EVS24
Stavanger, Norway, May 13-16, 2009

Application of large capacity Ni-MH battery packs in the public transportation demonstration project of Beijing 2008 Olympic Game

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Abstract

Three fuel cell hybrid city buses developed by Tsinghua University China provided services for athletes and common passengers during Beijing 2008 Olympic Games. Now the buses are travelling in a fixed Beijing public bus line, which will last for at least one-year. Road test data of the large capacity Ni-MH battery packs installed on the buses in some typical dates were analyzed. The energy efficiency and inconsistency characteristic of these battery packs were also discussed. The paper also gave out the opinions on the application prospects of large capacity Ni-MH battery in city public transportation system.

Keywords: HEV (hybrid electric vehicle), bus, nickel metal hydride battery, demonstration

1 Introduction

There is an about 20 years long history on the research of electric vehicles including pure battery vehicle, hybrid electric vehicle and fuel cell vehicles in Tsinghua University, which makes Tsinghua University one of the most important electric vehicle research and development base in China. Supported by the National High-tech R&D Program of the ministry of science and technology of China (MOST), Tsinghua University started the research on fuel cell hybrid city bus from 2001. Now Tsinghua University has the ability of developing an integral fuel cell city bus, grasp the key techniques on vehicle development, such as vehicle components development, system integration, vehicle control, vehicle safety test, and durability evaluation.

(a) In front of Bird's Nest Stadium

(b) Beijing 2008 Olympic Marathon

Figure 1. Tsinghua Fuel Cell Hybrid City Buses during 2008 Beijing Olympic Games

In order to realize the three themes of "Green Olympics, Scientific Olympics, Culture Olympics", MOST and Beijing government united some relative organizations together to start the "High-tech Olympic Action Plan" after China got the authorization to hold 2008 Olympic Game in 2001. In this plan, it was an important sub-plan to use energy-saving and new energy vehicle to provide service for Beijing public transportation during Olympic Games. During 2008 Beijing Olympic Games and Paralympic Games, many new energy vehicles run in Beijing , which was the biggest vehicle demonstration project during Olympic history. In this project, there were 3 fuel cell city buses developed by Tsinghua University and Beiqi Foton Motor Co., LTD. These 3 fuel cell city buses have been submitted to Beijing Public Transport Group on July 11, 2008, to start the business demonstration in a fix bus line for a year. Figure 2 shows the bus in the street. In this paper, the 3 fuel cell city buses are named No.1, NO.2 and No.3.

Figure 2. Fuel cell city bus in Beijing street

Table 1 shows the basic technical parameters of these fuel cell city buses.

Table 1. Basic parameters of fuel cell city bus

Length(mm)	10890
Width(mm)	2490
Height(mm)	3360
Wheelbase(mm)	5600
face area (m^2)	7.5
Total Mass(t)	14.2
Number of seats	30
Number of passengers	50

2 Road condition for bus demonstration

Beijing New Energy Vehicle Demonstration Park was set up before July 11, 2007 in Yongfeng high-tech industry base which is located in Beijing Zhongguancun Science Pack. Fuel cell city buses were refuelled hydrogen in Yongfeng base. During 2008 Beijing Olympic, Fuel cell city buses were one of the service vehicles in Beijing 2008 Olympic Marathon.

Figure 3. Map of the fuel cell city buses demonstration area in Beijing

Figure 3 shows the map of bus demonstration area. Buses kept running from Monday to Friday and stopped to maintain in Saturday, Sunday and holiday. In a demonstration day, buses departed from Yongfeng Base at 8:00 AM, arrived at North Gate of Summer Palace at about 8:30 AM. Then buses travelled between North Gate of Summer

Palace and RENMIN University as a circle for 4 times. After the circular travel, buses will go back to Yongfeng Base form north gate of Summer Palace at about 4:00 PM. One day travel Mileage for a fuel cell city bus was about 110 km. From the start time of demonstration beginning to March 28, 2009, the total travel Mileage of 3 fuel cell city bus is 31145km, travel time adds up to 2294 hours, passengers add up to 21767.

During the passing time of demonstration, fuel cell city buses experienced different weather conditions of summer, autumn and winter. Figure 4 shows the maximum temperature in battery pack of these fuel cell city buses during the passing demonstration time （July, August, September, October）. Figure 5 shows battery pack average temperature variation in a working day.

