The Technological Development of Domestic Li-ion Power Battery and Its Application on the Electric Vehicle

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Abstract

The reaction principium of Li-ion is introduced. The achievements of Li-ion battery are summarized on service performance and security performance. Take the Li-ion battery produced by some corporation for example, the basic performances of domestic Li-ion battery are introduced. The current situation is also explained that the Li-ion battery applied on the electronic vehicle.

Keywords

Li-ion power battery, charging and discharging characteristic, electronic vehicle

1. THE REACTION PRINCIPIUM OF LI-ION BATTERY

The Li-ion battery is a Li-ion dense difference battery, the anode and cathode is imbedded the chemical compound to make up of two kinds of different Li-ion, positive pole adopts lithium chemical compound $LixCoO_2$, $LixNiO_2$ or $LiMn_2O_4$, negative pole adopts the lithium-chemical compound $LixC_6$ among layer of carbon, the electrolyte is such organic lithium solution as $LiPF_6$, $LiAsF_6$, etc. Li+ imbedding and taking off, inlaying the course of charging and discharging which form the battery among the straight negative electrodes. When charging, Li+ inlay through negative pole by electrolyte to take off from positive pole, negative pole in rich lithium attitude, positive pole is in the poor lithium attitude. It is opposite when discharging, Li+ inlays through positive pole by electrolyte to take off from negative pole, positive pole in rich lithium attitude. It is as follows that the electrode of the Li-ion battery reflects the expression formula separately.

Anode reaction: $LiMO_2 \underset{discharging}{\overset{charging}{\Leftrightarrow}} Li_{1-x}MO_2 + xLi^+ + xe$

Cathode reaction: $LiMO_2 + nC \underset{discharging}{\overset{charging}{\Leftrightarrow}} Li_{1-x}MO_2 + Li_xC_n$;

Battery reaction: $nC + xLi^+ + xe \underset{discharging}{\overset{charging}{\Leftrightarrow}} LiCn$

In this pattern: FM represents metal such as Co, Ni, W, Mn, etc..

2. LI-ION POWER BATTERY STUDIES AT PRESENT

In recent years, as a new-type of power battery, a lot of corporations both at home and abroad launch research to such new-type power battery. Several corporations made a breakthrough to its research and development at home recently, especially in safe performance. Most of anode material is manganese acid lithium series.

For example: Li-ion power battery of the company A in Beijing (manganese acid lithium series: 18Ah, 100Ah), the single battery, past safety testing (include: Acupuncture, pinching, short circuit, over charging, falling, heating test). The energy density of battery reached 110 Wh/kg. Low temperature -20 degrees Centigrade of capacity of discharging are greater than 80%, high temperature 55 degrees centigrade of capacity of discharging are greater than 95%. High ratio discharging capacity is greater than 95%. Life span of DOD circulation 100% exceeds 300 times.

For example: Li-ion power battery of one Company B in Beijing area (manganese acid lithium series: 10Ah, 100Ah), the single battery, past safety testing (include: Acupuncture, pinching, short circuit, over charging, falling, heating test). The energy density of battery reached 110 Wh/kg. Low temperature -20 degrees Centigrade of capacity of discharging are greater than 80%, high temperature 55 degrees Centigrade of capacity of discharging are greater than 95%. High ratio discharging capacity is greater than 95%. Life span of DOD circulation 100% exceeds 300 times.

The energy density of Li-ion power battery of some Company in Tianjin (cobalt acid lithium series: 50Ah), is 110 Wh/kg. The low temperature discharging capacity is greater than 70%. The high temperature discharging capacity is greater than 95%. High ratio discharging capacity is greater than 95%. The battery has past the safety test included: Acupuncture, pinching, short circuit, over charging, falling, heating test).

The test above is the generally acknowledged that it is the most harsh and safe method of testing of power battery in the world at present.

Certainly, it is not easy that all of the electric performance, safety performance and life span reach a high competence. So there is less than 10% of the domestic Li-ion power battery that can totally pass the test.

The security problem of the Li-ion power battery has been solved. But it doesn't mean that industrialization is coming rapidly. The battery has to be improved and using technology in groups to solve the security problem after the extensive production, with the experience of accumulating in groups and in small scale.

