STUDIES ON THE APPLICATION OF PRISMATIC Ni-MH CELL AT LOW TEMPERATURES

M. Kopczyk[1], E. Jankowska[1], A. Sierczyńska[1]

[1] *Central Laboratory of Batteries and Cells, Poznań, Poland*

Abstract

The prismatic Ni-MH cells with nominal capacity 16.5 Ah, designed and manufactured in the CLAiO, were tested at low temperatures. The test cell shows high discharge capacities at low temperatures. Discharge capacity of prismatic nickel-metal hydride cells with pasted negative electrodes at 0ºC was determined as 18.5 Ah.

Introduction

Among the different types of electrochemical systems, nickel - metal hydride (NiMH) cells attract increasing attention due to several inherent advantages such as great tolerance to overcharge and overdischarge, good cycle life and high-rate charge-discharge capability [1-3]. The nickel-metal hydride cells are used in: communication, computers, camcorders, cellular phones, power tools and other home appliances. The Ni-MH cells can be promising as a new high performance energy sources for electric (EV's) and hybrid electric vehicles (HEV's) because of high energy density (180-210 Wh dm^{-3}, 60-70 Wh kg^{-1}) and power density (500-1000 Wh g^{-1}) [4-7]. The charge-discharge electrochemical process for the Ni-MH cell using $Ni(OH)_2$ as cathode, hydrogen storage alloy as anode and KOH as the electrolyte is the following: during the charging process $Ni(OH)_2$ at the positive electrode is oxidized to NiOOH, while at the negative electrode reduction of water produces atomic, adsorbed hydrogen. This hydrogen diffuses into the lattice of the intermetallic alloy to form metal hydride MH. The reactions are reversed during discharging [8-10].

One of the diagnostic parameters of Ni-MH batteries, used for assessment of them as a power sources for HEV's, is performance at low and high temperature conditions [11]. When the nickel-metal hydride cells are discharged at the temperatures below 0ºC, the discharge capacity becomes considerably decreased. In the temperatures above 0ºC this capacity decrease is only observed for the discharge current exceeding 3 C. The application of hydrogen storage alloy powders with appropriate composition leads to the increase in the discharge capacities at low temperatures. Much research works on improving the discharge efficiency for high-rate charges and discharges and at low temperatures. Up so far, temperature range 20-30 ºC has been recommended for the operation and storage of nickel-metal hydride cells.
In the present work, the low temperature charge-discharge characteristics of prismatic cells were determined. The prismatic Ni-MH cells with nominal capacity 16.5 Ah were designed and manufactured in the CLAiO.

Corresponding author: M. Kopczyk
Fax: +48-61-879-30-12, E-mail: kopczyk@man.poznan.pl

Experimental

The negative electrodes were prepared by pasting the electrode material into nickel foam as current collector. The electrode material made in the form of slurry by mixing hydrogen storage alloy powder (AB_5-type alloy having the nominal capacity 250 mAh g^{-1}), nickel powder and alcohol polyvinyl (PVA) as a binder. The mixture was pasted on the nickel foam (thickness 1,60 mm) and dried at 100 C. Electrodes prepared this way were subsequently pressed to a thickness of 0,6 mm and subjected to the activation process in 12M KOH solution. The positive electrodes $Ni(OH)_2$/NiOOH were prepared by filling a sintered nickel substrate with an active material.

The prismatic cell was composed of 12 negative electrodes and 13 positive electrodes. The positive electrodes were enclosed in pockets made of polyamide separators. The electrolyte was KOH electrolyte with a density 1.20 $g.cm^{-3}$. The role of separator was to prevent short-circuiting and to keep the appropriate amount of electrolyte between electrodes.

Results and discussion

Digatron BTS 600 system (Germany) was used to perform constant-current charge-discharge characterisation and monitoring of the studied cells. After assembling the Ni-MH cell, he was activated by 1 cycle at 0,05C rate charging for 32 h and 4 cycles at 0,1C rate charging for 16h and then 0,2C rate discharging down to 1V. Afterwards the capacity and voltage were tested according to the following conditions: charge at 0,2C for 8h and discharge at 0,5C rate down to 1V at various temperatures (Table 1).

Table 1 *Charge/discharge cycle at various temperatures*

No.	Temperature [ºC]	
	charge	discharge
1	-25	-25
2	-20	-20
3	-15	-15
4	0	0
5	15	15
6	20	20

The voltage and capacity characteristics at various temperatures for the test cell are shown in Fig. 1-2. The results presented in Fig.1 clearly show that the temperatures which the test cell is charged considerably the cell's en-of-charge voltage (EOC). Below 0ºC the EOC voltage raises markedly. The examined cell charged at -25ºC has the highest EOC voltage, about 1,70V. In the temperatures above -25ºC, considerable OEC voltage decrease is observed. The examined cell charged at 15ºC or 20ºC, show voltage about 1,45V and it is lower than that for the cell charged at -25ºC.

