance	Battery number	Battery cover internal resistance	Polar group resistance
C1	0.6968	4,248#	0.736	0.5
C2	0.691	1,159#	0.7425	0.5153
C3	0.6882	0070#	0.7466	0.5081
C4	0.7586	1,181#	0.8451	0.5982
C5	0.7562	1,613#	0.8358	0.5905
C6	0.7489	1,412#	0.8128	0.5979

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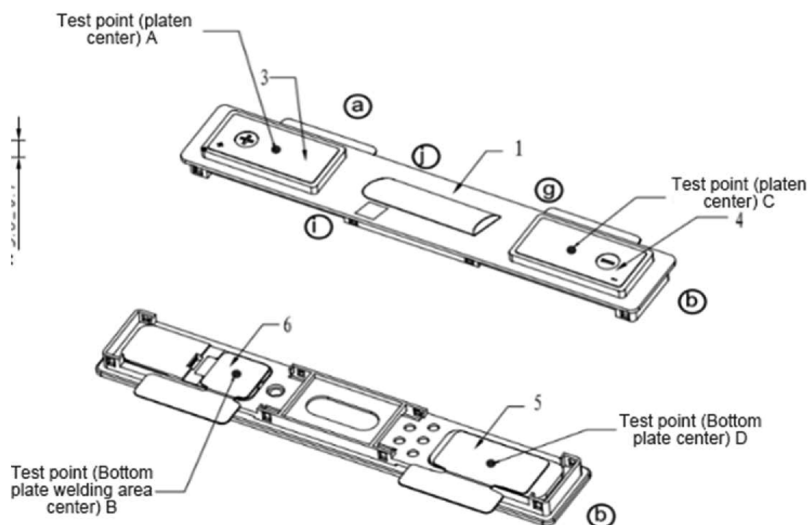
2.2 Battery cover internal resistance analysis

The internal resistance of the battery cover is analyzed, and its structure is shown in Figure 3. The internal resistance of the battery cover is mainly composed of positive terminal resistance and negative terminal resistance (Tang et al., 2007). The design requires an internal resistance of less than $0.15\text{ m}\Omega$, and the internal resistance of the tested battery cover is shown in Figure 4.

From the above data, it can be seen that the internal resistance of the positive terminal of the battery cover fluctuates greatly, and the difference between batches reaches 20%. By improving the manufacturing engineering capability of the battery cover, the process capability of the positive internal resistance of the battery cover is shown in Figure 5, and the consistency process capability of the internal resistance of the battery cover is improved from 0.90 to 1.35.

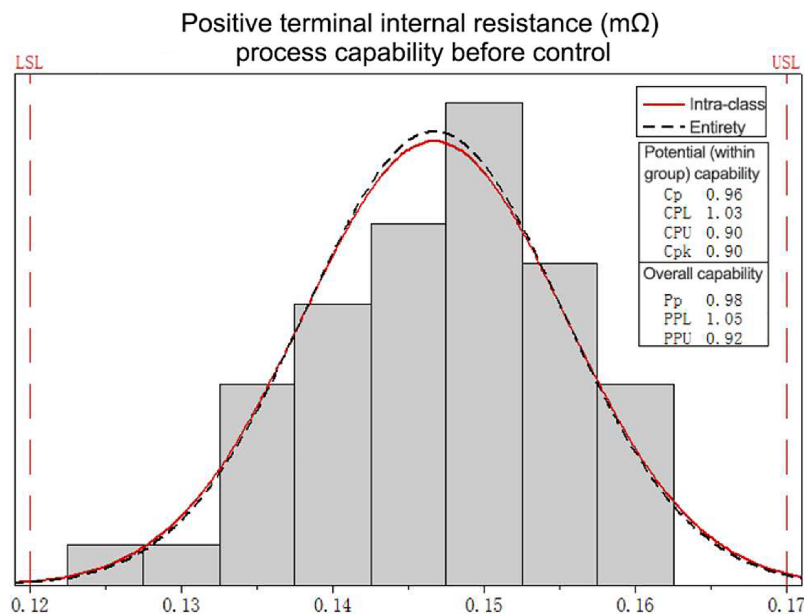
2.3 Electrolyte influence analysis

In order to analyze the influence of the conductivity and concentration distribution of the electrolyte inside the electrode group on the internal resistance of the battery, the internal