3. BASIC CHARGING AND DISCHARGING CHARACTERISTIC OF THE LI-ION POWER BATTERY

Take the security, reliability and charging efficiency in to account, the Li-ion battery charging should adopt the charge-up method of two sections of types. In stage 1 the current is kept permanent while the voltage is limited. In stage 2 the voltage is kept permanent while the current is limited. The supreme limit of the Li-ion battery charging is below 4.35V. Charge and discharge in the voltage curve is as Figure 1 shows. Charging and discharging curves in the picture adopt 0.3C. Two main differences are: (1) the permanent flowing value of the 1st stage is different from manufacturing engineering according to the anodal material of battery. The generally adopt the electric current range is 0.2-0.3C. (2) Different Li-ion battery is very different in permanent current time and in the proportion of changing capacity and the whole capacity. In terms of practical application of electric automobile, the longer the permanent current time is, the shorter is the charging time. It is positive to application of electric automobile.

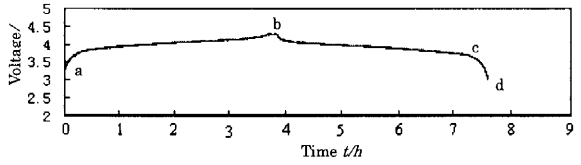

Fig. 1 Charging and discharging voltage curve of Li-ion battery

The voltage of the Li-ion battery is steady in the prophase, drops slowly. But the voltage drops rapidly in the anaphase, as the Figure 1 shows. In this phase, the battery is prevented from over discharging and avoids causing irreversibility damage to the battery.

As follows, took some typical 300Ah Li-ion power battery for example to introduce the discharging characteristic of the battery. It is mainly about the influence of the characteristic to the Li-ion battery under different environment temperature and different discharging rate discharges.

The test is less than 20 degrees Centigrade, fully charging the battery, discharging it in- 20 degrees Centigrade, 0 degrees Centigrade and 20 degrees Centigrade separately. First, the battery is discharged in 100A (0.5C), voltage drop to 2.5V, then the battery is discharged in 80A (0.4C). When the voltage is same, the battery is discharged in 60A (0.3C). In the same way, the battery is discharged in 40A, 20A, 10A. The result is as Table 1 shows. The discharging course in 100A (0.5C) is as Figure 2 shows.

Table 1 Parameter table in different temperature

Discharging current/A	20℃		0℃		−20℃	
	Capacity /A.h	Energy/ W.h	Capacity /A.h	Energy /W.h	Capacity /A.h	Energy /W.h
100	191.647	586.517	188.369	566.081	173.872	509.460
80	194.812	595.451	191.752	575.515	179.201	524.207
60	197.103	601.895	193.869	581.398	182.929	534.452
40	198.902	606.954	195.731	586.578	185.456	541.404
20	200.727	612.126	197.688	592.073	187.845	548.060
10	201.82	615.207	198.867	595.364	189.250	551.952

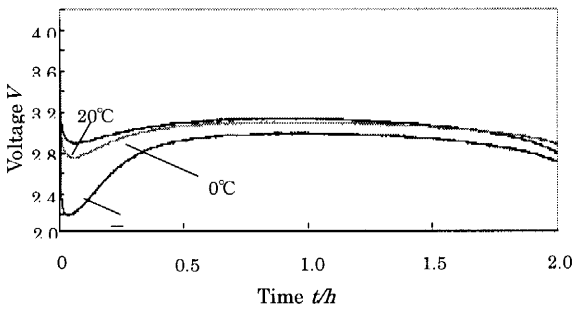

Fig. 2 Discharging voltage curve in different temperature 100A

As the Table 1 and Figure 2 shows, it can be seen that charge the battery under the tender feeling condition of the room, discharge in different temperature, and the impact on energy that the battery can be emitted is greater than correctly the battery discharges on the influence of the capacity. Under the different temperature, compare

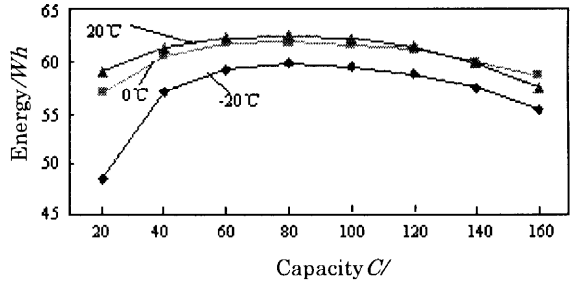

Fig. 3 Contrast of releasing energy indifferent temperature Ah (0.5C)

the energy that the battery released in 20Ah each time, as the Figure 3 shows.