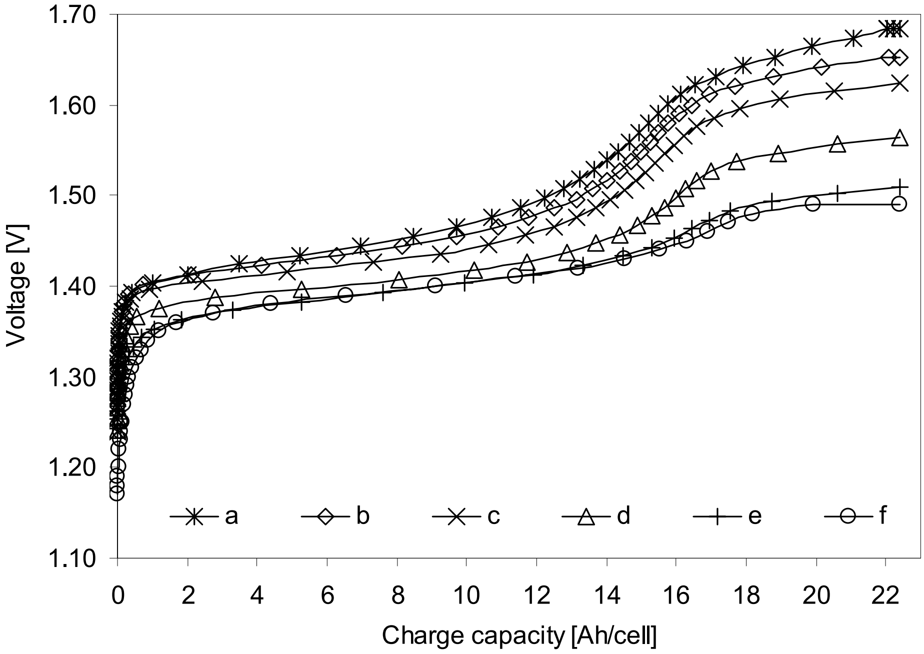

***Fig. 1** Voltages as a function of charge capacity of studied cell at various temperatures: (a) -25ºC; (b) -20ºC; (c) -15ºC; (d) 0ºC; (e) 15ºC; (f) 20ºC*

The discharge curves for the nickel-metal hydride cell for various temperatures are presented in Fig. 2. It is clearly visible that the discharge temperature significantly influences the cell's working voltages. Fig. 3 shows the cell's voltage dependence of the temperature under load. The cell's working voltage is understood in this work as the voltage in the point on the discharge curve corresponding to 9Ah of the charge which is approximately half of the discharge time and is designated as U_H. The value of U_H for the temperature 20ºC is 1.26V. When the temperature is lowered the U_H is obviously also diminished. This decrease of U_H is most pronounced between 20ºC and 15ºC and then below -15ºC. Between 15ºC and -15ºC there is an area of reasonably slow deterioration of the cell's performance in terms of the working voltage. Such a behaviour can be attributed to the decrease in the electrolyte conductivity at lower temperatures which causes an ohmic drop contributing markedly to the overall drop of the working voltage. However it is noteworthy that even at -25ºC the U_H remains fairly high (1.17V) and no really dramatic decrease of the working voltage is observed. This proves a good temperature capability of the examined cells.

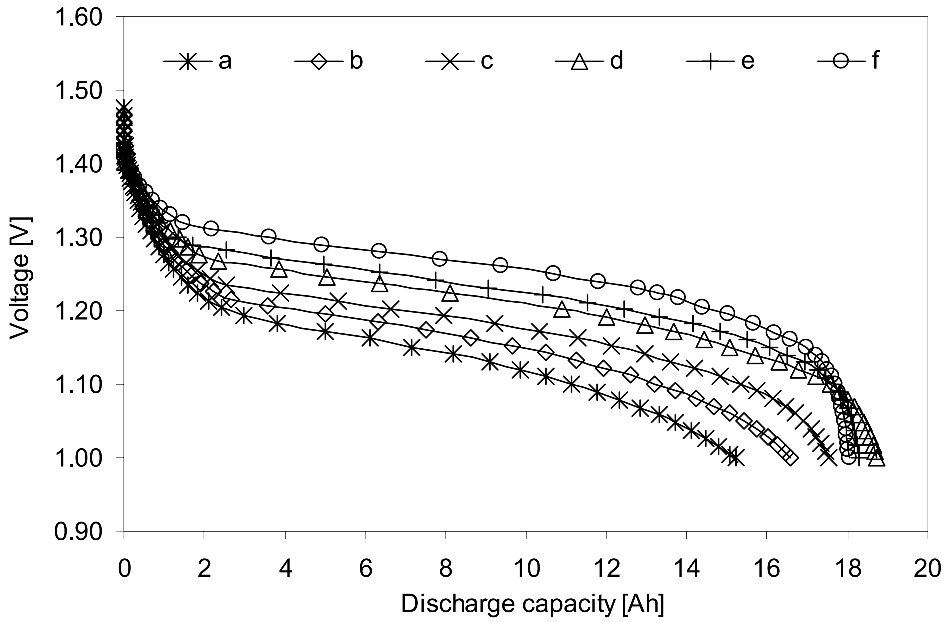

***Fig. 2** Discharge characteristics of the prismatic cell at various temperatures: (a) -25ºC; (b) -20ºC; (c) -15ºC; (d) 0ºC; (e) 15ºC; (f) 20ºC*

