Optimization and Application of MH/Ni Power Batteries System

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Abstract

In this paper, optimization of the Ni/MH power batteries used in fuel cell city bus was studied and analyzed. And the charging/discharging performance of these batteries was studied. Using power battery simulated testing system, it totaled 320 power batteries of 100Ah capacity selected. Then battery pack with voltage of 384V was assembled by serial and was tested in simulation by ARBIN equipment. The results showed that the charging/discharging efficiency reached 96 per cent at 1C and the environment temperature is 28 degree centigrade. The experiment indicated that the selected batteries showed excellent high-rate capability, good conformability and reliability.

Keywords

EV, MH/ Ni power battery, optimization, battery-simulated test, fuel cell city bus

1. INTRODUCTION

Hybrid power composing of storage battery and fuel cell is one of best power sources for fuel cell electric vehicle (FCEV) these days. Therefore it will benefit economically to use Ni/MH battery properly for hybrid application.

Ni/MH power batteries for FCEV are different from those for pure electric vehicle (PEV) and hybrid electric vehicle (HEV). Ni/MH batteries take an important role on power assistant for FC engine, which requires that batteries should discharge for over 3 minutes at 3C (300A) rate with special energy of 50Wh/kg and battery modules of 384V should charge/discharge at 1C.

During runtime, any battery invalidation will affect the function of the whole battery module, making it damage. Therefore it is very important for 384V/100Ah system to assemble battery module reasonably, which requires good conformability of the battery cell. That is to say, batteries must be selected and assembled elaborately before running. We have done much work to make our batteries consistent such as capacity, the internal impedance, and voltage plat of charging/discharging, the temperature rising grads, self-discharge rate, cycle life, etc.

As for battery selection, there are methods including the capacity method, internal resistance/capacity method, capacity/- ΔV method, characteristic curve method. In above methods, characteristic curve method is the best one that assures battery conformability of almost all kinds of the performance.

In this paper, the selection is done as follows: (1) Activation is first that batteries are charged/discharged at 1/3C rate. Then batteries are selected by weight analysis. Finally comparing their discharge capacity and the charge/discharge plat, temperature change; (2) After 12V module being assembled, simulated test is operated so as to comparing the high rate discharge performance; (3) When high voltage module of 384V are assembled, simulated test and intensifying experiment are run again, testing battery module conformability during high rate charge/discharge and estimate analysis of related performance.

2. EXPERIMENT

In view of the above request, our experiment is done by using the LBC-80 battery examination analysis system, the power battery simulation test system for the electric car, and Arbin battery testing equipment.

2.1 Optimization of battery cell

(a) Optimization by static shelf voltage of battery
The analysis of warp was done, taking conformability of static voltage into account.

(b) Optimization by conformability of capacity and charging/discharging plat

The batteries were formed by multi-stage current method and then classified by their capacity. Because the valid capacity of the battery is related to discharging current, that is to say, battery current is higher, and then the valid capacity is smaller. Under the same regime of charging and discharging, the selected batteries should meet the demand that the charge/discharge efficiency of the single battery is higher 95%, and their voltage plat and the temperature rising grads of charging/discharging is also considered.

(c) Optimization by the shelf voltage at different SOC
The 12V module is assembled by uniform battery, including uniformity of the shelf voltage at different SOC.

2.2 Batteries simulations selection

According to travel characteristic of the fuel cell city bus, the simulated operation is established. The simulation tests of the 12V module are carried in order to examine the performance uniformity of its high-rated charge and discharge.

2.3 The strengthening experiment of battery pack

The strengthened experiments of the 384V system are carried, including simulation operating mode test in lab experiment, to examine the uniformity of various modules at high-rated charge/ discharge and analysis the other related performance.

3. RESULTS AND DISCUSSION

3.1 Single battery optimization

(a) The optimization of the static shelf voltage uniformity
The uniformity of static shelf voltage is a important factor of optimization (Figure 1). The static shelf voltage of many single batteries are 1.13-1.195V. Reason for the OCV difference is that the self-discharge rate of batteries is inconsistent which relate to the positive and negative electrodes material, the electrolyte, the separator, etc.