When the battery emits 40-50% of capacity, it releases more energy for each Ah. In case of low-temperature, the discharge voltage is low, especially in a same one discharge electric current on the initial stage of discharging; a rapid decline will appear in the voltage of the battery, as Figure 2 shows, so discharging energy is lower; in middle period, the energy which is used up in the battery resistance made the battery's temperature rise, the material of Li-ion battery become more active, the voltage of the battery rise; in the last discharging period, the voltage of the battery is lower, the energy that each Ah emits is lower.

In the same temperature and the same ending discharging voltage, there are also some differences between the discharging capacity and the energy. 10A can emits about 5-7% more capacity and energy than 100A.

4. THE CURRENT APPLICATION OF THE LI-ION POWER BATTERY ON ELECTRIC AUTOMOBILES

Our school is regarded as the electric bus overall unit of the electric automobile major project of the National '863' Program. Assembling and using the battery group of Li-ion on the electronic motorbus that is researched and developed independently since July of 2001 has be started. The first round of BJD6100EV electronic bus in public transportation route has run more than 60,000 kilometers in Beijing safely and reliably since July 2001 to 2003. This helped us accumulate a lot of experience of battery application skill in-group. There are 4 Li-ion electric bus which is researched by the national '863' and Beijing Scientific and Technological Commission successfully, including electric bus, tourist coach and electric bus of low floor. Two types of Li-ion batteries have been applied in demonstration circulation, and they are cobalt-acid-lithium Li-ion battery and manganese-acid-lithium Li-ion battery. The capacity range of the electric automobile which is above 10 meters long, is 400Ah to 600Ah, while the rating voltage range of the battery group is 367.2v to 388.8v. Both of the parameters are as Table 2 shows.

Table 2 Performance parameter of Li-ion battery

Cobalt acid Lithium Li-ion battery	Nominal voltage	3.6V	Rating capacity	200Ah
	Circular life-span	≥500times	Temperature in using condition	-25℃~75℃
	External dimension	182×71×295 (mm)	Quality	5.8kg
	Volume rate energy	330Wh/L	Quality rate energy	135Wh/Kg
Manganese acid Lithium Li-ion battery	Nominal voltage	3.7V	Rating capacity	100Ah
	Circular life-span	≥500times	Temperature in using condition	-25℃~75℃
	External dimension	310×27×288(mm)	Quality	3.9kg
	Volume rate energy	120Wh/kg		

Now as it shows, the actuality of the Li-ion power battery on electric vehicles based on a kind of Li-ion power battery power bus developed by our university. Table 3 shows the basic parameter of vehicle, Li-ion power battery and battery group.

Table 3 Parameter table of Li-ion power battery coach

No.	Item		Structure and main parameters
1	External dimension of the coach (length×width×altitude) /mm		10660×2500×3560
2	Quality when the coach fully loaded /kg		12560
3	Lithium-ion Power Battery	Rating voltage	3. 7V
		Capacity	100Ah
		Weight	4kg
		Quality rate energy	115Wh/kg
		Attended mode	Parallel connection first than tandem connection
	Rating voltage (rating/maximum)		388.8V/459V

The battery group one the vehicle use first permanent current then permanent voltage charging strategy, rating permanent current is 100A charges finished current is 25A, the supreme limit of the single battery voltage is 4.30V. during the charge the course that the temperature of battery is measured, and it is obvious that battery temperature rises; the surface temperature of the battery is close to the room temperature. One course of charging for example, Figure 4 shows curve of the charge. It was about 4 hours to charge the battery group, capacity 334Ah, and energy 145.5kWh.

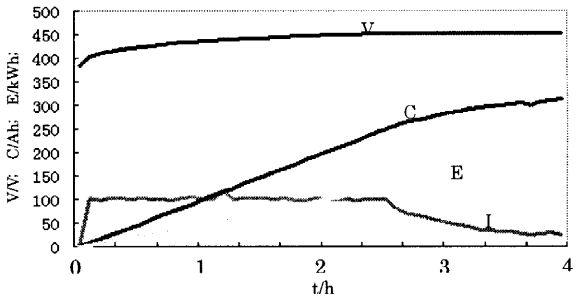

Fig. 4 Charging curve of the battery group

The battery-charging curve of the battery group is as Figure 5 shows. It can be seen that there are differences between battery voltages after the deep discharging. As it charges, the difference is reduced gradually and they are gonging to reach unanimity. The tested maximum

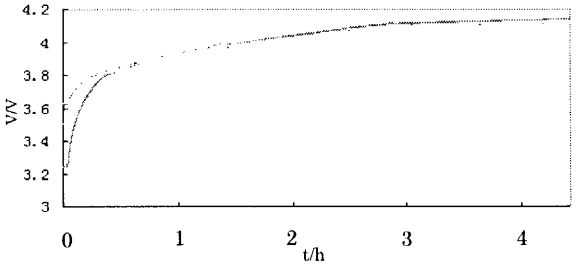

Fig. 5 Charging curve of the cell

voltage difference of 108 battery groups after charging is 0.09v.

