ELSEVIER

Journal of Alloys and Compounds 293–295 (1999) 804–808

Journal of ALLOYS AND COMPOUNDS

Characteristics of Ni/MH power batteries and its application to electric vehicles

F. Zhan*, L.J. Jiang, B.R. Wu, Z.H. Xia, X.Y. Wei, G.R. Qin

Department of Powder Metallurgy and Special Materials, Beijing General Research Institute for Non-ferrous Metals, Beijing, 100088, PR China

Abstract

Development of electric vehicles (EVs) has great significance for protecting the environment, saving energy and improving energy structure. The Ni/MH power battery is one of the most practical batteries as a power source for EVs. The properties of Ni/MH power batteries are described and the status of application of Ni/MH power batteries for EVs in Japan, USA and China is reviewed. A 150Ah 6V battery pack made by Beijing General Research Institute for Non-ferrous Metal (GRINM) has passed the test of National Key Laboratory and exhibits superior charge–discharge characteristics. A 100 Ah 120 V battery pack firstly has been fitted on an EVs in China and gained successful running demonstration.

Keywords: Ni/MH battery; Power battery; Electric vehicle; Charge–discharge characteristics

1. Introduction

It is very important to develop EVs for protecting the environment, saving energy and improving energy structure. With the enhancement of consciousness of environmental protection and the increasing exhaustion of oil resources, developed countries have drawn up development projects of EVs one after another. The sales volume of EVs will reach 290,000 in the USA and 200,000 in Japan by 2000 [1].

A middle-term and long-term plan has been worked out by the United States Advanced Battery Consortium (USABC). According to the requirements of the middle-term plan, the Ni/MH battery is the most promising candidate among Pb-acid, Ni/Cd, Ni/MH, Na/S, Li ion batteries and so on [2–4]. It was the only battery supported by USABC at the second stage of the middle-term plan in 1996. It was necessary that the development of Ni/MH battery could achieve the middle-term goal and that it could be put into commercialized production. In 1996, at the Beijing International Presentation Seminar and Exhibition on Electric Vehicles and Substitutional Fuel Vehicles, TOYOTA Motor Corp., Japan, asserted that RAV4 EVs driven by an Ni/MH battery had been developed and trial-sold. General Motors (GM) Corp., USA, also announced the plan to produce Ni/MH batteries to be used in EV1 by 1998. Some research and development of Ni/MH power batteries has been carried out in China. The first one, a 100 Ah 120 V Ni/MH battery pack used in an EV has been developed by GRINM and the running demonstration of the EVs gained success in September 1996.

2. Properties of Ni/MH battery and comparison of battery properties of different countries

Ni/MH batteries are products with the content of high science and technology developed in recent years. Their characteristics is as follows:

1. High energy density: Energy density of Ni/MH battery can reach 70~80 Wh/Kg, which is twice as high than that of Pb-acid batteries.
2. High power density: Test results by Argong State Laboratory, USA, show that power density of a Ni/MH battery is the highest among all batteries, which is also twice that of a Pb-acid battery, and can meet the need of a Bentone Blitz-type senior racing motor for accelerating from 0 to 100 Km/h within 6 s.
3. Long cycle life: The cycle life of a Ni/MH battery can reach 1000 cycles with 80% DOD, which is triple that of a Pb-acid battery.
4. Allowing charge–discharge at large current: 60% capacity of Ni/MH batteries can be obtained within a 15 min charge and 100% capacity within 1 h. The battery can discharge at 3 C in a short time.

*Corresponding author.

0925-8388/99/$ – see front matter
PII: S0925-8388(99)00361-8

5. No pollution: An Ni/MH battery is a kind of green battery with good performance because during the course of producing and using Ni/MH batteries, there is an absence of heavy metal, such as Pb and Cd, avoiding such pollution caused by the presence of heavy metal such as Pb-acid and Ni/Cd battery.
6. No memory-effect: An Ni/MH battery can charge or discharge at any time and exhibits no memory-effect while a Ni/Cd battery shows memory-effect in the case of charge under incomplete discharge which results in the decrease of capacity.
7. Free maintenance.

In view of the above-mentioned characteristics of Ni/MH batteries, the distinguishing features of an EVs driven by an Ni/MH power battery are as follows:

1. Fairly long running distance at one charge.
2. Good performance of accelerating.
3. Short charge time in emergency.
4. No emission.
5. Easy maintenance.

Comparison of properties of an Ni/MH power battery pack, both at home and abroad, is listed in Table 1. The results show that Ni/MH power batteries made by Matsushita Corp., Japan, and OVONIC Corp., USA, have a larger energy density, with a maximum of 70 Wh/Kg, than the Ni/MH battery made by GRINM. The capacity of each battery made by GRINM, however, can reach a large value.

