Development of Evaluation Test Methods for High Power Lithium Ion Batteries for Application to Fuel Cell Electric Vehicles

Background

Clean energy vehicles such as fuel cell electric vehicles (FCEVs) are being extensively developed, but establishment of the energy storage technology that can support the output power during high-load such as in acceleration, and can efficiently use regenerative energy at braking is essential to maximize energy consumption to enhance high-efficiency characteristics. From such a background, the development of a high-efficiency, long-life lithium ion battery as an auxiliary power supply device for FCEVs is expected. But evaluation test methods for on-board lithium ion batteries are not yet established. It is necessary to settle evaluation test procedures based on analysis of power characteristics and battery degradation, and develop accelerated calendar life evaluation test method to judge battery life in the short term.

Objectives

We aim to propose evaluation test procedures and to develop the calendar life evaluation test method for high power lithium ion batteries for FCEVs. We will then evaluate the prototype cells and battery modules developed by battery manufacturers with our test procedures.

Principal Results

1. Investigation of evaluation test procedures for lithium ion batteries

To evaluate the prototype cells and battery modules developed by battery manufacturers (Fig.1), we would like to establish a test method for the on-board lithium ion battery with reference to the Japan Electric Vehicle Association Standards (JEVS) for the HEV Ni-MH battery, the Freedom CAR battery test manual and the EUCAR test procedure for the HEV battery. We proposed the test conditions, such as a current of discharge (C/3 rate) in the capacity test, and a continuation time (for 10 seconds) in the power characteristics. Using the proposed test method, three types of battery module with 0.3 kWh-class capacity were tested to determine their properties such as capacity and power characteristics. Results of the evaluation tests of the prototype battery module are shown in Table 1. All the battery modules exhibit a high-power performance, such as a specific power greater than 2000 W/kg at 50 % of the state of charge (SOC).

2. Accelerated calendar life evaluation test of lithium ion batteries

(1) For about 2 years, we carried out an accelerated calendar life evaluation test using small capacity cells and accumulated the data that were necessary for analysis. As a result of having investigated various kinds of analytical methods based on the accumulated data, we made clear that it was effective to apply ‘square root rule’ as a method of analysis when we performed battery life estimation.

(2) We divided the degradation rate of the on-board lithium ion battery by using condition for FCEV. We applied the square root rule to capacity retention and power retention data, and clarified an acceleration coefficient for 25°C (standard condition) of 50°C (acceleration condition) from the ratio of the degree of leaning of a provided approximation straight line.

(3) We used large-capacity cells (from 7 to 18 Ah) and, carried out an accelerated calendar life evaluation test in the temperature-accelerated condition. We analyzed the data that accumulated in square root rule and estimated calendar life by extrapolation after an application by an acceleration coefficient (Fig.2). According to this evaluation technology, it was indicated that high power lithium ion battery life was faded by degradation of power performance rather than discharge capacity.

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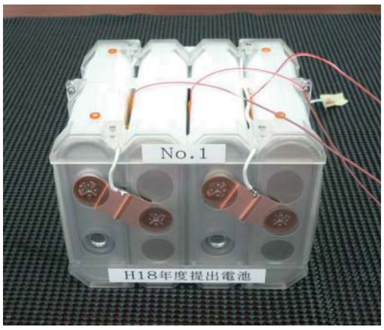
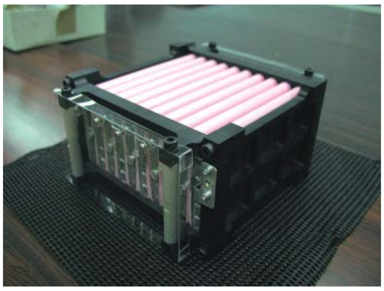
Reference

N. Kihira, et.al., 2006, “Development of Accelerative Life Evaluation Test Method for Lithium Ion Batteries for FCVs. (I),” CRIEPI Report Q05021 (in Japanese)

(a) 240 Wh-class battery module
・Ni-Mn-Co oxide cathode
・6.8 Ah x 10 cells



(b) 260 Wh-class battery module
・Mn oxide cathode
・18.4 Ah x 4 cells



(c) 260 Wh-class battery module
・Ni oxide cathode
・7.2 Ah x 10 cells

Fig.1 Appearances of prototype lithium ion battery module

Table 1 Evaluation test results of prototype lithium ion battery

Item	Goal	Ni-Mn-Co system	Mn system	Ni system	Remarks (# ; our proposition)
Specific Power*1) (W/kg)	1,800	2,200	2,100	2,100	# SOC50% output
Specific Energy*1) (Wh/kg)	70	71.8	74.5	70.7	# C/3 rate*2) discharge capacity
Calendar Life*3) (years)	15	15～40	3～6	12	End of life ; A condition reached when battery under test is no longer capable of meeting 80 % of initial value in capacity or power. # Annual run time for FCEV is 876 hours.
Energy Efficiency*4) (%)	96	91.4	93.2	93.4	# Energy efficiency over the SOC range between 70% and 30% using *JEVS D709* dynamic stress profile

*1) Conversion values as 3 kWh battery pack
*2) C/3 rate ; The rate corresponding to the manufacturer's rated capacity (in Ah) for three-hour constant current discharge.
*3) Results of prototype single cells
*4) 96 - 97 % at C/3 constant current discharge rate

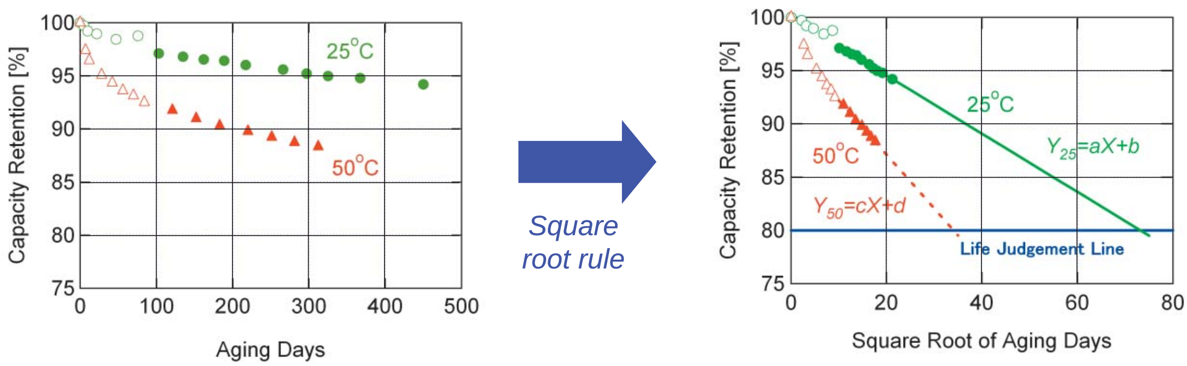


Fig.2 Conceptual graphs of calendar life estimation