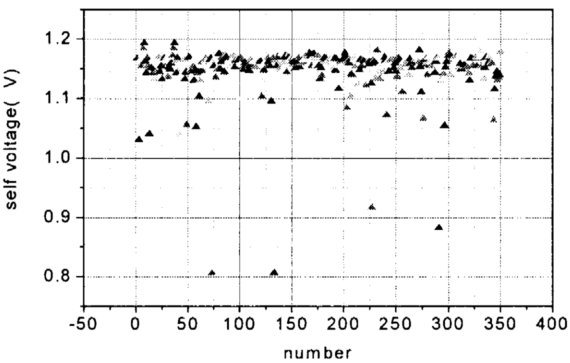
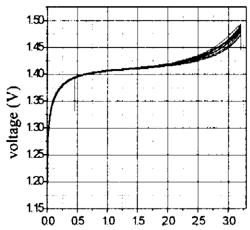
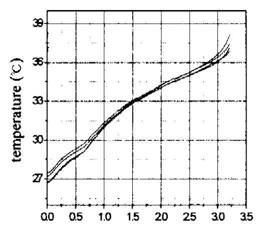


Fig. 1 Scatter plot for voltage during rest time

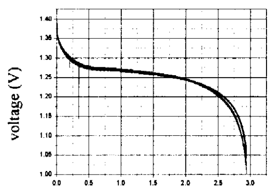
(b) Optimization by conformability of capacity and charging/discharging plat
By the regime of the 1/3C charging /discharging, the characteristic curves of the single activated battery were analyzed including their charging / discharging platform and temperature grades, then the single batteries meeting our demands are selected.
The single battery, with the same performance as Figure 2, could be assembled into a module. Many single batteries were primarily selected by this method. The voltage of batteries with lower static shelf voltage is higher when they are charged and lower when they discharged. It indicates that the batteries with lower static voltage have bigger internal impedance. The battery, which has higher temperature grade and lower efficiency when charged/ discharged, will be ruled out.



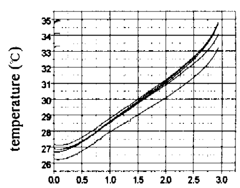
(a) Voltage-time curve during charging



(b) Temperature-time curve during charging



(c) Voltage-time curve during discharging



(d) Temperature-time curve during discharging

Fig. 2 Performance of single batteries during charging/ discharging

(c) Optimization by conformability of self-voltage with different SOC
Table 1 shows the open circuit voltage at different SOC. From the Table 1, it can be seen that the uniformity of the module is the best between 0.2-0.8 SOC, so we can deduce that the best working range of the battery should be within 0.2-0.8 SOC. The 12V module is up to the mustard .

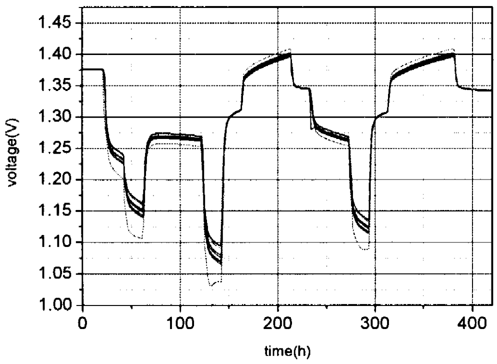
Table 1 Voltage coherency of MH/Ni batteries under different SOC (V)

Number / SOC	1	2	3	4	5	6	7	8	9	10	Cell deviation
0	1.201	1.201	1.202	1.204	1.202	1.202	1.201	1.204	1.206	1.205	<0.005
0.3	1.370	1.370	1.370	1.371	1.371	1.370	1.369	1.370	1.370	1.369	<0.002
0.75	1.382	1.381	1.381	1.380	1.381	1.381	1.379	1.381	1.381	1.381	<0.001
1	1.417	4.414	1.412	1.409	1.402	1.411	1.408	1.412	1.413	1.417	<0.009

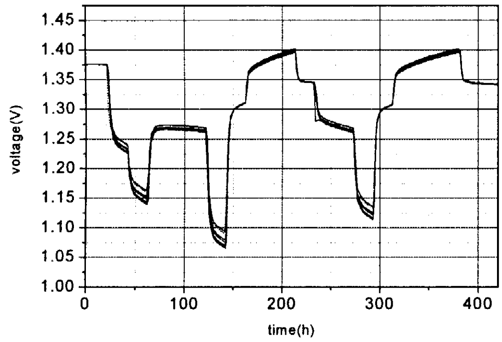
3.2 Selection of 12V battery module

The 12V modules selected was tested on the power battery stimulant test analysis system for electric vehicle. According to the performance requirement of battery module for electric vehicle, we established a series of programs including the starting, the climbing, the acceleration, the braking and so on under various stimulant-operating conditions. The largest discharging current of the simulation experiments reaches 300A. Experimental results show as Figure 3(a).