3. Characteristics of Ni/MH power batteries made by GRINM

The foam-type negative electrode is made of rare earth-based hydrogen storage alloys developed by GRINM. The effect of the factors, such as porosity, size of pore, thickness, visual density of nickel foams, particle distribution of hydrogen storage alloys, composition of active material, characteristics of slurry, and forming technology on the performances of the batteries was investigated. Large-capacity negative electrodes with capacity density of 1300 mAh/cm^3 were obtained under utilization ratio of active material up to 90%. On the basis of such studies, a sintered-type positive electrode with capacity density of 450 mAh/cm^3 was selected and 35~150 Ah Ni/MH power batteries were fabricated.

A 35 Ah battery, using stainless steel as shell, is sealed by laser welding process with a structure of liquid-poor and gas-sealed. The open pressure of safety valve is 4.1 Kg/cm^2. An 80 Ah battery and a 150 Ah battery uses AS plastic and MBS plastic as shell respectively both with a structure of liquid-rich and liquid-sealed.

A 150 Ah/6V battery pack has been tested by National Key Laboratory of Motor Safe and Energy-saving, Tsinghua University using BTS-M second batteries automatic test system. The test results of charge–discharge properties of the battery pack are shown in Table 2, and Figs. 1–3.

The conclusions drawn are as follows:

1. The capacity of the 150 Ah/6 V Ni/MH power battery pack with stable properties reaches the requirement of design.

Table 1
Comparison of properties of Ni/MH power battery packs

Country	Organization	Voltage (V)	Capacity (Ah)	Weight (Kg)	Energy density[a] (wh/Kg)
Japan	Northeast	12	100	30	40 (60)
	Electric Power	6	90	12.5	43.2 (50)
	Matsushita	12	100	17.2	70
		6	130	11	70
	NEW KOBE	7.2	70	12.5	40.3 (70)
	YUASA	12	100	18.5	64.9 (67)
	TOYOTA	12	100	18.5	64.9 (67)
USA	Electric Ltd. Co.	12	20	4.8	50
		13.2	95	17.8	70
	OVONIC	12	100	17.25	70
Germany	VARTA	1.2	40	0.96	(50)
		1.2	60	1.2	(60)
China	Tianjin	1.2	20	0.55	(43.4)
	18 Institute	1.2	70	1.62	(51.8)
		12	35	10	42
	GRINM	12	80	19	50.5
		6	150	22.5	40

[a] Data in () is the energy density of single battery.

Table 2
Charge–discharge properties of a 150 Ah/6 V battery pack

Number	Charge process	Static time	Discharge current	Cut-off (V)	Capacity (Ah)
1	0.2 C 5 h, 0.1 C 1 h	15 h	0.2 C constant	5.0	148
2	0.2 C 5 h, 0.1 C 1 h	15 h	0.2 C constant	5.0	148
3	0.2 C 5 h, 0.1 C 1 h	7 days	0.2 C constant	5.0	138
4	0.5 C 1 h, 0.2 C 2.5 h, 0.1 C 1 h	15 h	0.2 C constant	5.0	149
5	0.5 C 2 h, 0.1 C 1 h	4 h	0.2 C constant	5.0	152
6	0.5 C 2 h, 0.1 C 1 h	15 h	0.5 C constant	5.0	145.6
7	0.5 C 2 h, 0.1 C 1 h	15 h	1 C constant	4.5	143.2
8	0.5 C 2 h, 0.1 C 1 h	1 h	2 C constant	4.5	143.5
9	0.5 C 2 h, 0.1 C 1 h	2 h	C/3 constant	5.0	151

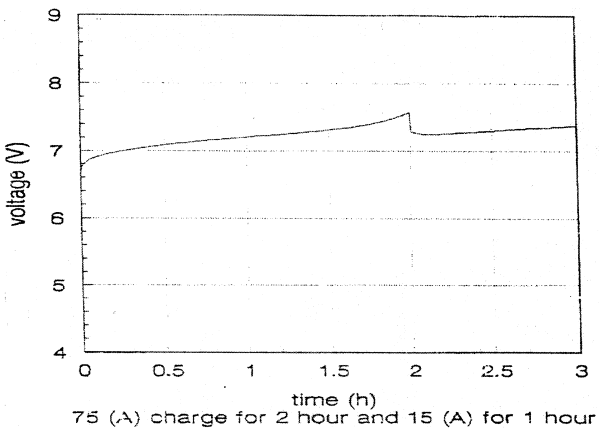

Fig. 1. Charge curve of a 150 Ah/6 V battery pack.