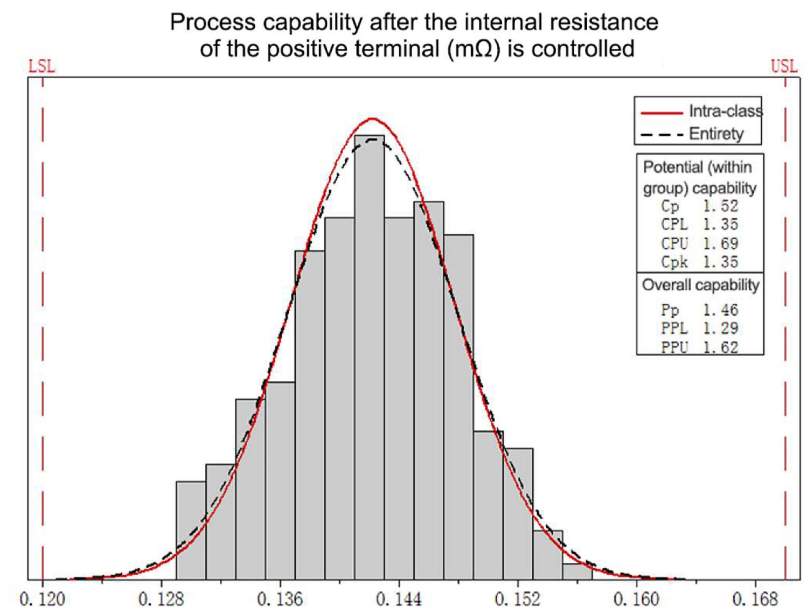
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Figure 3. Dismantling test of battery lid internal resistance analysis



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Figure 4. Process capability of battery positive terminal before control



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Figure 5. Process capability of battery positive terminal after control

resistance data of the battery under the same batch of electrolyte were tested, as shown in Figure 6.

As can be seen from Figure 6, the internal resistance of the battery mutates during the use of the same batch of electrolyte, so the electrolyte batch is not the cause of the internal resistance fluctuation of the battery. Test the conductivity of the electrolyte and conduct process capability analysis, as shown in Figure 7. The CPK value of the electrolyte conductivity is 1.75, that is the consistency of the electrolyte conductivity is good.

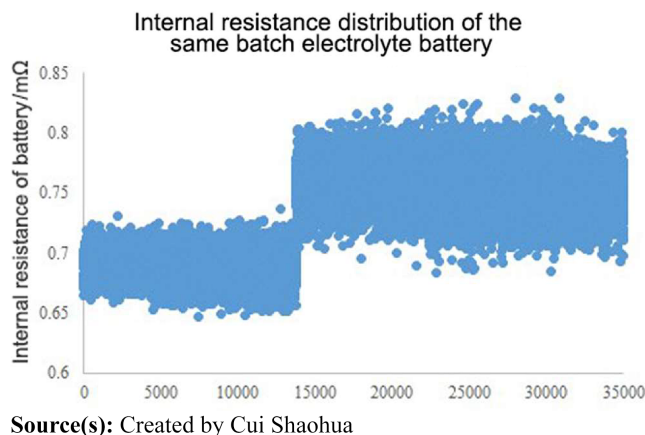


Figure 6. Analysis of battery internal resistance under the same batch of electrolyte