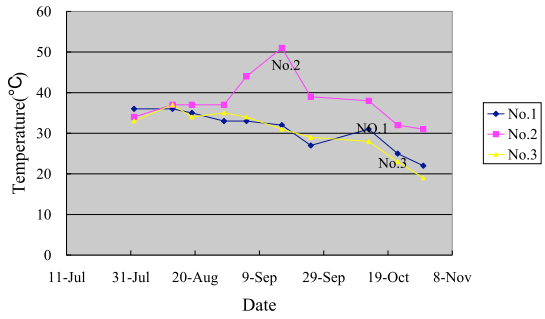


Figure 4. Maximum temperature of the battery pack in different months

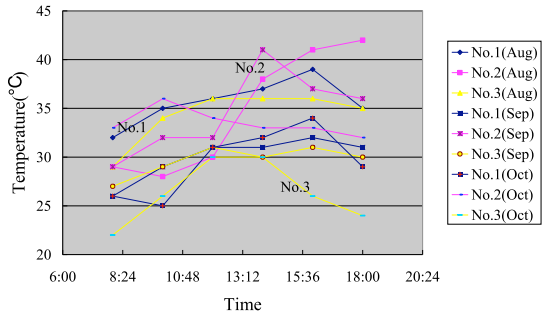


Figure 5. Temperature variation of the battery packs during a working day

3 Technical parameters of Ni-MH battery Pack

Figure 6 shows the powertrain configuration of a fuel cell city bus, the bus driven power is provide by two power sources, battery pack and fuel cell stack. The fuel cell stack rated power is 100 kW. The Ni-MH battery pack is in series by 280 Ni-MH cells developed by Beijing General Research Institute for Nonferrous Metals. Its rated capacity is 80Ah, rated voltage is 336V, storage energy is about 25kW.

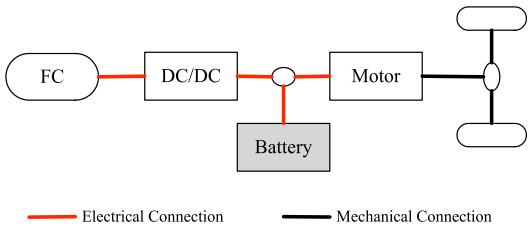


Figure 6. Powertrain configuration of Tsinghua fuel cell hybrid city bus

Figure 7 shows the Ni-MH battery pack connected with a test bench in Tsinghua University electric vehicle laboratory. Figure 8 shows the installation position of the battery pack on fuel cell city bus. Battery packs were laid to the left side and right side under the bus floor. Air outside bus was used as the coolant of the battery packs. Table 2 shows the technical parameters of the Ni-MH battery pack obtained from laboratory test.

Figure 7. Ni-MH battery packs connected with test bench in laboratory

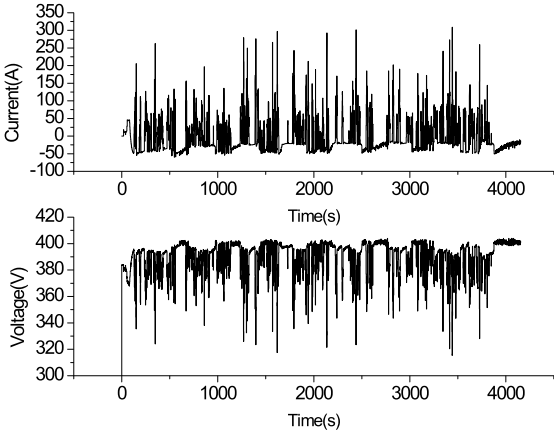
Figure 8. Ni-MH battery packs installed in Tsinghua fuel cell hybrid city bus