2. The fast-charge property of the battery pack is good. Compared with normal charge (0.2 C, 5 h and 0.1 C, 1 h), the capacity exhibits no decrease under fast-charge (0.5 C, 2 h and 0.1 C, 1 h).
3. The battery pack shows superior charge properties at large current. Decrease in capacity is less than 5% at 1 C and 2 C discharge than at 0.2C.
4. The rate of self-discharge is small with decrease in capacity of 6.7% for 7 days.

4. Application of Ni/MH power battery packs to EVs

Studies on EVs running experiments driven by Ni/MH power batteries have been intensively documented in Japan and the USA. Some works for Ni/MH power battery have been carried out in China recently. Table 3 shows the properties of EVs driven by Ni/MH batteries.

The first EVs in the world driven by sealed Ni/MH batteries was made by Matsushita Battery Industry Corp., Japan, in 1992. The power of the EVs is equal to that of gasoline vehicles with an exhaust volume of 1500 mL. The weight of the battery is about 400 Kg and the output voltage is 216 V. The capacity of each battery is 130 Ah with energy density of 70 Wh/Kg. The driving range is 140 Km at one charge and the accelerating time from 0 to 40 Km/h is 7 s.

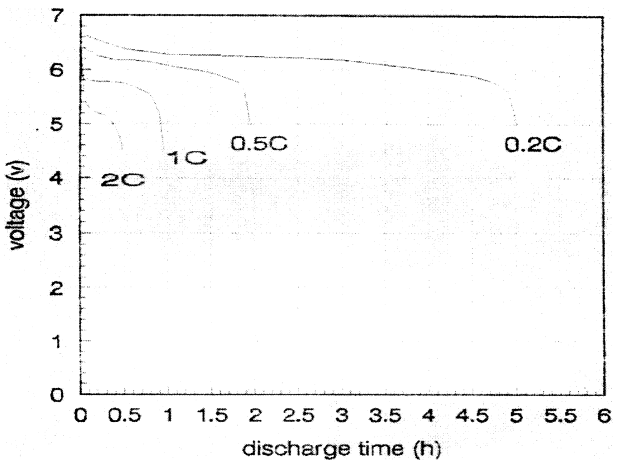

Fig. 2. Discharge curve of a 150 Ah/6 V battery pack.

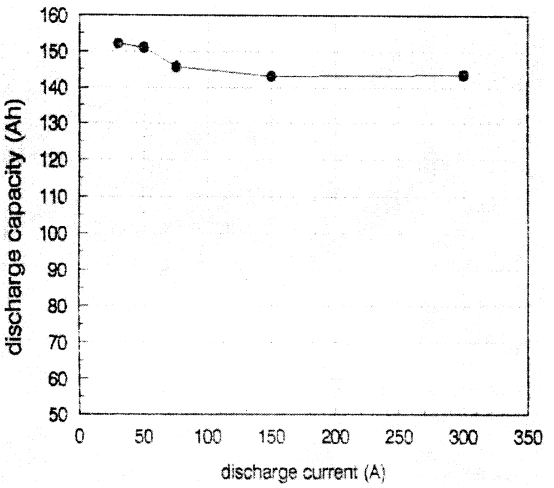

Fig. 3. Relation between discharge capacity and discharge current.

Table 3
Properties of EVs driven by Ni/MH battery pack

Country	Organization	Type	Voltage (V)	Capacity (Ah)	Running range (Km)
Japan	TOYOTA	RAV4 EVs	288, 24 packs (12)	95	215
	HONDA	HONDA EVs	288, 24 packs (12	95	210
	Northeast	WAVE EVs	120, 10 packs (12)	125	150
	Electric Power	WAVE EVs	120, 20 packs (6)	90	64~106
	MATSUSHITA	EVs	216, 36 packs (6)	130	140
USA	OVONIC	SF EVs	240, 20 packs (12)	100	272
	Electric Ltd. Co.	Hybrid EVs	252, 21 packs (12)	20	–
China		Electric	24, 2 packs (12)	35	60
	GRINM	Tricycle	24, 2 packs (12)	80	120
		EVs	120, 20 packs (6)	100	121

The hybrid WAVE prototype equipped with 20 Ni/MH battery packs as a main power and a small-scale engine as an assistant power was made by Northeast Electric Power Corp., Japan in March, 1993. The prototype is designed to carry four people and the weight is 1500 Kg, allowing for a top speed of 90~100 Km/h and a running distance of 100~150Km at one charge.

