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Robustness of 50 Ah-Class Lithium-ion Cell for Electric Vehicles

Atsushi Funabiki[1], Hiroshi Tasai[2], Shinya Kitano[1], Koichi Nishiyama[1]
[1]Corporate R&D Center, GS Yuasa Corporation
1, Inobanba-cho, Nishinosho, Kisshoin, Minami-ku, Kyoto 601-8520, Japan
E-mail: atsushi.funabiki@jp.gs-yuasa.com

[2] Battery Development Group, Engineering Department, Lithium Energy Japan
8-10-5, Kasayama, Kusatsu, Shiga 525-0072, Japan

Abstract

A variety of tests such as shock, immersion, crush, vibration, impact, thermal test, and altitude simulation of 50 Ah-class lithium-ion cell "LEV50" have been performed based on the FreedomCAR test manual and the recommendations of the United Nations to simulate actual use and abuse conditions. There observed no rupture and no fire, indicating that this cell is highly robust. This feature should be attributed to the structure of the cell designed to tolerate abused conditions; metal case, current collectors firmly fixed with electrode assemblies, and tight sealing. The robustness of LEV50 cell provides its high reliability on the safety issues as well as cycle life for EV applications.

Keywords: Lithium-ion cell, Robustness, Abuse test

1 Introduction

In the last EVS conference [1], the superior performances of 50 Ah-class large-sized lithium ion cell "LEV50" and its module are presented for energy storage device of electric vehicles (Fig. 1). This cell can provide high energy density, high power, long calendar life, and so on. In addition to these electrical features, the robustness of a cell is also required for EV applications because it strongly affects reliability on the safety issues as well as cycle life of the cell. In this paper, a variety of tests based on the FreedomCAR test Manual [2] and the recommendations of the United Nations [3] have been performed to examine the robustness of our developed cell focusing on its mechanical characteristics.

2 Structure of LEV50 cell

Fig. 2 shows an inner structure of the developed cell. This cell has various outstanding features; prismatic case made of stainless steel, two electrode assemblies, current collectors firmly fixed with the assemblies in the short distance from terminals, and tight sealing between the cover plate and the case and between current collectors and

(a)

(b)

Fig. 1 Appearances of (a)LEV50 cell and (b)its module.

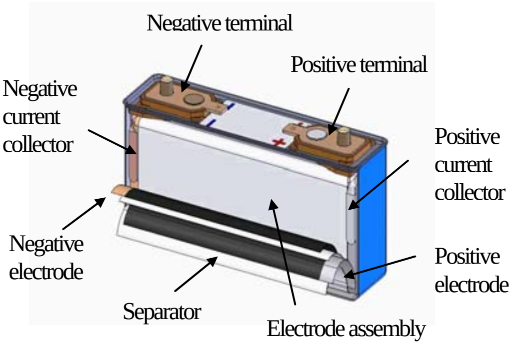

Fig. 2 Structure of LEV50 cell.

terminals. The prismatic shape provides space-efficient cell layout resulting in higher energy density of the cell module. The multiple electrode assemblies have an advantage than a single one in terms of smaller dead space in a cell, which gives higher energy density of the cell. The current collectors fixed with the assemblies in the short distance from terminals offer remarkably low internal resistance and thus high power. A cover plate and a case are welded together and the electrode current collectors and terminals are connected tightly enough to protect the cell from air and water permeation. From these unique structures, our cell is expected to show high tolerance against abused conditions.

3 Evaluation of the Robustness of LEV50 cell

The FreedomCAR test manual covers a variety of tests which simulate abused conditions under driving; mechanical, thermal, and electrical ones for cells, module, and pack are included. The recommendations of the United Nations, on the other hand, require the fundamental characteristics during transport for cells and module as altitude simulation, thermal test, vibration, shock, external short circuit, impact, overcharge, and forced discharge. Among those tests, the mechanical ones such as shock, immersion, crush, vibration, impact, thermal test, and altitude simulation have been performed to obtain direct information on the robustness of LEV50 cell.

3.1 Procedure for the abuse tests

3.1.1 Shock

The test is first conducted based on FreedomCAR test manual; a half-sine wave of peak acceleration of 25 G and pulse duration of 30 ms is given on the cell. Fig. 3 shows an image of the cell set on the machine before testing, and the acceleration curve applied to LEV50 cell is presented in Fig. 4.

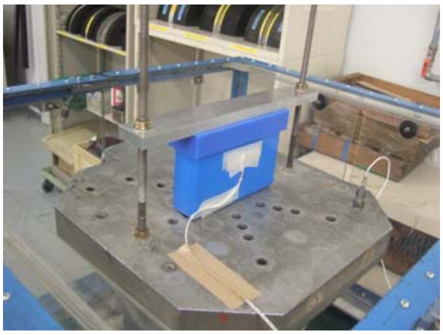

Fig. 3 Image of LEV50 cell set on the shock test machine before measurement.