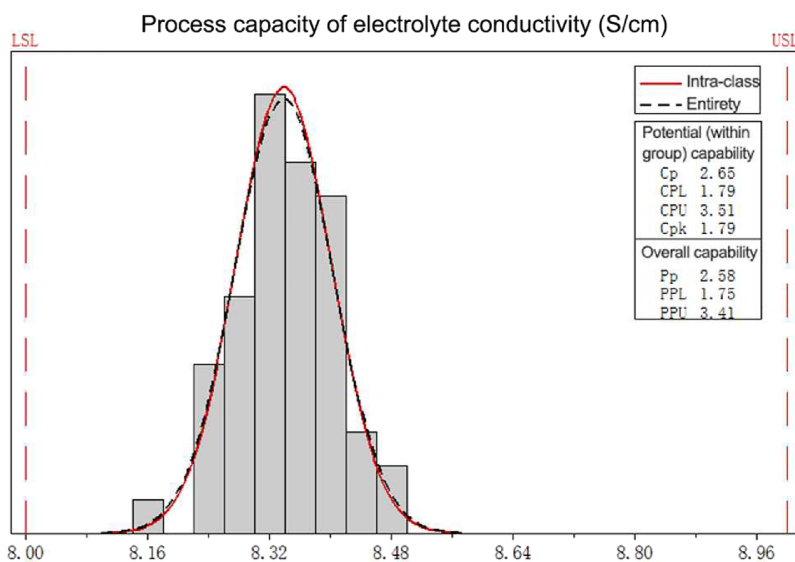


Figure 7. Process capability of electrolyte conductivity

2.4 Influence analysis of diaphragm air permeability

The air permeability of the diaphragm reflects the ability of ions to pass through the diaphragm, and has a certain influence on the ionic resistance of the pole group (Reynolds *et al.*, 2021). The diaphragm air permeability test values of different batches were analyzed, as shown in Figure 8, and no major fluctuations occurred. Therefore, it can be concluded that the internal resistance of the battery is not related to the diaphragm batch.

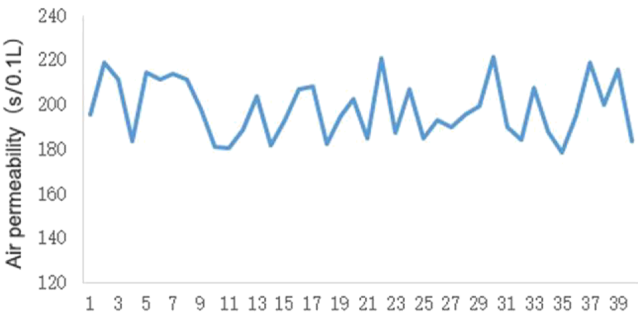
2.5 Influence analysis of internal resistance of positive electrode plate

In order to detect the influence of the battery electrode plate on the internal resistance, three groups of batteries were selected to test the corresponding battery internal resistance and the positive electrode plate resistance. The test results are shown in Table 2.

The battery resistance corresponding to the batch of batteries with large internal resistance is significantly higher than the previous electrode resistance.

The electrode sheet is divided into composite layer (active material layer), collector and its interface (Zhao *et al.*, 2022). The test is shown in Figure 9. The constant current power supply is used to measure the multipoint voltage through the probe, and then the resistance is calculated. The resistivity of the electrode composite layer and the interface resistance between the electrode composite layer and the collector layer of two different slurry batches were respectively tested, as shown in Table 3 and Table 4. The corresponding test results of the battery internal resistance were shown in Table 5.

