Research on Influencing Factors for Consistency Performance of Lithium Ion Batteries

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Abstract. The capacity, energy, internal resistance and open-circuit voltage are key indicators to represent the performance of lithium ion batteries. The battery rate characteristic refers to the battery charge and discharge performance; the higher rate battery can withstand higher discharge current. This paper researched the influencing factors for consistency performance of Lithium ion batteries which were tested at 1/3C, 1.5C and 2C charge and discharge. The result shows that the charge and discharge voltage of the series-connected cell group is different slightly, and the basic electric performance (capacity, internal resistance) is not affected basically when the charge rate is less than 1C, the temperature rises slightly when charging the series-connected cell group when the charge rate is larger (higher than 1C), and proposes a method for select the appropriate battery charge and discharge rate, to eliminate the adverse batteries and ensure the good performance of batteries.

1. Introduction
The battery rate characteristic refers to the battery charge and discharge performance; the higher rate battery can withstand higher discharge current. The battery may cause discharge current inconsistency because of its internal structure, active material of positive electrode and electrolyte difference, in hybrid power cars, most of discharges are performed at high current with less energy consumption, the design shall consider more power performance factors [1-3]. The power battery mainly plays the role of auxiliary power sources in accelerating and climbing up, the greater the battery discharge current is, the more the dynamic performance of the vehicle can be ensured, the higher the energy utilization rate is [4-5]. This paper researched the influencing factors for consistency performance of Lithium ion batteries, and proposes a method for select the appropriate battery charge and discharge rate, to eliminate the adverse batteries and ensure the good performance of batteries.

2. The consistency tests

2.1. Test sample
The model and the parameters of cell in this paper as follows:
- The model: domestic battery, rated voltage 3.7 V, rated capacity 11 Ah, internal resistance < 6 mΩ, weight < 320 g
- Dimensions: 133 mm×66 mm×18 mm.
• The composing of the battery: the cathode material is LiMn2O4, the anode material is graphite, the electrolyte is LiPF6, EC and DMC, and battery separator is celgard 2325.

2.2. Test Instrument
Thermostat box, model SPHH-101; Integrated battery tester, MACCOR battery performance test systems; Data acquisition system, model MV2000. The test is shown in Figure 1.

![Figure 1. The consistency tests.](image)

2.3. Test Method
Select 4 cells of good capacity and internal resistance consistency, and inconsistent initial open-circuited potential (for example, the initial open-circuit potentials of the test sample at 20ºC: sample 1: 4.121V, sample 2: 4.122V, sample 3: 4.120V and sample 4: 4.121V), to form two battery cell blocks connected in series, respectively, 1/3C, 1.5C and 2C charge and discharge condition and monitor the real-time voltage.

3. Results and Discussion
The results of Lithium ion batteries which were tested at 1/3C, 1.5C and 2C charge and discharge in consistency tests are shown in Table 1, Figure 2, Figure 3 and Figure 4.

| Sample No. | The maximum charge voltage /V | The minimum discharge voltage /V |
|------------|--------------------------------|---------------------------------|
| 1/3C       |                                |                                 |
| RC-1-3     | 8.401                          | 5.400                           |
| RC-2-6     | 8.401                          | 5.400                           |
| 1.5C       |                                |                                 |
| RC-1-1     | 8.401                          | 5.399                           |
| RC-2-2     | 8.401                          | 5.400                           |
| 2C         |                                |                                 |
| RC-1-7     | 8.393                          | 5.350                           |
| RC-2-10    | 8.393                          | 5.368                           |
Figure 2. The voltages curve of two battery groups at 1/3C charge and discharge condition.

Figure 3. The voltages curve of two battery groups at 1.5C charge and discharge condition.

Figure 4. The voltages curve of two battery groups at 2C charge and discharge condition.
According to Figure 2, Figure 3 and Figure 4, when the series-connected cells charge and discharge at 1/3C condition, the charge voltages of two groups of series-connected cells are different slightly; when the series-connected cell group charge and discharge at 1.5C condition, the charge and discharge voltages of two groups of series-connected cells produce inconsistency, especially the greater the discharge voltage gap, the greater and greater the charging time gap; when the series-connected cell group discharge under 2C condition, the discharge voltages of two groups of series-connected cells also produce a certain inconsistency, especially the charge and discharge time gap becomes greater and greater.

The temperature of battery in consistency tests was shown in Table 2 and Figure 5.

**Table 2.** The results of the consistency tests.

| Sample No. | The maximum temperature /℃ | The minimum temperature /℃ |
|------------|----------------------------|----------------------------|
| 1/3C       |                            |                            |
| RC-1-3     | 18.25                      | 18.21                      |
| RC-2-6     | 18.21                      | 18.17                      |
| 1.5C       |                            |                            |
| RC-1-1     | 18.18                      | 18.13                      |
| RC-2-2     | 18.19                      | 18.15                      |
| 2C         |                            |                            |
| RC-1-7     | Test point 3               | 31.99                      | 18.33                      |
| Test point 4| 32.34                      | 18.36                      |
| Test point 5| 29.88                      | 18.06                      |
| RC-2-10    | Test point 1               | 30.53                      | 18.24                      |
| Test point 2| 34.23                      | 18.38                      |

**Figure 5.** The temperature curve of battery group 1 at 2C charge and discharge condition.
4. Conclusions

1) When the charge rate is less than 1C, the charge and discharge voltage of the series-connected cell group is different slightly, and the basic electric performance (capacity, internal resistance) is not affected basically.

2) When the charge rate is larger (higher than 1C), the charge and discharge voltage of series-connected cell group produces inconsistency, especially the discharge voltage gap is bigger, and the charge and discharge time gap is also larger and larger.

3) When the charge rate is larger (higher than 1C), the temperature rises slightly when charging the series-connected cell group.

At present, the criteria for evaluation of lithium-ion power battery consistency are: capacity, internal resistance and average discharge voltage. The common screening method is to collect the discharge capacity and average discharge voltage of lithium-ion battery by capacity check at 0.35C and the battery internal resistance in fully charged state as the basic data, to screen, grade and group the batteries. However, after such small current process for capacity checking and screening, the grouped batteries will still have slightly low open circuit voltage and more and more obvious electric performance differences in many cases in the process of use, which leads to failure of a complete group of modules, even of a whole battery pack due to abnormal individual monomer battery, and brings additional costs to the battery production and use. This shows that the 0.35 C current screening process can't achieve the expected result for screening the adverse batteries. Therefore, according to the results of this section, select the appropriate battery charge and discharge rate, to achieve the purpose to eliminate the adverse batteries and ensure the good performance of batteries.

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References

[1] Tang Jin, Xu Guofeng, Li Jianling 2017 Study on cycling performance of lithium iron phosphate battery at different discharge rates Nonferrous Metals Science and Engineering Vol 8 PP 95-102

[2] Chen Ping, Li Yu, Zhang Jiarong. et al 2013 Impact of discharge current strength on battery group consistency Power Supply Technolog Vol 37 PP 427-429

[3] Wang Zhen-po 2003 Study on Inconsistency of Electric Vehicle Battery Pack Chinese Journal of Power Sources PP 438-441

[4] Su L, Zhang J, Huang J, et al 2016 Path dependence of lithium ion cells aging under storage conditions Journal of Power Sources PP 35-46

[5] Martin-Martin L., Gastelurrutia J, Nieto N, et al 2016 Modeling based on design of thermal management systems for vertical elevation applications powered by lithium-ion batteries Applied Thermal Engineering PP 1081-1094