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A study of the main factors affecting Ni–MH battery activation

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Abstract

Changes in capacity, plateau voltage and internal resistance during the activation process of Ni–MH batteries were investigated. The result shows that the amount of electrolyte, the temperature, aging time and the charge–discharge regime are the main factors affecting the activation of Ni–MH batteries. A method for activating Ni–MH batteries is suggested.

Keywords: Ni–MH batteries; Activation process; Electrochemical properties

1. Introduction

The cost of production, the production cycle and the comprehensive properties of Ni–MH batteries are affected by the activation method and activation regime adopted [1]. The comprehensive properties of Ni–MH batteries set by our government are lower than those in advanced country, such as Japan, one of the reasons is that the activation method and activation regime in the production of Ni–MH batteries is different. Therefore, it is necessary to study the activation method and activation regime. It is well known that the purpose of activation is to increase the lattice defects and surface area of the active material so as to increase the reaction activity and ensure the batteries have a balanced capacity after several charge–discharge cycles [2]. The technique of activation after sealing is widely used in the production of Ni–MH batteries in advanced countries. This technique has many advantages such as reducing the cost of production, reducing environmental pollution, shortening the production cycle and improving the characteristics of Ni–MH batteries. Therefore, in recent years, many universities, institutes and companies have studied this technique and some progress has been made. However, the influence of the activation conditions on the properties of Ni–MH batteries is not clear, so this technique cannot be used in the production of Ni–MH batteries in our country. In this work, the amount of electrolyte, aging time, aging temperature and charge–discharge regime, etc. were investigated, and the main factors affecting the properties of Ni–MH batteries are discussed. Furthermore, a method for activating the batteries is suggested.

2. Experimental

The positive and negative electrodes used in the experiment were prepared from foamed nickel plates. The dimensions of the positive and negative electrodes were 85 mm×41 mm×0.66 mm and 110 mm×41 mm×0.32 mm, respectively. The weight of spherical $Ni(OH)_2$ and hydrogen storage alloys added to the positive and negative electrode was 5.2 and 7.0 g, respectively, and the capacity of the negative electrode was surplus. Nickel powder was added to both electrodes as conductor. Acetylene black was used as another conductor in the negative electrode. Superfine Co powder and a Co compound were used as additives in the positive electrode. The spherical $Ni(OH)_2$ and polypropylene separator used were both made in Japan.

The positive electrode, negative electrode and separator were wound together and assembled in an AA size battery spacer and sealed after the electrolyte was added (30 wt% KOH solution); the battery was then ready for activation.

The sample batteries were subject to aging for 18 h at 25°C before the test, except in the case of the study of aging time and temperature. The criterion for complete activation is that the capacity of the Ni–MH battery reaches a stable capacity. In addition, the testing temperature was 25°C unless indicated otherwise.

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Table 1
Properties of Ni–MH batteries with different amounts of electrolyte

	Battery No.								
	1	2	3	4	5	6	7	8	9
$W_{\text{electrolyte}}$ (g)	2.45	2.50	2.60	2.70	2.80	2.90	3.00	3.10	3.20
$C_{0.2\text{C}}$ (mAh)[a]	1153	1120	1263	1310	1359	1392	1331	1249	1151
$k_{0.2\text{C}}$ (%)[b]	78.69	76.20	87.49	86.34	87.20	86.80	80.70	76.70	68.37
$C_{1\text{C}}$ (mAh)[c]	1015	1020	1137	1179	1266	1322	1264	1185	1070
$k_{1\text{C}}$ (%)[d]	57.1	60.2	65.2	66.7	70.5	73.0	75.5	77.0	70.0
Internal resistance (mΩ)	17.7	17.3	14.5	15.6	13.3	13.5	17.5	18.1	20.3

[a] Discharge capacity at 0.2C when charged with 0.2C.

[b] $k_{0.2\text{C}} = C_{\geq 1.2\ \text{V}} / C_{0.2\text{C}} \times 100\%$, where $C_{\geq 1.2\ \text{V}}$ represents the discharge capacity at 0.2C when the plateau voltage is $\geq$1.2 V.

[c] $C_{1\text{C}}$ represents the discharge capacity at 1C when charged with 1C.