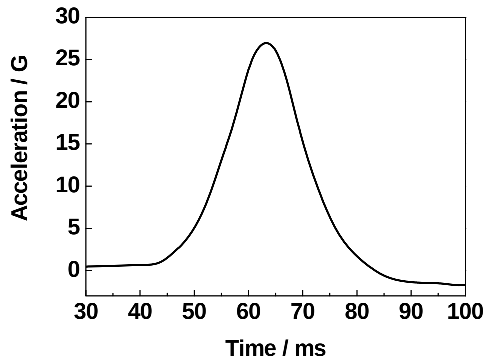

Fig. 4 Acceleration curve applied to LEV50 cell.

Next, the test based on the recommendations of United Nations is carried out; the cells are mounted on the testing machine, followed by a half-sine shock of peak acceleration of 150 G and pulse duration of 6 ms.

3.1.2 Immersion

This test is performed based on the FreedomCAR test manual. The cells are immersed in salt water for 6 hours.

3.1.3 Controlled crush

This test is carried out based on the FreedomCAR test manual. The modules are used for this test. They are compressed for x, y, and z axes between flat and textured plates. The textured plate has semicircular projections with a 75-mm radius that have been placed 30 mm apart across the face of the plate. Both plates are made of insulating material. The modules are pressed for 5 minutes with 7500 kgf which is 1000 times the module's mass.

3.1.4 Vibration

This test is undertaken based on the recommendations of the United Nations. The cells are firmly fixed on the vibration machine. A sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz is repeated 12 times for x, y, and z axes.

3.1.5 Impact

This test is done based on the recommendations of the United Nations. The cells are mounted on a flat surface with a 15.8 mm diameter bar placed across the center of the cell. Then, a 9.1 kg mass is dropped from a hight of 61.5 cm onto the cell.

3.1.6 Thermal test

This test simulates cell seal integrity and internal electrical connections, and is performed based on the recommendations of the United Nations. The cells are stored for 6 hours at 75°C, followed by storage for 6 hours at –40°C. The interval between these sequences is 30 min. This procedure is repeated 10 times, after which the cells are stored for 24 hours at 20°C.

3.1.7 Altitude simulation

This test simulates air transport under low-pressure conditions, and is conducted based on the recommendations of the United Nations. The cells are stored at a pressure of 11 kPa for 6 hours at ambient temperature of 20°C.

3.2 Results and Discussion

For the tests of shock, vibration, impact, thermal test, and altitude simulation, there observed little mass reduction, no electrolyte leakage, no rupture, no fire. Further, the cell voltage and the temperature of the surface of the cells were unchanged during the tests. These results suggest that the contact between current collectors and the electrode assemblies are strong enough to tolerate the hard shock and vibration, and that the portions between the cover plate and the case and between current collectors and terminals are tightly sealed. The little mass change in the thermal test and altitude simulation indicates that the cell is highly airtight, which is also due to the superior sealing technology. The stainless steel case contributes to the robustness against the impact.

Fig. 5 shows the image of the cell just after immersed in the salt water. During the test, electrolysis of water occurs, and hydrogen gas

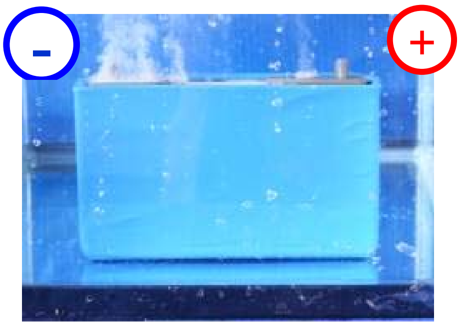

Fig. 5 Image of the cell just after immersed in the salt water.

was generated at the negative terminal. At the positive terminal, on the other hand, aluminum which is a constituent element of the terminal was dissolved.

Fig. 6 compares the images of the cells before and after the test. Corrosion was observed on the positive terminal, but no electrolyte leakage, no rupture, and no fire were seen. These results indicate that the cell is enough durability against corrosion by sea water.

(a)

(b)

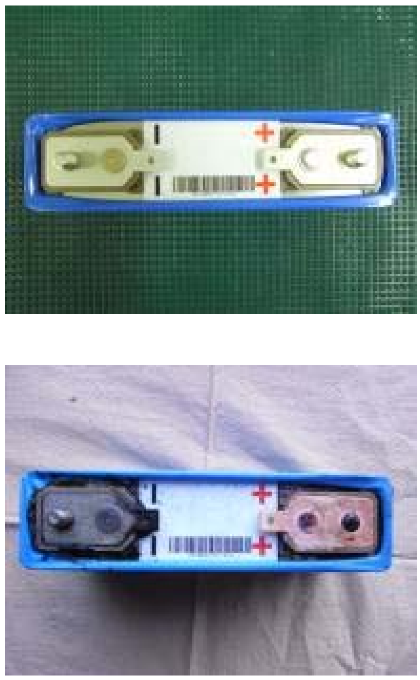

Fig. 6 Images of the cells (a)before and (b)after the immersion test.

