IOP Conf. Series: Materials Science and Engineering **359** (2018) 012018 doi:10.1088/1757-899X/359/1/012018

Evaluation Method for Low-Temperature Performance of Lithium Battery

H W Wang, Q Ma, Y L Fu, Z Q Tao, H Q Xiao, H Bai and H Bai

Institute of Industrial and Consumer Product Safety, Chinese Academy of Inspection and Quarantine, No. A3, Gaobeidian Bei Lu, Chaoyang District, Beijing, PR China, 100123

Email: wanghongwei-1978@163.com

Abstract. In this paper, the evaluation method for low temperature performance of lithium battery is established. The low temperature performance level was set up to determine the best operating temperature range of the lithium battery using different cathode materials. Results are shared with the consumers for the proper use of lithium battery to make it have a longer service life and avoid the occurrence of early rejection.

1. Introduction

The mobile power, also called as 'Charger', is a portable device integrated the power storage, boost and charge management, can charge or supply power in standby to the mobile phone and other digital devices whenever and wherever possible, and has become a most essential digital device for customers in daily life. Because the majority of mobile powers on the market are composed of 3 major parts combined with lithium battery (including 18650 or polymer), circuit board and shell, but the low temperature performance of lithium battery is poor, the research shows that the capacity and operating voltage of the common-used lithium ion battery will be significantly reduced at -10ºC,significantly deteriorated at -20ºC, its discharge capacity at -14ºC is about 30% of that at room temperature, or individual lithium-ion battery even can't operate at -40ºC. Moreover, there is no special standard for mobile power products in China, therefore, the establishment of an evaluation method for low temperature performance of lithium battery is required, and the low temperature performance level should be set up to determine the best operating temperature range of the mobile power of lithium battery using different cathode materials, so that the consumers have a clear perception of the low temperature performance of the mobile power purchased.

2. Method and Procedures

The purpose of this paper is to provide an evaluation method for low temperature performance of lithium batteries, and can be used to evaluate the performance of the mobile power under low temperature condition, thus sorting out the best operating temperature range of the lithium battery using different cathode materials, to provide the consumers with advices for proper use of lithium battery mobile power to make it have a longer service life and avoid the occurrence of early rejection.

To this end, the present paper provides a method for evaluating the low temperature performance of lithium battery (mobile power), the steps are as follows:

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

2.1. Discharge Performance Test and Required Results

Discharge the mobile power to termination voltage specified by the manufacturer at $1I_3$current under ambient temperature (20ºC±2ºC), and then charge the mobile power in the mode specified by the manufacturer under ambient temperature (20ºC±2ºC). After 10 cycles, put it in a place for 8 hours at 10ºC, 20ºC and30ºC, respectively, and then conduct discharge performance test of the mobile power at $1I_3$ current, the required test results are as shown in table 1.

Table 1 Discharge Performance Test and Required Results

Ambient Temperature	Discharge Capacity(Ah)/Initial Discharge Capacity(Ah)	Discharge Energy (Wh)/Initial Discharge Energy(Wh)	Subentry value	Weight coefficient	Score
-10℃	>90%	>80%	3 points	0.5	S1
	80%≤ratio≤90%	70%≤ratio≤80%	2 points		
	70%≤ratio<80%	60%≤ratio<70%	1 point		
	<70%	<60%	0 point		
-20℃	>80%	>70%	3 points	0.3	
	70%≤ratio≤80%	60%≤ratio≤70%	2 points		
	60%≤ratio<70%	50%≤ratio<60%	1 point		
	<60%	<50%	0 point		
-30℃	>70%	>60%	3 points	0.2	
	60%≤ratio≤70%	50%≤ratio≤60%	2 points		
	50%≤ratio<60%	40%≤ratio<50%	1 point		
	<50%	<40%	0 point		

2.2. Charge Performance Test and Required Results

Charge the mobile power under ambient temperature (20ºC±2ºC), and discharge to termination voltage specified by the manufacturer at $1I_3$ current, and then charge the mobile power in the mode specified by the manufacturer under ambient temperature (20ºC±2ºC). After 10 cycles, place it in a place for 8 hours at 10ºC,20ºC and30ºC, respectively, and then conduct charge performance test of the mobile powerat$1I_3$ current, the required test results are as shown in table 2.

Table 2 Charge Performance Test and Required Results

Ambient Temperature	Charge Capacity(Ah)/Initial Charge Capacity(Ah)	Charge Energy (Wh)/Initial Charge Energy(Wh)	Subentry value	Weight coefficient	Score
-10℃	>90%	>80%	3 points	0.5	S2
	80%≤ratio≤90%	70%≤ratio≤80%	2 points		
	70%≤ratio<80%	60%≤ratio<70%	1 point		
	<70%	<60%	0 point		
-20℃	>85%	>75%	3 points	0.3	
	75%≤ratio≤85%	65%≤ratio≤75%	2 points		
	65%≤ratio<75%	55%≤ratio<65%	1 point		
	<65%	<55%	0 point		
-30℃	80%	>70%	3 points	0.2	
	70%≤ratio≤80%	60%≤ratio≤70%	2 points		
	60%≤ratio<70%	50%≤ratio<60%	1 point		
	<60%	<50%	0 point		

2.3. 3) Determination of Low Temperature Performance Rating and Proposal of Operating Temperature

According to table 1 and table 2, obtain the comprehensive score S of the mobile power, and S=S1+S2, the comprehensive score and low temperature performance rating is set as shown in Table 3.