[d] $k_{1\text{C}} = C'_{\geq 1.2\ \text{V}} / C_{1\text{C}} \times 100\%$, where $C'_{\geq 1.2\ \text{V}}$ represents the discharge capacity at 1C when the plateau voltage is $\geq$1.2 V.

3. Results and discussion

3.1. Relationship between the amount of electrolyte and the comprehensive properties of Ni–MH batteries

The amount of electrolyte ($W_{\text{electrolyte}}$) in the battery should not only be enough to ensure the transmission of ions, but also not too much to block the separator so as to make the internal pressure increase [3], so it is important to add the correct amount of electrolyte. Table 1 shows the discharge capacity and discharge plateau voltages of sample batteries with different amounts of electrolyte at 0.2C and 1C rate. The trend of the change of the batteries' capacity with testing cycle is shown in Fig. 1.

The discharge capacity and discharge plateau voltage were obtained after three charge–discharge cycles, and the charge–discharge regimes were as follows: (1) 0.1C×5 h, /0.5 h/, 0.2C→1.0 V; (2) 0.1C×14 h, /0.5 h/, 0.2C→1.0 V; (3) 0.2C×7.5 h, /0.5 h/, 0.2C→1.0 V.

From Table 1 it can be seen that with differences in the amount of electrolyte, the discharge capacity and discharge plateau voltage of the batteries at the 0.2C and 1C rate were different. When 2.6 g$\leq W_{\text{electrolyte}} \leq$3.0 g, the discharge capacity, plateau voltage and internal resistance are much higher than when $W_{\text{electrolyte}}<$2.6 g or $W_{\text{electrolyte}}>$3.0 g. When the amount of electrolyte is >3.0 g, the battery internal pressure rises rapidly and the battery would leak. As seen from Fig. 1, no matter how much electrolyte there is, the capacities of the batteries are all >1100 mAh after two to three activation cycles; with a further increase in the number of cycles, the capacities change little. This means that when 2.45 g$<W_{\text{electrolyte}}<$3.20 g, the activation speed

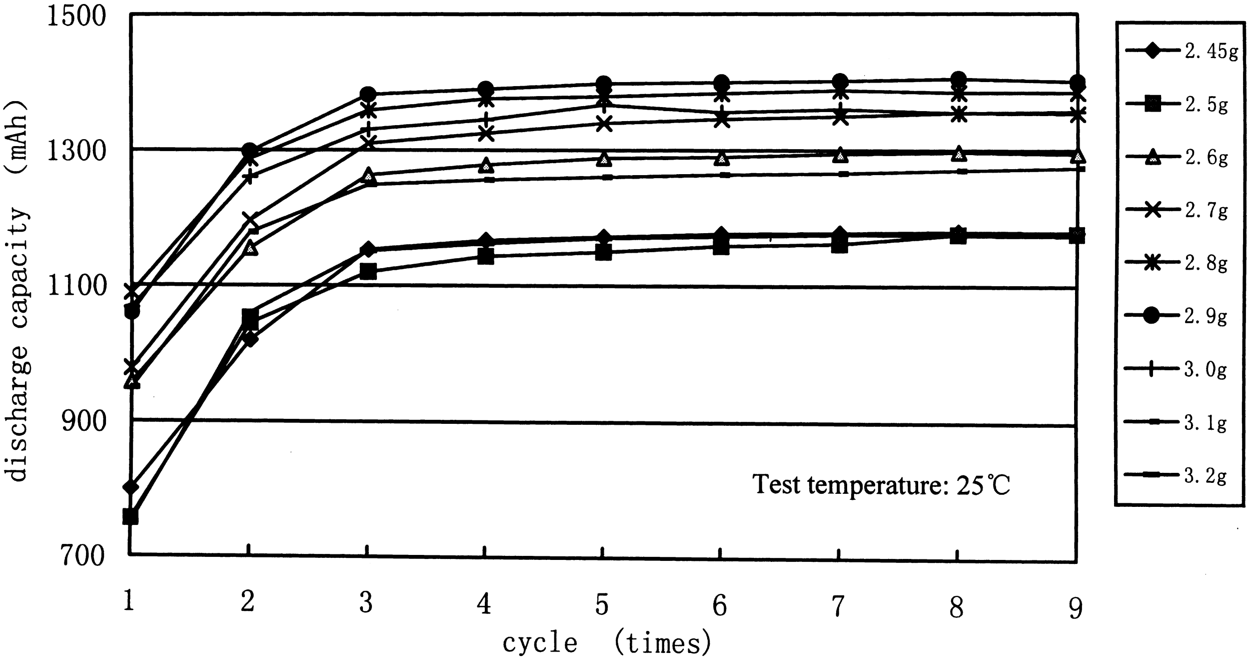

Fig. 1. Change in the discharge capacity with different amounts of electrolyte.