Table 2 Technical parameters of the Ni-MH battery Packs

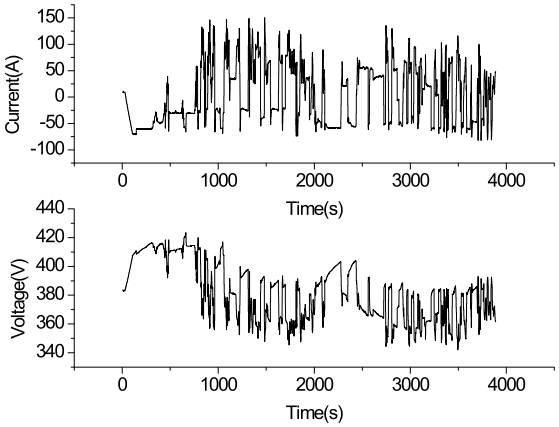
No.	Test item	Result
1	Resistance (10 cell module)	8.6 mΩ
2	Resistance (280cell pack)	233.5 mΩ
3	Capacity (280cell pack)	77.45Ah
4	Cell voltage range (module)	0.0084V
5	Energy density(module)	63.23Wh/kg
6	Energy density(module)	503.85W/kg
7	Capacity (20±5℃) (module)	82.14Ah
8	Capacity (55℃)(module)	77.54Ah
9	Capacity (-20℃)(module)	71.25Ah
10	Self discharge (module, 4 weeks)	83%
11	Safety test	Pass short, crash, nail, fall and thermal impact test

4 Ni-MH battery road test data analysis

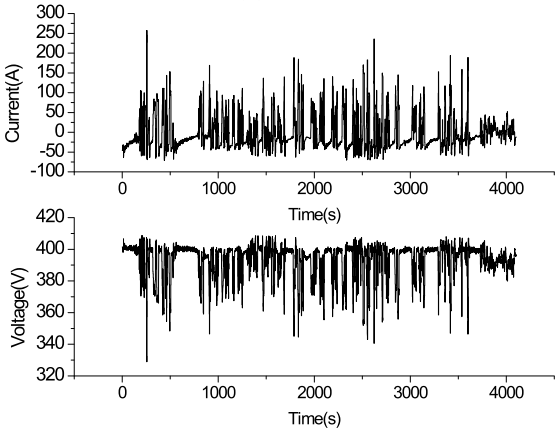
Figure 9 shows the typical current and voltage curves of battery pack on the 3 fuel cell city buses when buses were travelling in Beijing public bus line respectively. Figure 10 shows the SOC variation of the battery packs respectively. In these buses, battery provided energy to drive motor, also received energy from fuel cell stack and motor regeneration. Controlled by the energy management strategy, SOC of the battery pack changed in a narrow window. Protected by DC/ DC converter, fuel cell stack often worked in steady condition, but battery pack often worked in hard and often varying load. These work condition was a challenge to the durability of the battery packs.



(a) Bus No.1



(b) Bus No.2



(c) Bus No.3

Figure 9. Typical current and voltage curves of the battery pack during working

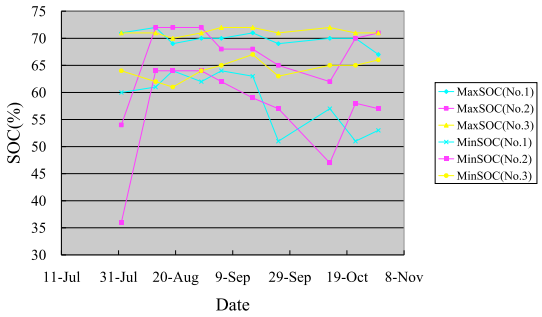
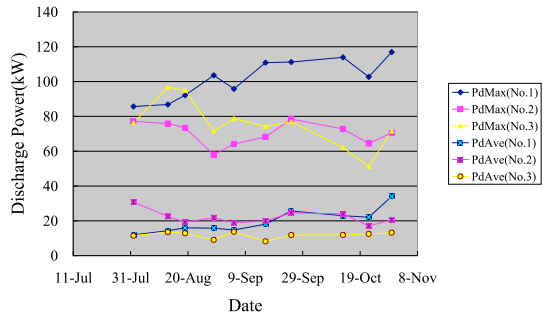


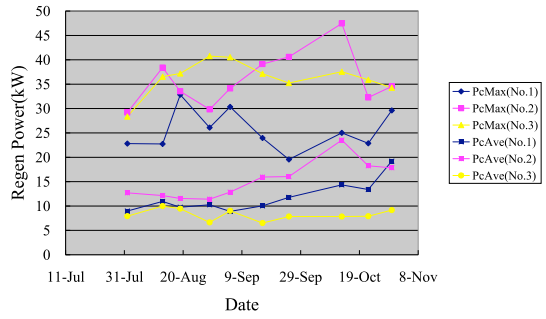
Figure 10. SOC variation of the battery pack during working

