

Decrystallization with high current pulses technique for capacity restoration of industrial nickel-cadmium battery

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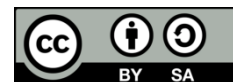
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High battery temperature

ABSTRACT

The process of crystallization occurred due to the process of charging and discharging during the usage of the Nickel-Cadmium (Ni-Cd) battery where crystalline formed on the surface of the battery plate. This situation causes the impedance of the Ni-Cd battery increased and contribute to the increment of the battery temperature and battery impedance. High battery temperature will cause the performance of Ni-Cd battery deteriorates. Therefore, this study is investigated on the performance of industrial Ni-Cd battery during the process of crystallization and de-crystallization with high current pulses. By this technique, it is capable to break the formed crystalline to recover back the capacity loss and enhanced the performance of Ni-Cd battery. Therefore, the study results shown that the life cycles and capacity of the Ni-Cd battery increased up to 41% of its capacity after the de-crystallization take place by injecting high current pulses. Consequently, the life span of the Nickel-Cadmium battery enhanced, and the battery is revived.

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1. INTRODUCTION

In recent years, high needs in the maintenance of batteries is emerging due to the energy transition from vehicles that used combustion as energy to electrical energy [1-5]. With this the emission of greenhouse gases is reduced as it become major concern issues nowadays [6-9]. Battery is a technology that capable to transform chemical energy to electrical. The energy stored in the battery is used through the process of oxidation-reduction where the movement of the electron produced an electromotive force which also known as voltage. Batteries are generally classified as either primary or secondary. Primary batteries are the type that may only use one time because the active materials are used up when the cell discharges. Once the primary battery is discharged completely, it is discarded. Meanwhile, the secondary batteries may be used repeatedly because the chemical reaction which produces electrical energy can be reversed by recharging the battery. Ni-Cd batteries is one of the secondary batteries that have used in massive applications in different industrial area especially in transportation and UPS due to their high performance and able to recharge rapidly [10]. Moreover, the Ni-Cd battery have high energy density.

In the Ni-Cd cell, nickel oxyhydroxide (NiOOH) is the charged active material in the positive plate. During discharge, the charge nickel hydroxide goes to a lower valence state by accepting electrons from

external circuit Ni-Cd battery. Meanwhile, cadmium (Cd) metal is the charge active material in the negative plate. During discharge it is oxidized to cadmium hydroxide and releases electrons to the external circuit. Also, an aqueous solution of potassium hydroxide is used as their electrolyte. These reactions occur in the electrolyte which acts as a medium of ion transfer only, therefore there are no significant changes that can be observed during the charge or discharge cycle.

However, the performance of the Ni-Cd batteries degrades over time after undergoing charging and discharging processes due to the formation of crystalline [11]. Crystallization is an electrochemical reaction that occurs when the Ni-Cd battery is in a discharge state that builds gradually on the battery cell plates [12-13]. During the discharging process, the Nickel-Hydroxide in a liquid state transforms into solid crystalline and forms on the plate surface of the battery. As the formation of the crystalline is accumulated, the size of the surface area of the plate decreases and the internal impedance of the Ni-Cd battery is higher. Thus, the battery temperature also increases [14]. This condition causes the Ni-Cd battery to suffer from capacity loss as the life expectancy is correspondingly reduced [15-17]. The formation of the crystalline also contributes as a factor that causes the memory effect in the Ni-Cd battery [18-19].

In order to overcome this issue, the process of de-crystallization is required. There are few researches that have been conducted to improve the performance of Ni-Cd battery. One of the ways is using the conventional way where additives such as carbon powder, carbon nanotubes, titanium dioxide, glass fibres, silicon dioxide, aluminium oxide and boric acid [20-22] are added. Other than that, the application of low current and high current pulses method to restore the capacity of the batteries is also possible [23, 24]. However, these methods have their own merits and demerits in terms of the effectiveness of the technique. Therefore, in this study, de-crystallization with the technique of high current pulses is chosen as the study focus where the injected high current pulses force the electrons at the battery plate to move and a chemical reaction occurs. To generate high current pulses during de-crystallization, a power converter [25, 26] is considered to generate DC pulses as the main power supply from the main grid in AC state.