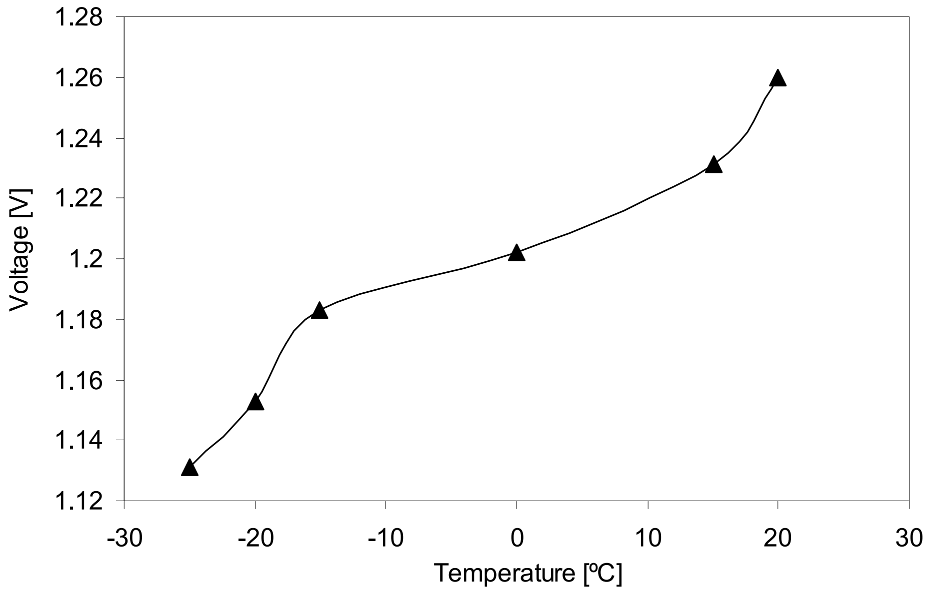

***Fig. 3** The cell's working voltage (U_H) dependence of the temperature*

The capacities of the cell remains fairly stable down to 0ºC (over 18Ah, see diagram in the Fig. 4). Below this temperature a slow capacity decrease is observed to reach the value of 15 Ah at -25ºC. In the temperature range from -20ºC to +20ºC the discharge capacities of the investigated cell has exceeding the cell's nominal capacity (up to 18,5Ah). Decreasing the temperature below 0ºC leads to a change in the discharge capacities.

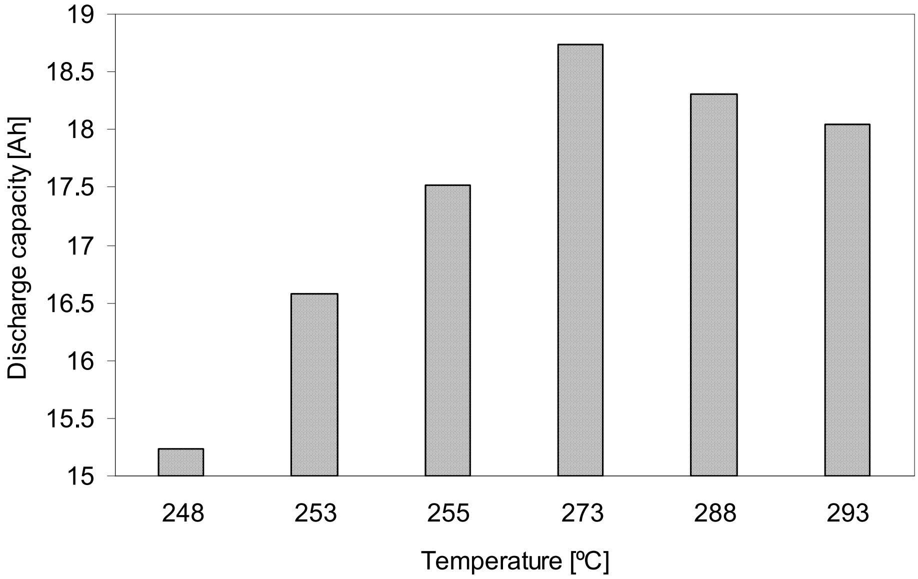

Fig. 4 *Temperature dependence of the cell's discharge capacity (Q_{disch})*

The temperature range from -15ºC to +20ºC is a range, in which the cell has the best discharge capacity.

Conclusions

Studies on the application of prismatic cells with pasted negative electrodes were done. The carried out studies show that the changed of temperatures influence the charge-discharge voltage and capacities of Ni-MH cells. The examined cell, which was designed and manufactured in the CLAiO, is characterised by good discharge capacities at temperature range from -15ºC to +20ºC. The studies indicated that it will be possible to exploit this cell in low temperatures.

Acknowledgements

Financial support was provided by the Polish National Committee for Scientific Research (KBN) under contract No. 5 T07B 00325. One of us (E.J.) has been supported by the Fellowship from the Foundation for Polish Science (2004).

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