The test results show that the internal resistance of the electrode sheet, the internal resistance of the composite layer and the interface resistance of the composite layer and the



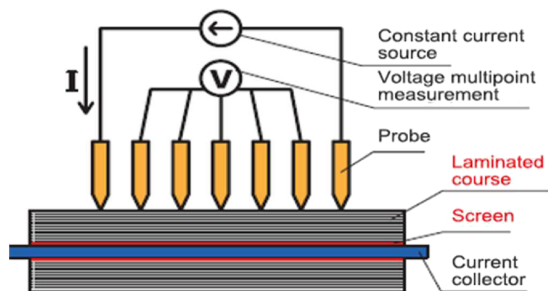
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Figure 8. Diaphragm air permeability

Table 2. Internal resistance of positive plate

Polar group number	Internal resistance of battery	Pole piece	Test 1(Ω)	Test2(Ω)	Test 3(Ω)
C217-680#	0.6982	1	23.721	34.228	23.858
		2	27.03	26.482	26.982
C105-208#	0.8428	1	58.123	75.363	60.192
		2	58	62.131	58.237
C104-802#	0.9436	1	83.127	74.271	70.127
		2	78.127	84.727	81.423

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Figure 9. Measurement mode diagram

Table 3. Volume resistivity of electrode material layer Ω/cm

	Stock batch 1			Stock batch 2		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Polar plate A side	143.3	184	261.9	70.65	49.97	55.74
Polar plate B side	185.2	264	158.8	100.9	82.73	49.47

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Table 4. Interface resistance between electrode material layer and current collector Ω/cm^2

	Stock batch 1			Stock batch 2		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Polar plate A side	1.12	1.39	1.5	0.48	0.48	0.44
Polar plate B side	1.25	1.49	1.06	0.48	0.45	0.51

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Table 5. Internal resistance of the corresponding batch of batteries $\text{m}\Omega$

	Stock batch 1	Stock batch 2
Internal resistance of battery	0.7253	0.6638

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fluid collector are significantly different between different slurry batches, and the internal resistance of the battery corresponding to the electrode sheet with large internal resistance is also significantly increased (Amanor-Boadu and Guiseppi-Elie, 2020).

3. Process optimization

The positive and negative slurry of lithium-ion battery is a typical multi-component system (active particles, binders, conductors, etc.), and the preparation of positive and negative slurry includes a series of technological processes such as mixing, dissolution and dispersion between liquid and liquid, liquid and solid materials (Nie *et al.*, 2019). In the production of high solid content slurry, the active particles, conductive agents and other solid particles are

easy to settle and agglomerate during pulping mixing, the particle material is easy to destroy, and it is difficult to form a stable connected bond and conductive network structure to ensure the safety and performance of the battery. The existing pulping processes, such as double-planet stirring, tend to form a dispersed “dead zone” far from the impeller area, resulting in uneven slurry mixing. Meanwhile, solid components need to be added in batches in different batches, and the pulping speed is low, which is difficult to meet the application requirements of new energy vehicle power batteries (Yang *et al.*, 2021). Therefore, the twin-screw pulping process of power lithium-ion battery was independently developed and designed, as shown in Figure 10.

The mathematical expression of the shear rate (γ) of the twin screw system at the edge of the cylinder wall is:

$$\gamma = \frac{\pi \times D_0 \times N}{60 \times h} \quad (1)$$

Where D_0 represents the outer diameter of the screw (mm), N represents the speed of the main screw (rpm), and h represents the distance between the wall of the screw cylinder and the point where it is located (mm).

The viscosity of twin-screw extruder is defined as: (Zhuang *et al.*, 2020) (see Figure. 11)

$$\eta = \frac{\tau}{\gamma} = \frac{K\gamma^n}{\gamma} = K\gamma^{n-1} \quad (2)$$

Where K is the fluid consistency coefficient, and the greater K is, the greater the flow resistance. n is a non-Newtonian exponent, and in general, for most polymer fluids, K and n can be regarded as constants over a small range of variations. Then the viscosity dependence on shear can be expressed as:

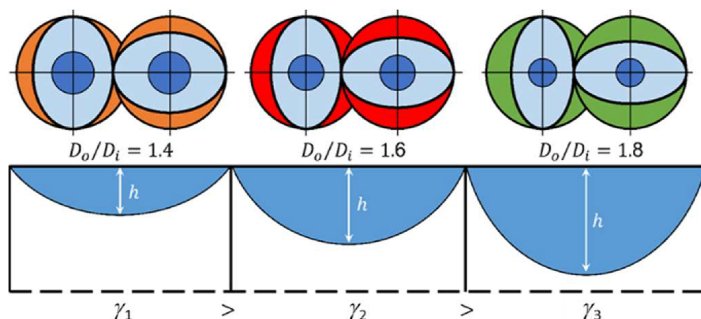
$$\frac{d\eta}{d\gamma} = (n - 1)K\gamma^{n-2} \quad (3)$$

Where, when $n = 1$, $d\eta/d\gamma = 0$, the fluid is Newton fluid; When $n < 1$, $d\eta/d\gamma < 0$, The fluid is pseudoplastic. When $n > 1$, $d\eta/d\gamma > 0$, the fluid is dilatant plastic (Forouzan *et al.*, 2018). It can be seen from the relationship between shear viscosity and shear rate that pseudoplastic



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Figure 10. Core structure of twin screw extruder



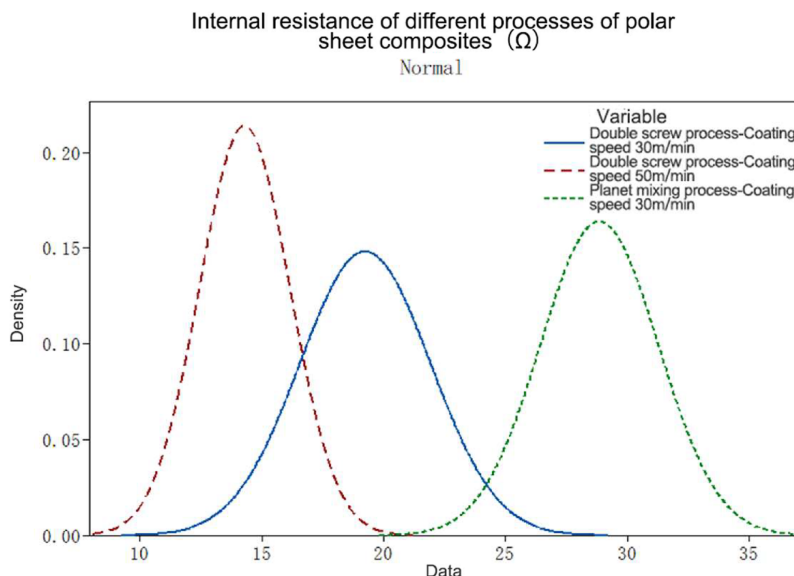
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Figure 11. Traditional batch mixing schematic diagram

fluid has shear thinning behavior (lithium battery slurry belongs to this property), and dilatant plastic fluid has shear thickening behavior (Song *et al.*, 2020).

Use the double-screw pulp process, the planet's mixing pulp process to make the pulp, and make the polar sheet according to different coating speeds to perform the resistance test of the compound layer. The measurement results are shown in Figure 12.

It can be seen that the internal resistance of the polar section of the different pulp production is large. Under the same slurry process, the internal block resistance of the polar section of the coating speed is small. Combined with the above, the slurry process is solidified, the internal blockage of the polar sheet is monitored, and the coating speed is changed to ensure the stable process.



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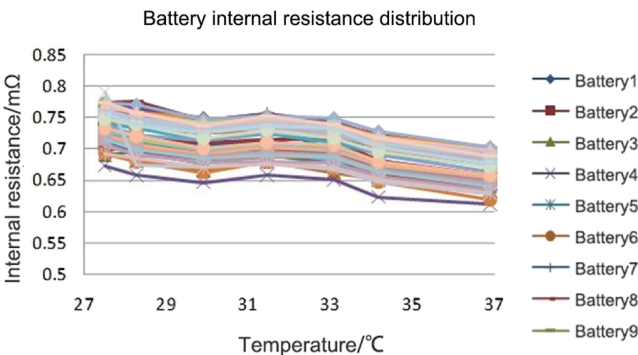
Figure 12. Comparison of internal resistance distribution of the composite layer