(a)

(b)

(c)

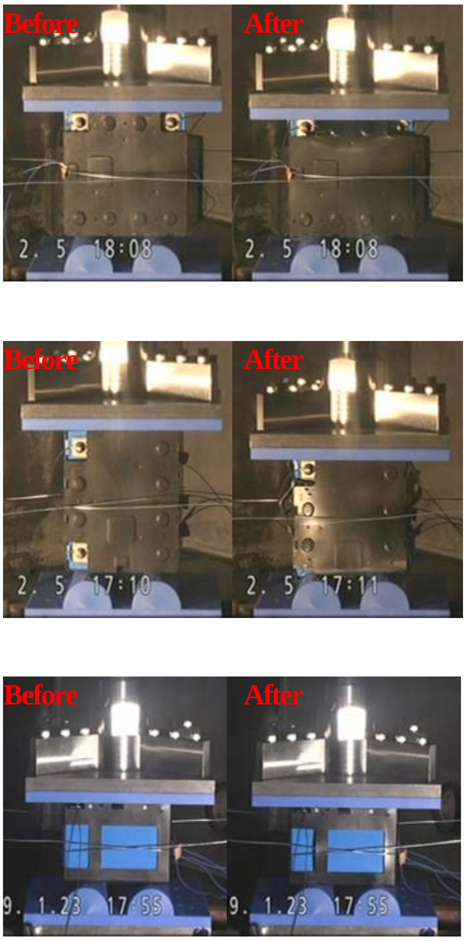

Fig. 7 Images of modules before and after the controlled crush test for (a)x, (b)y, and (c)z axes.

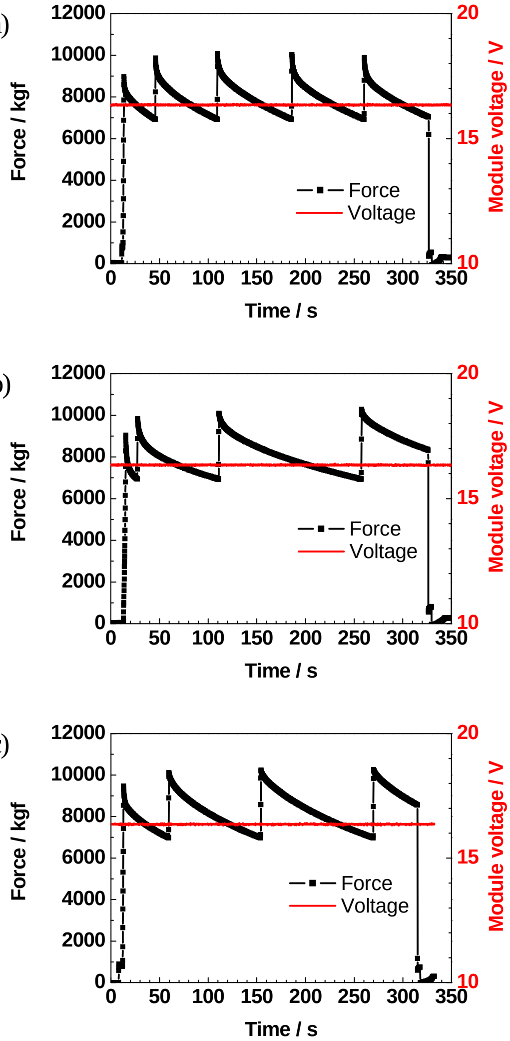

Fig. 8 Variations of press force with time for (a)x, (b)y, and (c)z axes.

Fig. 7 presents the images of modules before and after crush tests for x, y, and z axes. The corresponding graphs for the variations of press force with time are represented in Fig. 8. Even at the force of 10 ton, there observed no voltage decrease as well as no rupture and no fire for each case of the crush, indicating that short circuit in a cell was inhibited. The metal case and the current collectors tightly fixed with both the electrode assemblies and terminals should contribute to this high robustness.

As can be seen in Fig. 7, the deformation ratio of the module for y axis is much larger than those for x and z axes. This phenomenon is caused by the reduction of a space between cells and by a large deformation of the cell attached to the textured plate for the y axis.

4 Conclusion

A variety of tests based on the FreedomCAR test manual and the recommendations of the United Nations have been performed to evaluate the mechanical characteristics of LEV50 cell. These tests confirmed that this cell is highly robust. This feature should be attributed to the structure of the cell designed to tolerate abused conditions. The robustness of LEV50 cell provides its high reliability on the safety issues as well as cycle life for EV applications.

References

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Authors

Atsushi Funabiki
Corporate R&D Center
GS Yuasa Corporation

Hiroshi Tasai
Battery Development Group
Engineering Department
Lithium Energy Japan

Shinya Kitano
Corporate R&D Center
GS Yuasa Corporation

Koichi Nishiyama
Corporate R&D Center
GS Yuasa Corporation