There are two types of crystalline which are soft crystalline and hard crystalline. Normally, most of the soft crystalline is able to break down into electrolyte through the normal process of discharging. But, soft-crystalline that is unable to break during the discharging process will form hard-crystalline on the battery plate after a period of time. Therefore, high current pulses are required to be injected to the Ni-Cd battery so that some of the hard crystalline in solid state is able to break down and transform into liquid state of Nickel-Hydroxide. Hence, the aim of this study is to observe the significant parameters of the Ni-Cd battery such as battery group voltage, discharging time and battery capacity during before and after de-crystallization by using the technique of high current pulses.

The remainder of the paper is organized as follows. A brief technical framework and experimental block diagram description is discussed in Section 2. The results and analysis are deliberated in Section 4. Lastly, Section 5 summarizes all the findings.

2. DESCRIPTION OF DE-CRYSTALLIZATION SYSTEM

2.1. Battery Regenerator

Battery regenerator is used to help the battery undergo capacity restoration (reviving battery) in order to improve the performance of the degraded batteries and extend the battery life. For Ni-Cd battery, de-crystallization process is one of the refurbishment techniques to reverse the crystallization of the Ni-Cd battery. De-crystallization is achieved by sending high current pulses that break down the crystalline layer formed by amorphous Nickel-Hydroxide. The battery regenerators restore the lost battery capacity through carefully controlled current pulses. These current pulses sent by the rectifier controller are sufficient to break soft-crystallization and hard-crystallization of Nickel-Hydroxide. By this, the capacity of the regenerated battery is enhanced, and the life cycles of the battery extend. Besides, the process of the de-crystallization also can be achieved by sending low frequency of electrical pulses. This results in the capacity of the regenerated battery and the life span of the battery being increased.

2.2. High Current Pulses

During the process of de-crystallization, current pulses with high power are applied to the Ni-Cd battery to break the formed crystalline according to the feedback of the battery. High battery voltage indicates high internal impedance which indicates the crystalline formation on the surface of the plate is high. Therefore, high current pulses in the range of 100 A to 300 A are required. However, if the voltage detection is low, the working principle that applies is vice versa. The block diagram of the working principle of high current pulses in de-crystallization of the Ni-Cd battery is shown in the following Figure 1.

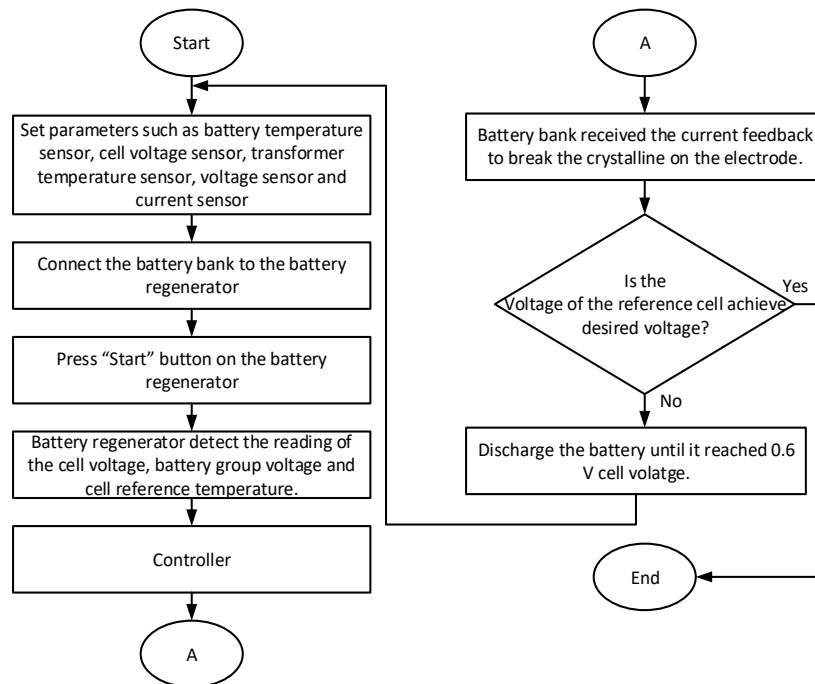


Figure 2: Flowchart for the reviving battery process.