In the initial using stage of statistical automobiles, if it is basically steady in the range of 210-220km after a road haul of 5,000km and 10,000km, and there is no obvious change, the battery performance is basically steady.

When the automobile travels, the voltage is reduced with increase of the distance. Because of the variety of the operating mode, it is different in battery discharging curve. The Figure 6 shows the voltage statistics of different phase in the initial discharging stage, the phase that discharge 40%-50% (road haul of 117km), the phase that discharging is over (road haul of 217km). As the figure shows, when it discharged 40%-50%, it reveals the variance. Finally the discharging is over because of the low voltage of a few batteries. This illuminates the variance of battery's capacity. As the Figure 7 shows, voltage of the battery changes with the discharging current. The curve shows the statistics of the battery, which is in the last discharging phase, after the road haul is about 180km. The variance of voltage in power state is also obvious. In the initial stage, difference of voltage is smaller than 0.02v. But the voltage rises when it is discharging. In power state, it may rise to 0.5v. This also reveals that in the last discharging phase, the battery voltage with low capacity reduces rapidly. If the accident cannot be found out in time and stopped, it will cause the irreversible harm to the battery.

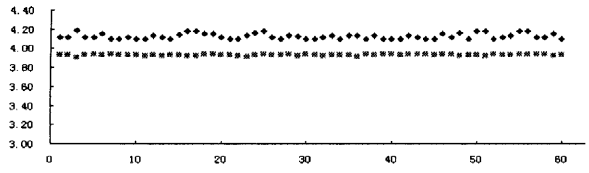

Fig. 6 Voltage distributing map in different discharging depth

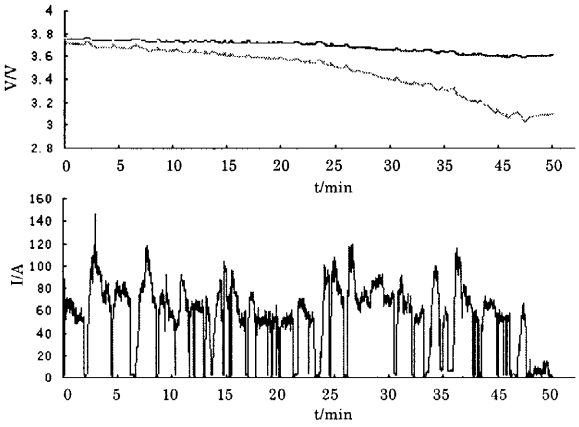

Fig. 7 The cell discharging voltage curve changing with the current

The 400Ah battery group is measured separately after the road haul is longer than 5,000km. And draw a conclusion: the absolute value of battery resistance is smaller (between 0.2mΩ and 0.3mΩ), but there are difference between battery resistance, and the difference of the maximum value and the minimum value is 0.04mΩ. The average value of two resistance numerical value is 0.272mΩ and 0.276mΩ. The statistical average value of the resistance increases a bit.

5. CONCLUSIONS

(1) The technological level of domestic Li-ion power battery has already been close to or reached the international leading level at present.

(2) The Li-ion battery security problem has basically resolved, part of Li-ion power batteries of some producers have measured up to the security standard.

(3) The preliminary experimental result of the application of the Li-ion power battery has proved the Li-ion battery's applicability on the electric automobiles.

References

Chan, C. C., and K. T. Chau, *Modern Electric Vehicle Technology*, Oxford University Press, 2001.

Dai, Y., Q. Xi, and Z. Huang, Li-ion battery research, *Battery Industry*, No. 7, 2002.

Huang, K., Z. Lv, and X. Liu, Analyse of the Li-ion battery capacity damanfy reason, *Battery*, No. 1, 2001.

Sun, L., Electric automobiles system matching, performance emulation, key parts research and sample auto mobile development, *Report of the postdoctoral research, Beijng Institute of Technology*, 21-32, 2000.

Wang, Z., and F. Sun, Analysis of the Characteristics of Li-ion Battery pack for EV, *Proceedings of 19th International Electric Vehicle Symposium*, CD-ROM, 2002.

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