Table 2
Relationship between activation cycle and aging time

	Aging temperature (°C)			
	15	20	30	40
Activation cycle when capacity becomes balanced (times)	4–5	2–3	2–3	2–3
Activation cycle when the voltage platform becomes balanced (times)	6–7	5–6	5–6	5–6

is little affected, but when the amount of electrolyte is <2.6 g or >3.0 g, the discharge capacity and plateau voltage decrease and the internal resistance increases. Thus, a suitable amount of electrolyte is 2.6–3.0 g.

3.2. Relationship between aging temperature and activation cycle

In general, the higher the temperature, the faster the activation speed, but a high temperature (>80°C) would deteriorate the characteristics of the separator and reduce the cycle life of the battery, and, in addition, the heat-resisting ability of the insulation gasket is limited. Therefore, the experimental temperature range was selected to be from 15 to 40°C for the activation test, and then to observe the effect of temperature on the activation speed of batteries with equal aging time. The activation cycles when the discharge capacity and discharge plateau voltage are balanced are listed in Table 2. The charge–discharge regimes were as follows: (1) 0.1C×5 h, /0.5 h/, 0.2C→1.0 V; (2) 0.1C×14 h, /0.5 h/, 0.2C→1.0 V; (3)–(7) 0.2C×7.5 h, /0.5h/, 0.2C→1.0 V. The aging time is 24 h.

As can be seen from Table 2 the activation speed at 20, 30 and 40°C is the same, all the activation cycles were 2–3 times when the capacity becomes balanced, and all the activation cycles were 6–7 times when the voltage becomes balanced, but the activation cycle was slower by two times at 15°C. This shows that it has no obvious effect on the battery activation speed with aging for 24 h at 20–40°C with the present ingredients and dimensions of the positive and negative electrodes, but the activation time will be much longer if the aging temperature is <15°C. Therefore, the aging temperature should not be less than 20°C.

3.3. Relationship between battery voltage before initial charge and aging time

The aim of aging was to promote the permeation of electrolyte in the electrodes and separator, and, at the same time, to promote the conversion of the Co powder or Co compound in the positive electrode to CoOOH [4]. Therefore, it is very important to select the correct aging time.

Fig. 2 shows the trend of the change in battery voltage with aging time. It can be seen that the increase of the battery voltage can be divided into two steps. In the first 7 days, the battery voltage clearly increases. A possible reason for this is that the Co powder or Co compound in the battery is converted into CoOOH. Then, from the eighth day, the increase in the battery voltage becomes