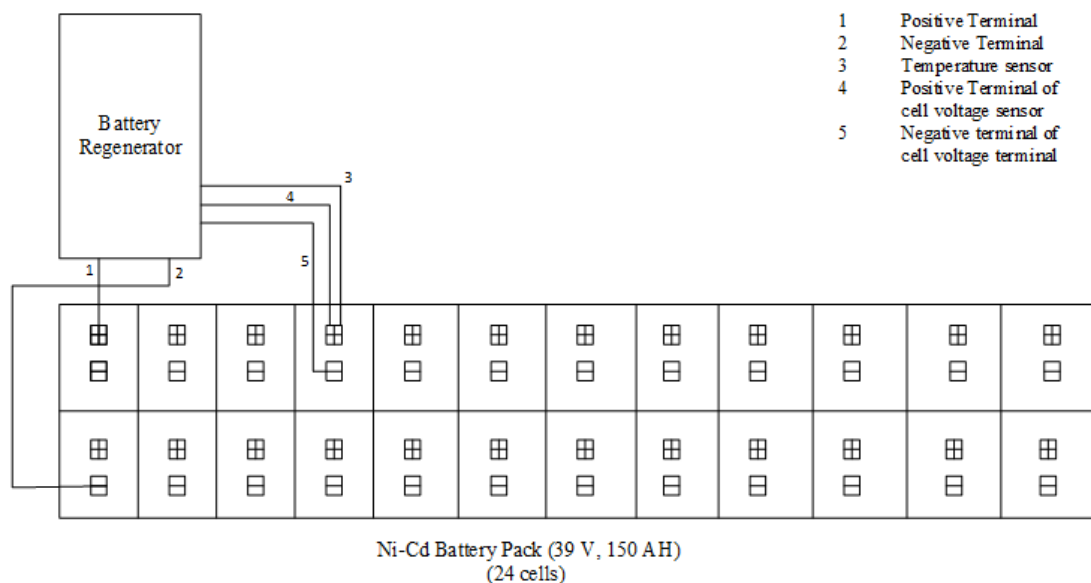


Figure 3: Block diagram of battery regeneration setup.

When the Ni-Cd batteries is received, proper inspections are performed on the battery by filling the service form, battery cleaning and repair any visible external damage. Then, the received Ni-Cd batteries will undergo complete charging process by connecting it to the charger machine with set parameters. After the charging process is complete, the Ni-Cd batteries undergo for discharging process by using discharger machine with set parameters. During the discharging process, the Ni-Cd batteries undergo deep discharge where the discharge voltage is set to 0.6 V to clear the memory effect [10]. After completing the discharging process, the batteries were ready to enter regeneration process. The process is repeated until the desired battery voltage which is above 0.8 V is achieved.

3. RESULTS AND ANALYSIS

In this section, results analysis on de-crystallization of Ni-Cd battery is discussed. Before the de-crystallization process is start, capacity test is performed on the Ni-Cd battery with 80% of depth of discharge to identify the initial performance of the Ni-Cd batteries. The observed parameters are battery group voltage, discharged time and capacity of the battery. The graph of discharged battery group voltage before and after de-crystallization is shown in Figure 4.

