PERFORMANCE OF A PRISMATIC NICKEL / METAL-HYDRIDE (3.6 V / 13.9 AH) THREE-CELL BATTERY

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Abstract

The performance of a nickel metal-hydride 3.6 V / 13.9 Ah three-cell battery is reported in terms of charge/discharge characteristics. The metal-hydride negative electrodes were made of a stoichiometric AB_5 alloy with composition [Mm(Al-Mn-Co-Fe-Ni)$_5$] and nickel foam as current collector. The positive $Ni(OH)_2$/NiOOH electrodes were made on sintered nickel carrier. The effect of varying charge and discharge rate was examined.

Introduction

Nickel metal hydride (Ni-MH) technology has been used commercially since the early 1990's, mainly with consumer applications [1]. At the time, nickel cadmium (Ni-Cd) was the mainstream technology to which Ni-MH was often compared. Even in the early days, it was recognized that Ni-MH batteries not only is able to achieve higher energy density then Ni-Cd, but is also more environmentally friendly. Since both systems employed 1.2 V in nominal voltage also share many performance characteristics, it was relatively easy to adapt Ni-Cd applications for use with Ni-MH [2-4]. Up to now rechargeable batteries used for mining lamps were exclusively Ni-Cd battery system. In the present work the nickel metal-hydride three-cell battery used for mining lamps is investigated. The performances of the battery are demonstrated for the following conditions: charging up to 100, 110, 120 % of the nominal capacity, applying charging rates from 0.1 C to 1 C.

Experimental

The metal-hydride electrodes were prepared from [Mm(Al-Mn-Co-Fe-Ni)$_5$] alloy powder (< 100 μm grain size) and 10 wt.% nickel powder by mixing with 3% polyvinyalcohol (PVA) solution, and then pasted into a nickel foam with density 500 g m^{-2} (thickness 1.6 mm). The negative electrodes were then dried at 100º C before pressing. The thickness of the finished electrodes was about 0.6 mm. The positive $Ni(OH)_2$/NiOOH electrodes were prepared by impregnate a sintered nickel carrier. Before testing the negative electrodes composed of metal hydride electrode (MH) and the positive $Ni(OH)_2$/NiOOH electrodes were chemically preactivated in KOH solution.
Positive-limited, nickel / metal hydride cells were assembled by alternatively stacking twelve nickel-positive electrodes (average capacity: 1.2 Ah) and eleven metal-hydride negative electrodes (average capacity: 1.4 Ah). The positive electrodes were inserted into pockets made out of polyamide separator cloth. The positive and negative electrodes were

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welded to respective terminals and then placed in a polypropylene container (dimensions: 113 x 53 x 35 mm). The electrolyte was KOH solution with a density 1.20 g cm^{-3}.
Thus manufactured the nickel metal-hydride cells were subjected to formation. The cells were found to form and achieve their rated capacity values within about 5 charge-discharge cycles. During the first cycle, the cells were charged at the 0.05 C rate, and subsequently, at 0.1 C rates. The cells were typically discharged at 0.2 C rates.
The test battery was built of three Ni-MH cells connected in series, giving a nominal voltage of 3.6 V. Nominal capacity of this battery was 13.9 Ah. All results in this paper were obtained at room temperature.

Results and Discussion
The three-cell battery was subjected to various charge rates from 0.1 C to 1 C to determine its performance over a range of conditions.
The voltage and capacity characteristics were controlled according to the following conditions: charge from 100 % to 120 % nominal capacity, at the 0.1 C; 0.2 C; 0.5 C and 1 C rates. The battery was typically discharged at the 0.2 rates down to 3 V.
Figure 1-3 shows charge/discharge capacity of the prismatic three-cell battery at various rates.
The data show that the maximum efficiency for all the charge inputs (100, 110, and 120 %) is observed for the rates 0.5 C and 1 C.

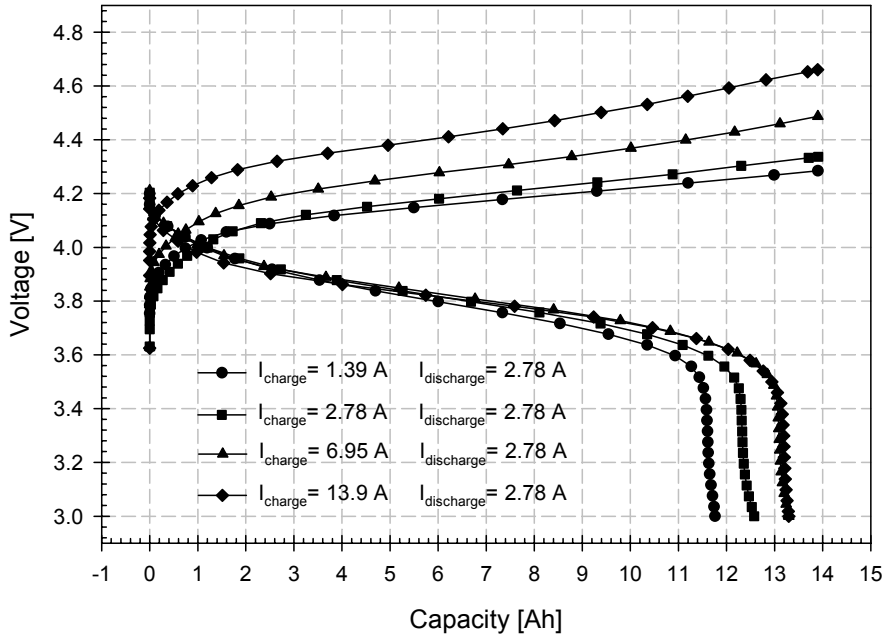

Fig. 1 *Performance of nickel metal-hydride three cells battery at various charge rates and at 100 % charge input*