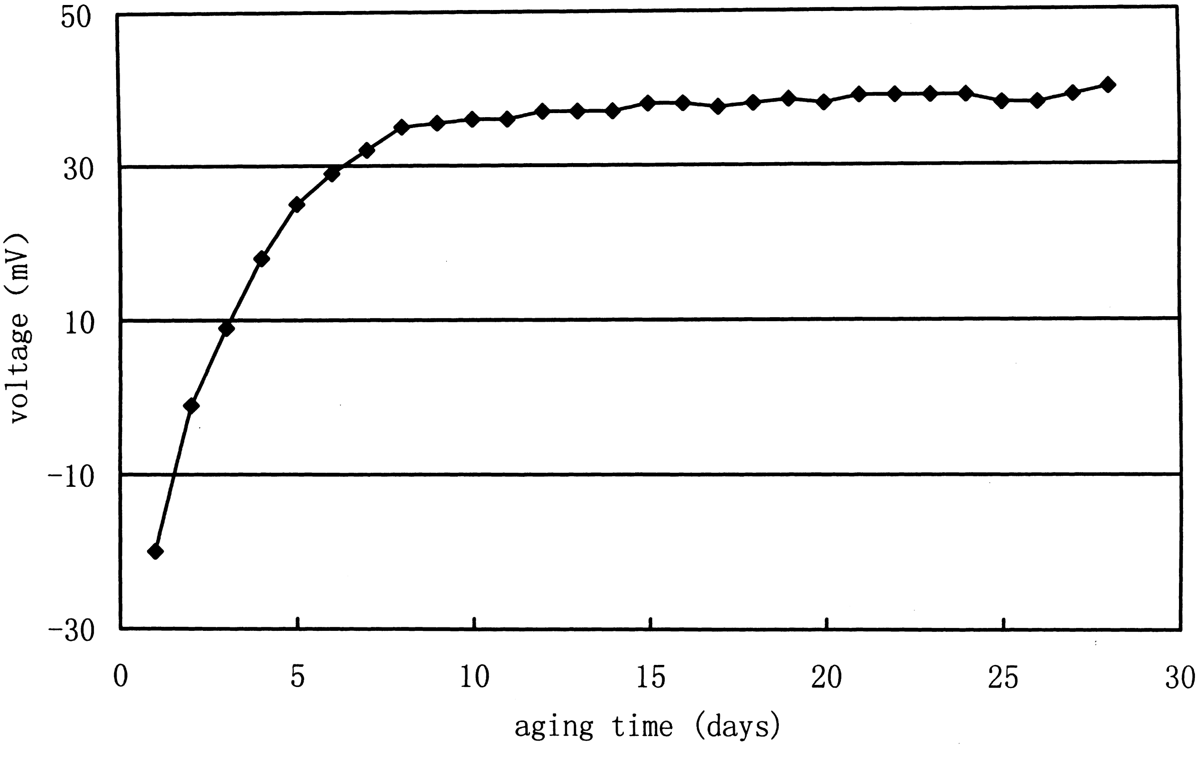

Fig. 2. Change in battery voltage with increasing aging time.

Table 3
Eight activation regimes

	Total activation time (h)	First activation	Second activation
A	24	0.1C×8 h, /0.5 h/, 0.2C→1 V	0.2C×5 h, /0.5 h/, 0.2C→1 V
B	34	0.1C×16 h, /0.5 h/, 0.2C→1 V	0.2C×7 h, /0.5 h/, 0.2C→1 V
C	26	0.1C×4 h+0.2C×2.57 h+0.4C× 40′+1C×16′, /0.5 h/, 0.2C→1 V	0.2C×7.5 h, /0.5 h/, 0.2C→1 V
D	43	0.1C×16 h, /0.5 h/, 0.2C→1 V	0.1C×16 h, /0.5 h/, 0.2C→1 V
E	74.5	0.1C×5 h, /48 h/, 0.2C→1 V	0.1C×14 h, /0.5 h/, 0.2C→1 V
F	50.5	0.1C×5 h, /24 h/, 0.2C→1 V	0.1C×14 h, /0.5 h/, 0.2C→1 V
G	44.5	0.1C×5 h, /18 h/, 0.2C→1 V	0.1C×14 h, /0.5 h/, 0.2C→1 V
H	27	0.1C×5 h, /0.5 h/, 0.2C→1 V	0.1C×14 h, /0.5 h/, 0.2C→1 V

slower, the reaction in the battery becomes balanced, and the effect of aging for a longer time is very small; therefore, the aging time should not be longer than 7 days.

3.4. Relationship between charge–discharge regime and comprehensive properties of Ni–MH batteries

Because different charge–discharge regimes affect the activation cycle of Ni–MH batteries and their comprehensive properties, we formulated a series of charge–discharge regimes and studied their effect on the activation cycle and properties of the batteries in order to determine a suitable activation regime. The activation regimes are listed in Table 3.

First, the sample batteries were aged for 24 h at 25°C, then activated using the eight regimes listed in Table 3, then finally tested at 0.2C rate. Fig. 3 shows the relationship between the discharge capacity and the charge–discharge cycle. As can be seen the activation speeds were different for different charge–discharge regimes. From curves B and D it can be seen that the discharge capacity did not become stable after nine cycles, and the discharge capacities are lower than the others. This shows that the activation speeds under these two regimes were slower than those of the other regimes and that the two regimes had a bad effect on the batteries' capacity. The reason for this was probably that the batteries were charged into too high capacity (150%) at initial charging, which could cause irreversible capacity loss. The capacities of systems A, C, E, F, G and H were all in a steady state from the third cycle, which means that the batteries were fully activated after two cycles. On the other hand, different charging times and currents also affect the batteries' final capacity, as it can be seen clearly from Fig. 3 that, after the

