Research on Safety of Li-ion Batteries in Crushing Test

Hong-wei Wang, Yan-ling Fu, Yi CAI, Ziqiang Tao and Hai-qing Xiao

ABSTRACT

The crushing tests are generally performed at room temperature based on actual standards, but in fact, the power battery works in a variety of different environment temperatures. Therefore, the crushing tests of the power battery were researched at different environment temperatures (-30°C, 20°C, 40°C and 65°C). The results showed that the crush can induce the internal short circuit, thermal runaway, and even fire and explosion. The other result is that the higher the environment temperature is, the worse the battery thermal stability is. That is to say, the battery is prone to induce thermal runaway when the temperature is high.

INTRODUCTION

Li-ion battery has the advantages of high operating voltage, no memory effect, low self-discharge rate, long using life and operating range, etc [1-2], and the Li-ion battery has been widely used in electric vehicles (EV) and hybrid electric vehicles (HEV) recently.

As EV and HEV battery, it is usually used in a variety of different ambient temperatures, but based on the standards QC/T 743-2006 Lithium-ion Batteries for electric vehicles and 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, and so on [3-4], the crushing test only carry out at room temperature, Therefore, the crushing tests of Li-ion battery were researched at different ambient temperatures (-30°C, 20°C, 40°C and 65°C) to obtain the temperature influence to the thermal stability in the crushing tests.

EXPERIMENTAL PROCEDURE

Test sample. The parameters of power Li-ion batteries in this paper as follows: 1) The model: domestic battery, rated voltage 3.7V, rated capacity 11Ah; 2)
Dimensions: $133\text{mm} \times 66\text{mm} \times 18\text{mm}$; 3) The composing of the battery: the cathode material is LiMn$_2$O$_4$, the anode material is graphite, the electrolyte is LiPF$_6$, EC and DMC, and battery separator is celgard 2325 [5].

**Test Instrument.** Crushing test chamber, model H-FJ-500, thermostat chamber, model SPHH-101, integrated battery tester, model Xin Wei TC53 High-precision battery performance test systems, and data recorder, model WT 210 DIGITAL POWER METER, the test photo is shown in Figure.1~Figure3. The temperatures are collected with thermocouples which was stick in the middle of battery.

![Figure 1. The test photo.](image)

![Figure 2. The charge curve under different temperature.](image)

![Figure 3. The discharge curve under different temperature.](image)
Test Method. The method of crushing tests in this paper as follows: 1) The SOC100% battery was put in the thermostat box which temperature is set -30°C, 20°C, 40°C and 65°C, and was laid aside for 180min. 2) Each battery which removed from thermostat chamber, was immediately transferred and crushed between two flat surfaces in an ambient temperature. The force for the crushing is 13kN±1kN. Once the maximum force has been applied, or an abrupt voltage drop of one-third of the original voltage has been obtained, or 10% of deformation has occurred compared to the initial dimension, the force is released (whichever condition occurs first should be the indication that the force should be released)[3-4, 6-7].

RESULTS AND DISCUSSION

The results of power Li-ion batteries under different environment temperatures in crushing test is shown in Table 1.

| Temperature | The results of test |
|-------------|---------------------|
|             | Sample  | Fire / Explosion                  |
| 20°C± 2°C   | CT201   | Short circuited. (Figure.4(a))    |
| 20°C± 2°C   | CT202   | No                               |
| -30°C± 2°C  | CT-301  | No                               |
| -30°C± 2°C  | CT-302  | No                               |
| 40°C± 2°C   | CT401   | No                               |
| 40°C± 2°C   | CT402   | Fired and a lot of smoke. (Figure.4(b)) |
| 65°C± 2°C   | CT652   | Short circuited and fired. (Figure.4(c)) |
| 65°C± 2°C   | CT653   | Fired and released great flame [8]. (Figure.4(d)) |

(a) (b)

(b) (d)

Figure 4. the photo of tests.

Table 1. The results of test.
The temperature curve of sample CT202 which no fire or explosion in the crushing test is shown in Figure.5, and the temperature curve of sample CT653 which fired and released great flame in the crushing test is shown in Figure.6.

**Figure 5.** The temperature curve of sample CT202 (No fire or explosion).

**Figure 6.** The temperature curve of sample CT653 (Fired and flame was very great).

The temperature curve of sample CT-301, CT201, CT401 and CT653CT202 under different temperature (-30°C, 20°C, 40°Cand 65°C) is shown in Figure.7.
Crushing test is simulated the battery thermal runaway which was caused of battery short circuit. In the crushing test, the severe crushing of a battery shall not cause fire or explosion.

According to Table 1 and Figure 4 to Figure 7, it can be see that all the samples of crushing tests under -30℃ temperature didn’t fire, explosion and leakage, one sample of crushing tests under 20℃ and 40℃ temperature fired, all the samples of crushing tests under 65℃ temperature fired and released great flame. This show that the higher the environment temperature is, the worse the battery thermal stability is.

SUMMARY

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

(1) The crushing can induce the internal short circuit, thermal runaway and even fire and explosion.

(2) The higher the environment temperature is, the worse the battery thermal stability is. That is to say, the battery is prone to induce thermal runaway when the temperature is high.
ACKNOWLEDGMENT

The authors would like to acknowledge the financial support provided for this research work by Fund: Fundamental scientific research projects of Chinese Academy of Inspection and Quarantine (CAIQ) (No. 2015JK011).

REFERENCES

[1] Hu Xin-guo. Power battery technology and application. Chemical Industry Press (2009)(In Chinese).
[2] Lin Cheng-tao, Li Teng, Tian Guan-yun. The life test of Li-ion power battery for electric vehicle. Battery Bimonthly, 40(2010), P23.
[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] Wang Hong-wei, Liu Jun and Deng Shuang, et al. Failure analysis of LiMn2O4 power battery, Power supply technology, 2012.9. Vol. 36: 1276-1278.
[6] IEC 62660-2-2010, Secondary lithium-ion cells for the propulsion of electric road vehicles - Part 2: Reliability and abuse testing. 2010.
[7] UL 2580-2011, Standards for batteries of use in EV. 2011.
[8] Wang Hong-wei, Liu Jun and Xiao Hai-qing, et al. Investigation of Impact Test of Power Battery under Different Environment Temperatures, Applied Mechanics and Materials vols. 229-231(2012): 1064-1067.