Table 3 Comprehensive Score and Low Temperature Performance Rating

Comprehensive Score S	Low Temperature Performance Rating	Proposal of Operating Temperature
9<S≤12	A level	not lower than -20°C
6<S≤9	B level	not lower than -15°C
3<S≤6	C level	not lower than -10°C
0<S≤3	D level	not lower than -5°C

3. Experimental Procedure

Test sample. Li-ion cell: rated voltage 3.7 V, rated capacity 5200 mAh. Dimensions: 96 mm×45 mm×23.9 mm, weight 126g, Input power: 5V DC, output voltage: 5V DC, input current 1000mA, output current 1000mA.

Test Instrument. Test Instrument: Integrated battery tester, MACCOR battery performance test systems, thermostat box, model ZPS-16 and Multimeter (UT33B).

4. Results and discussion

Conduct 10 charge-discharge cycles of 3 mobile powersunder room temperature (20ºC±2ºC) condition by using constant-current and constant-voltage charge system and constant-current discharge system, i.e. discharge the mobile powers to be tested at 1800 mA under the test temperature condition until the last blue LED light of the mobile power went off or starts flashing, put them in a place for 1 h, and then conduct constant current charge at 1800 mA until the mobile power voltage reaches 3.7V,conduct constant voltage chargeand stop charging as the charging current drops to 180 mA, so repeat 10 charge-discharge cycles, and put the mobile powersin the places at 10ºC (one piece), 20ºC (one piece), 30ºC (one piece), respectively for 8 hours, respectively, conduct discharge performance test of the mobile power at a current of 1800 mA, the test results are as shown in Table 4. Conduct charge performance test of the mobile power at a current of 1800 mA, the test results are as shown in Table 5.

Table 4 the test results

Ambient Temperature	Charge Capacity(Ah)/Initial Charge Capacity(Ah)	Charge Energy (Wh)/Initial Charge Energy(Wh)
-10℃	92.1%	75.6%
-20℃	82.3%	71.6%
-30℃	69.5	57.2

According to Table 1 and Table 4,

S1=3×0.5+2×0.5+3×0.3+3×0.3+2×0.2+2×0.2=5.1

Table 5 the test results

Ambient Temperature	Charge Capacity(Ah)/Initial Charge Capacity(Ah)	Charge Energy (Wh)/Initial Charge Energy(Wh)
-10℃	89.4%	74.7%
-20℃	78.3%	64.6%
-30℃	60.5	56.8

According to Table 2 and Table 5,

S2=2×0.5+2×0.5+2×0.3+1×0.3+1×0.2+1×0.2=3.3

Finally, Comprehensive Score S is:

S=S1+S2=5.1+3.3=8.4

According to table 3, the low temperature performance of the mobile powers is level A, the recommended operating temperature is not less than -20ºC.

5. Summary

Based on the foregoing test results, analysis and discussions, the conclusion can be obtained as follows:

1) The evaluation method for low temperature performance of lithium battery mobile power is proposed for the first time.

2) This method uses the commonly used test device with simpleoperating procedures and clear results.

3) This method is easy to popularize.

6. Acknowledgment

The authors would like to acknowledge the financial support provided for this research work by Fund: National key R & D program of China (2017YFF0210703), National key R & D program of China (2017YFF0210002), and Fundamental scientific research projects of Chinese Academy of Inspection and Quarantine (2017JK024).

References

[1] SU Xiao-hui, GAO Jun, YANG Yong. Low temperature electrolytes for Li-MnO_2 batteries. Power Supply Technology, 2009.3 Vol.33 No.3: 221-223.

[2] ZHAO Hui, DUAN Yan-li, GE Gui-lan, CHEN Yi-kui. Study on performance of low temperature type lithium ion battery. Power Supply Technology, 2009.1 Vol.33 No.1: 44-46.

[3] QCT 743-2006 Lithium-ion Batteries for electric vehicles. National Development and Reform Commission, 2006.

[4] IEC 62133: 2002, Secondary cells and batteries containing alkaline or other non-acid electrolytes-Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications. 2002.

[5] IEC 62660-2-2010, Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing. 2010.

[6] UL 2580-2011, Standards for batteries of use in EV. 2011.

[7] Lei Zhiguo，Zhang Chengning，Li Junqiu, et al. A Study on the Low-temperature Performance of Lithium-ion Battery for Electric Vehicles. Automotive Engineering, 2013(Vol．35) No．10: 927-933.

[8] WANG Hong-wei, DU Chun-yu, WANG Chang-bo. Study of low temperature performance of Li-ion battery. Battery bimonthly, Vol. 39, No.4, Aug., 2009: 208-210.