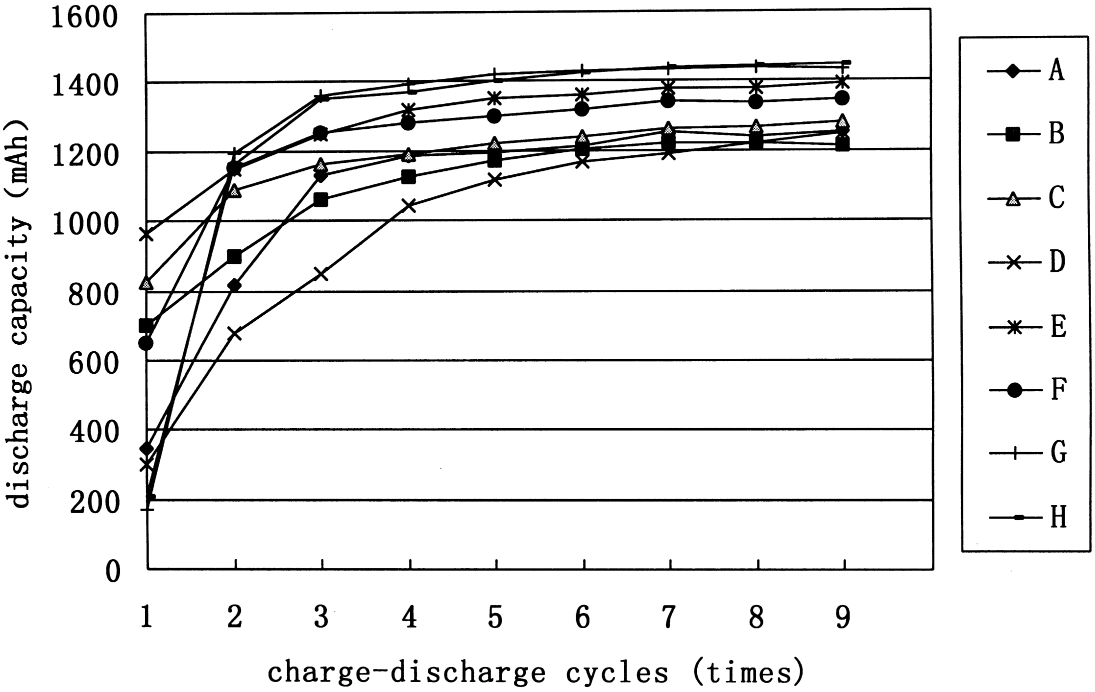

Fig. 3. Discharge capacity of a Ni–MH battery with charge–discharge cycle.

ninth cycle test, the capacity with regimes E, F, G and H is 50–100 mAh higher than that with systems A and C. This indicates that the charge capacity in the activation process strongly affect the battery's activation speed and the final capacity.

Thus, regimes E, F, G and H could be selected as suitable regimes. Regime H is suggested by us because its total activation time is less than the others.

4. Conclusions

1. The amount of electrolyte will affect the discharge capacity, discharge plateau voltage and the cycle life; the correct amount of electrolyte we selected in this study is 2.6–3.0 g.
2. The aging temperature has an effect on the battery's activation speed; the aging temperature should not be less than 20°C.
3. The correct aging time will benefit the battery's activation; a suitable aging time is about 7 days.
4. The result of battery activation is affected by the regime; the charge capacity in the activation process will affect the final capacity of the battery directly. The most suitable charge–discharge regime is

$$0.1\mathrm{C} \times 5\ \mathrm{h},\ /0.5\ \mathrm{h}/,\ 0.2\mathrm{C} \rightarrow 1\ \mathrm{V} \tag{1}$$

$$0.1\mathrm{C} \times 14\ \mathrm{h},\ /0.5\ \mathrm{h}/,\ 0.2\mathrm{C} \rightarrow 1\ \mathrm{V} \tag{2}$$

References

[1] M.W. Meng, M.D. Liu et al., Chin. J. Power Source 22 (4) (1998) 155.
[2] W.X. Lü, Chemical Power Source, Tianjing University Press, p. 241.
[3] Y.Q. Wang, Z.Y. He, Dianchi 27 (5) (1997) 226.
[4] JP 06 215763.