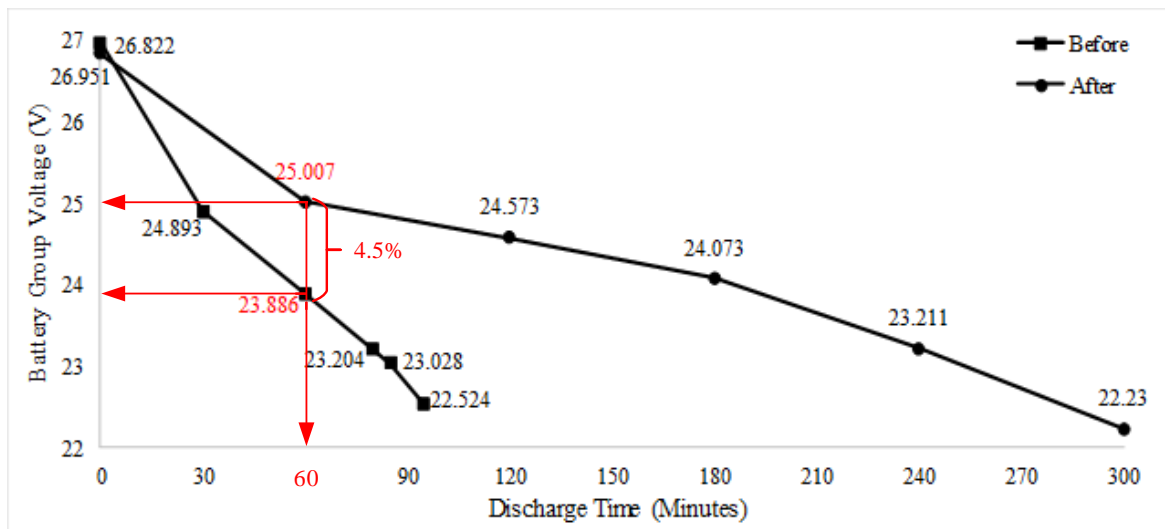


Figure 4: Graph of battery group voltage against discharge time.

From the graph that presented in the Figure 4, it is observed that the trend of the Ni-Cd battery total voltage is decrease against time. Before the process of decrystallization, most of the Ni-Cd battery voltage is on the average of 1.3 V and the total Ni-Cd battery voltage is 26.95 V. After an hour of discharged before decryatallization, the battery group voltage dropped 10.9% from the initial battery group voltage and the time taken for the Ni-Cd battery bank complete discharged is 95 minutes. This happened due to the accumulation of crystalline at the surface of the Ni-Cd battery electrode which result the internal resistance of the Ni-Cd battery is high and create memory effect. The high internal resistance in the Ni-Cd battery cause the battery unable to deliver the current to the load effectively. Moreover, high internal resistance in the Ni-Cd battery leads to increment of temperature and voltage to drop. Therefore, the Ni-Cd battery is required to undergo the de-crystalline process to break the crystalline formation on the battery plate and deep discharged to clear the memory effect.

After the process of de-crystallization with high current pulses technique, the battery voltage dropped 7.2% from the initial battery group voltage after an hour and the total discharged time is 300 minutes. From this results, the difference percentage of the battery group voltage at 4.5% between before de-crystallization and after de-crystalline after an hour is observed. Moreover, the discharged time after the Ni-Cd battery bank undergo de-crystallization is extended for 205 minutes. This indicated that the technique of high current pulses is able to enhance the capacity of the Ni-Cd battery and thus the life cycles of the Ni-Cd battery is improved. This is because the crystalline that formed on the surface of the electrode is broke by the injected high current pulses which up to 150 A into the Ni-Cd battery. Hence, the discharge capacity of the Ni-Cd battery is increased from 22 AH to 58 AH. The performance parameter of the Ni-Cd batteries before and after regeneration is tabulated as in Table 3.

Table 3: The overall performance parameter of Ni-Cd batteries.

	Before Regeneration	After Regeneration	Difference
Total discharge capacity	22 AH	58 AH	36AH
Time of discharge	1 hour 32 minutes (95 minutes)	4 hours 15 minutes (255 minutes)	2 hours 40 minutes (160 minutes)
Percentage of capacity	40%	81%	41%

With reference from Table 3, it is observed that the time of discharge is enhanced from 95 minutes to 255 minutes and capacity percentage of the Ni-Cd battery is increased for 41%. Besides, the total discharge capacity of the Ni-Cd battery is improved from 22 AH to 58 AH after the decrystallization. With this, it is proved that the technique of high current pulses in restoring the Ni-Cd battery capacity is reliable.

4. CONCLUSION

Based on the results discussed, the de-crystallization of Ni-Cd batteries with high current pulses managed enhanced the performance of the Ni-Cd battery as the discharge capacity is increased for 41% and the life cycles of the Ni-Cd battery is extended as the discharging time is improved 160 minutes.

At first, the period of the Ni-Cd battery usage is short due to the formation of crystalline that have accumulated on the surface of the battery plate during the process of charging and discharging process. Due to this crystalline formation, the internal resistance of the Ni-Cd battery is high as the discharging time of the battery shorten and thus the performance of the battery declined.

However, with high current pulses the formation of the crystalline is capable to break. Consequently, the parameters of the Ni-Cd battery such as battery capacity, battery cell voltage and life cycle of the Ni-Cd battery is improved and the Ni-Cd battery is revived. Last but not least, the used technique is environmental friendly as it use electrical energy during the process of decrystallization.

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