In September, 1996, TOYOTA Corp., Japan, announced that EVs driven by Ni/MH battery could be trial-sold as commercial vehicles in Japan. In the Beijing International Exhibition on Electric Vehicles held in December, 1996, a RAV4 EVs was displayed by TOYOTA Corp. The EVs can carry four people with 24 100 Ah/12 V Ni/MH, battery packs. The energy density and voltage of the packs are 64 Wh/Kg and 288 V respectively. The total weight of the battery pack is 450 Kg. The EVs can run 215 Km with a maximum speed of 125 Km/h at one charge [5].

The HONDA EVs was provided by HONDA Corp., Japan, in 1996. The EVs is driven by 24 95 Ah/12 V sealed-type Ni/MH battery packs with a voltage of 288 V, allowing for a top speed of 130 Km/h and a running range of 210 Km.

OVONIC Battery Corp., which is supported by USABC, developed an Ni/MH power battery used in EVs in May, 1992. These batteries were fitted on Chrysler TEV and Solectria Force EVs in 1993. In April, 1994, the Solectria EVs tested by the California Air Resource Research Committee could run 274 Km at one charge at a speed of 80.5 Km/h. In March, 1994, GM Corp., cooperated with OVONIC Corp., and founded a factory venture. The EVs driven by Ni/MH batteries made by OVONIC-GM Corp., passed the test of the American EVs Association in October, 1995. The weight energy density and volume energy density of the battery pack with a voltage of 13.2 V and a capacity of 95 Ah is 70 Wh/Kg and 165 Wh/L respectively. The life of the battery could exceed 600 cycles (80% DOD). In January 1996, USABC signed a contract ($28.4 million) with OVONIC Corp., requiring that the development of Ni/MH batteries must reach USABC's middle-term objective and put into production by 2000. GM Corp., plans to apply Ni/MH power batteries to EV1 by 1998 [6].

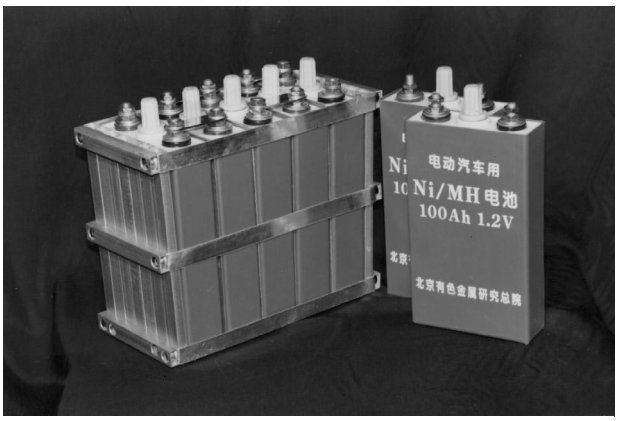

Fig. 4. A 100 Ah/6 V battery pack.

China has researched and developed the Ni/MH battery since the early 1990s. In 1994, the EVs Project Forum held in Tsinghua University, GRINM displayed an electric tricycle and bicycle driven by Ni/MH batteries. A prototype of an electric tricycle fitted with a 35 Ah/24 V Ni/MH battery pack can run 60 Km at a speed of 18 Km/h at one charge. On the basis of this work, 80~150 Ah

Fig. 5. The first EVs in China driven by Ni/MH batteries.

square Ni/MH batteries were developed. The electric tricycle, driven by a 80 Ah/24 V Ni/MH battery pack, allows a maximum speed of 18 Km/h and a driving range of 120 Km. A 150 Ah/6 V battery pack passed the test of the National Key Laboratory of Motors Engineering, Tsinghua University and could meet the needs of EVs. The electric vehicle, driven by the first Ni/MH battery pack (100 Ah, 120 V) developed by GRINM in China, allowed a top speed of 112 Km/h and a running range of 121 Km at one charge in September, 1996, as shown in Figs. 4 and 5 and Ref. [7]. The EVs can carry five people and the accelerating time from 0 to 40 Km/h is 6.2 s.

References

[1] M. Dunckley, J. Power Sources 42 (1993) 291–295.
[2] S.R. Orshiusky, M.A. Fetcenko, J. Ross et al., Science 260 (1993) 176–181.
[3] D.F. Grosden, J. Power Sources 45 (1993) 62–71.
[4] S.R. Ovskinsky, Science 260 (1993) 176–181.
[5] D.H. Davis (GM), Beijing International Presentation Seminar Exhibition on EVs & SFV Tech., Golden China Science & Technology Development Comp. December, 1996.
[6] Fujii Yuichi, (TOYOTA), Beijing International Presentation Seminar Exhibition on EVs & SFV Tech., December, 1996.
[7] Z. Feng, J. Lijun, Chinese J. Power Sources 21 (1) (1997) 35.