Figure 11 shows the statistic of battery pack work power. Figure (a) is the maximum value and average value of battery pack discharge power. Figure (b) is the maximum value and average value of battery pack regeneration power. Because the average speed of fuel cell city bus is lower than 30km/h, the average discharge power is lower than 25kW in most driving condition, and the average regeneration power is lower than 15kW in most driving area. When the buses are started from

parking or accelerating, battery pack power need would be large to 120kW, current need would reach 4C (320A). During some regeneration condition, battery charge current can be 2C (160A).



(a) Battery pack discharge power



(b) Battery pack regen power

Figure 11. Power Typical current and voltage curve of the battery pack during working

Figure 12 and Figure 13 are the analysis of the battery performance variation caused by long time application. Figure 12 shows the energy efficiency of battery pack variation in 4 months' driving. Figure 13 shows the module voltage range change during the early 4 months demonstration.

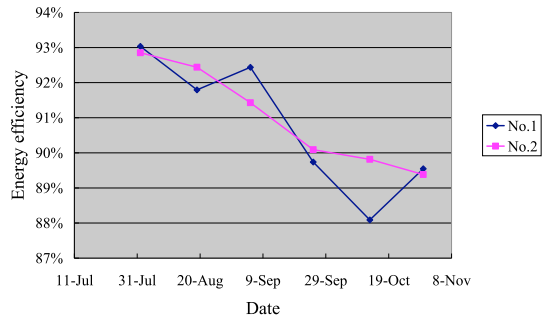


Figure 12. Variation of energy efficiency of the battery packs

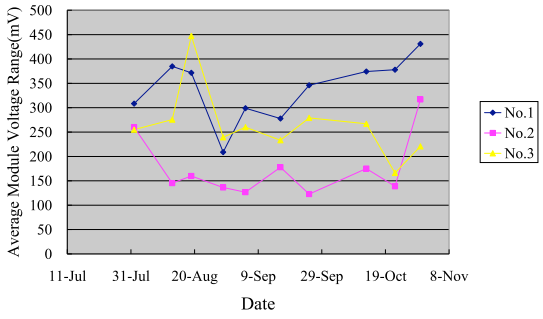


Figure 13. Variation of inconsistency of the battery packs

When calculate battery pack energy efficiency, a set of test data in which the initial SOC and the end SOC were the same value was chosen. The ratio of the net discharge energy and the net charge energy of this set of test data is the energy efficiency. From the trend of the curves in figure 12, we can conclude that the battery pack energy efficiency would degrade with travel time despite some light fluctuate.

Module voltage range is an important parameter reflects the inconsistency degree of battery pack. The quality control level of battery manufacture determines module voltage range. It can be seen in Figure 13 that the voltage range value increases by inches. Till now, the fuel cell city buses have finished 8 months of the one-year demonstration. Every month average travel distance of the buses is about 1300km. The bus performance is good enough endure the high temperature, heavy humidity, cold and rainy weather. The 8 months' excellent records of the fuel cell buses during demonstration show that one-year demonstration is not a difficulty.

5 Conclusion

The fuel cell city bus research progress in Tsinghua University is introduced in this paper. Some important information about the one-year demonstration project including demonstration area, bus line and climate condition were also introduced. The Ni-MH battery pack installed in the demonstration fuel cell buses showed excellent performance, safety and durability, can expect to finish one-year demonstration successfully. From the battery pack demonstration data analysis, it can be concluded that the large capacity Ni-MH battery can meet the requirement of widely application in city public transportation system. The energy efficiency and consistency degree of battery pack degraded gradually with the travel mileage increasing. Although the one-year demonstration of fuel cell city bus did not finish, from the demonstration data analysis and bus development experience, it was difficult for these buses to reach

10,000 km continued driving mileage. The more exact conclusion would be given out when the one-year demonstration project finished.

Acknowledgments

The research presented by the paper has been sponsored by The Chinese Ministry of Science and Hi-Tech Research and Development Program of China. The author would like to thank all the supporters in the project.

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