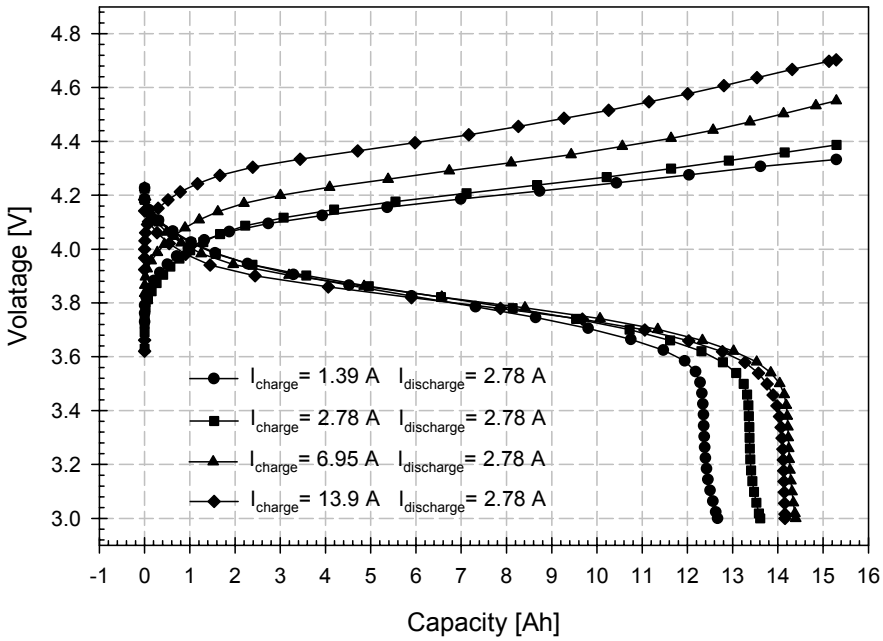

Fig. 2 *Performance of nickel metal-hydride three cells battery at various charge rates and at 110 % charge input*

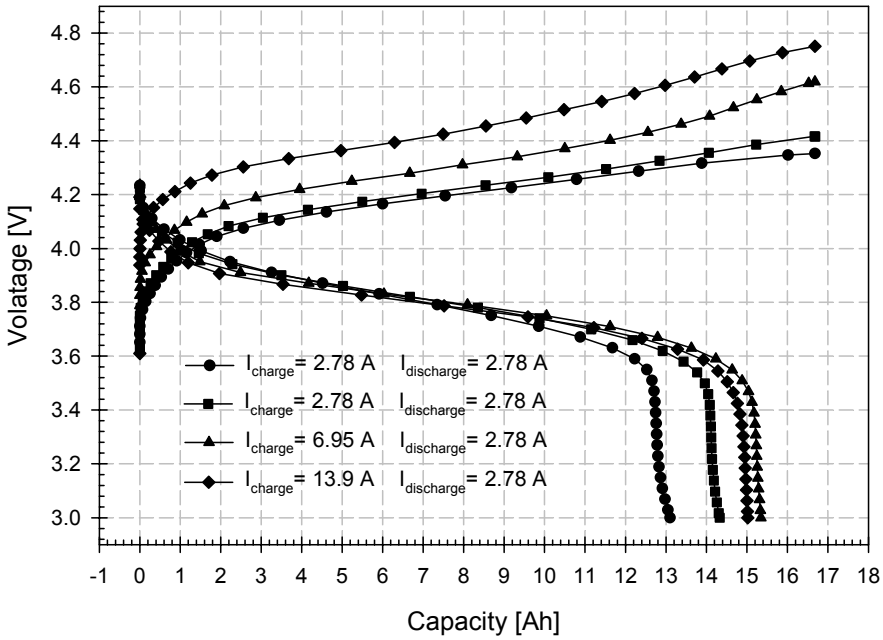

Fig. 3 *Performance of nickel metal-hydride three cells battery at various charge rates and at 120 % charge input*

For 100 % charge input, the battery was found to deliver a maximum discharge capacity value of 13.3 Ah at 1 C rate. The ampere-hour efficiency (discharge capacity / charge capacity • 100 %) obtained was 95.7 %. For 110 % charge input, the battery was found to

deliver a maximum discharge capacity value of 14.4 Ah at 0.5 C rate, and at 120 % charge input a maximum discharge capacity value of 15.4 Ah at 0.5 C rate. The ampere-hour efficiency obtained was 94.1 % and 92.0 % respectively. The battery shows a loss from 5 % to 12 % in ampere-hour efficiency for charge 0.1 C and 0.2 C rates. The data shows that a fast charge of the test three-cell battery allows better characteristics. As can be seen in Fig. 1-3 the battery shows an increase in voltage when the rate of charging rises from 0.1 C to 1C. Interestingly, high voltage during the charge process didn't influence negatively on the efficiency of this process.

Conclusions

The study suggests that the three-cell nickel metal-hydride battery can be successfully employed for producing commercial-batteries. Fast charging of the prismatic nickel metal-hydride three-cell battery resulted in higher efficiency, probably due to the application of nickel foam as negative (MH) electrode current collector. This current collector ensures good contact of the active material in all volume of the negative electrodes. The investigation of the prismatic Ni-MH three-cell battery designed and manufactured in the CLAiO was charging higher current with insignificant charge losses. In spite of increase of voltage during charging at various rates from 0.1 C to 1 C, the ampere-hour efficiency is relatively high. Probably only small amount of charge is spent on the water decomposition and loss of heat. The positive-limited configuration of the battery facilitates oxygen recombination during overcharge of the battery. The highest discharge capacity is obtained for the 120 % charge input and 0.5 C rate.

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