According to the document, it may also affect the internal resistance of the battery (Zhang *et al.*, 2020) to the internal resistance test of the internal resistance test of the internal resistance test. (See Figure 13)

It can be seen that as the temperature rises, the internal resistance value is declining, the temperature rises by 10 °C, and the internal resistance is reduced by 0.078 MΩ. The relationship between the internal resistance of the battery and the real -time temperature of the production is shown in Figure 14. There is no obvious relationship with the temperature. The temperature has a certain effect on the internal resistance of the battery, but the actual production process is not the dominant factor (Li *et al.*, 2014). Therefore, the control workshop temperature is 25–28 °C, which can ensure the consistency of the battery internal resistance testing test.

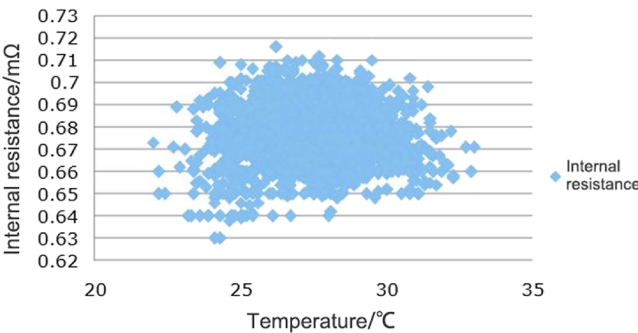
4. Improvement effect verification

By the improvement of the production control, uniform slurry and coating process of the battery cover, and the improvement of the temperature control of the workshop, the internal resistance of the battery produced has significantly improved. (see Figure 15).



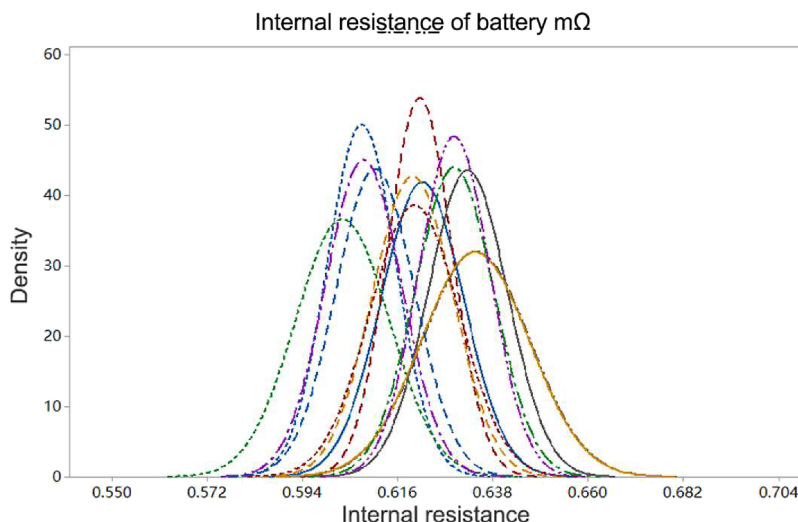
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Figure 13. Change chart of battery internal resistance with temperature



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Figure 14. Relationship between internal resistance and temperature



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Figure 15. Distribution diagram of battery internal resistance produced by different production lines

According to the actual production results, the battery internal resistance data produced by different production lines does not fluctuate obviously, and the difference in the standard difference between the internal battery resistance from 0.017 is reduced from 0.017 to 0.0097.

5. Conclusion

Through the analysis and improvement of the internal resistance of power lithium-ion batteries, a comprehensive understanding of the internal resistance of the power lithium-ion battery has a comprehensive understanding of the influencing factors of power lithium-ion batteries. The use of power lithium-ion batteries on new energy vehicles has played a supporting role (Li, 2018).

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