By the above test, some batteries were break up, and then replaced with other acceptable batteries. After the selection, the battery module curve show as Figure 3(b). Using above method, we can make sure the quality request of the 12V battery module. Figure 4 shows the measurement results of the 12V battery pack at the high-rate discharge, which indicates that its performance has surpassed the request.



(a) Voltage curve before selection



(b) Voltage curve after selection

Fig. 3 Simulated curves for 12V module

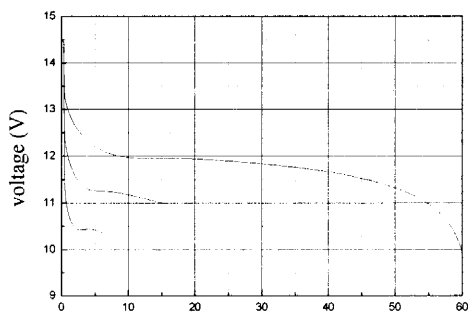


Fig. 4 High-rate discharge curve of 12V/100Ah battery module

3.3 384V high voltage stimulant operating conditions tests

The 384V system at the 0.5SOC, which consists of the 12V battery pack module series, was tested in the lab. Figure 5 gives the voltage-time curve that shows the superposition of voltage curves is good, which indicates battery pack selection method is reasonable.

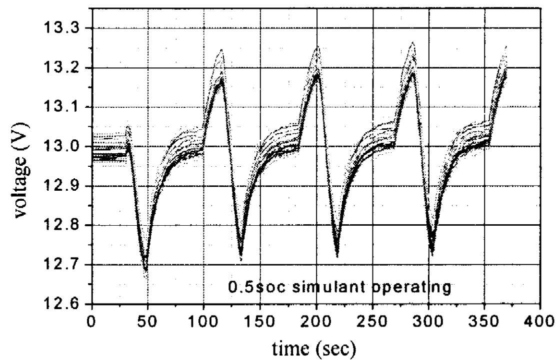


Fig. 5 Simulated curves of 384V/100Ah battery pack (SOC=0.5)

3.4 384V/100Ah battery pack tests and predictions

According to the demands of fuel cell bus, we had done the 384V/100Ah battery pack performance test on the ARBIN battery test system. The test result in Figure 6 shows that the 1C charge discharging efficiency reaches 96%. This battery pack has the outstanding high-rate performance, the good performance uniformity and the reliability. In order to fit the fuel cell city bus application, we have done the calculation of the battery pulse power capacity, so we know the working ability of the battery pack at different DOD. If the electric automobile biggest demanded power and the biggest back coupling electric current of the electromotor in regeneration brake were known, we may obtain the feasible working region of the battery. Then we can know the range of DOD where the battery pack can be fit for the electric-vehicle driving and regeneration brake. The discharge pulse power capacity of the battery pack can be described as discharge power ability of the battery pack at specific DOD, and the group charging pulse power capacity can be described as charging power ability which the battery pack can accept at specific DOD. Figure 5 shows the DOD- pulse power capacity curve of 384V/100Ah system. The curve shows that this battery system performance meets the operation requirements of the fuel cell city bus by far.

4. CONCLUSIONS

In this article, the optimization method of the battery has considered many factors including the battery capacity, the internal impedance, charge/discharge voltage platform, the charge/discharge temperature rising grads, self-discharge rate and so on, and the battery performance test shows that this method is successful.

This method is an effective way to improve its high-rated charge/discharge performance, and the specific energy of the 12V battery module by optimization is higher than 55Wh/kg. On the lab test, the 1C charge/discharging efficiency of the 384V battery system reaches above 96%. The experiment is done on the Arbin battery test system under the room temperature, and the temperature of battery does not surpass 28℃ during the charging and discharge. The results show that the optimized batteries have the good uniformity and reliability.

According to 384V/100Ah the pulse power capacity test at different DOD, this battery system suits for the fuel cell city bus well.

References

Fellner C, and J. Newman, High-power batteries for use in hybrid vehicles, *J Power Sources*, 85, 229-236, 2000.

Gifford, P., J. Adams, and D. Corrigan, Development of advanced nickel/metal hydride batteries for electric and hybrid vehicles, *J Power Sources*, 80, 157-163, 1999.

Yang, Y., Measurement of the maximum charge and discharge powers of a nickel/metal hydride battery for hybrid electric vehicles, *J Power Sources*, 75 19-27, 1998.

Zhan, F., L. J. Jiang, and B. R. Wu, Characteristics of Ni/MH power batteries and its application to electric vehicles, *J Alloys Comp*, 1999, 293-293, 804-808.

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