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Energy Efficiency of Zinc-Carbon and Standart Accumulator

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Abstract – Energy Efficiency of Zinc-Carbon accumulator and Standart Accumulator Model 6N4-2A-4 have been studied. The accumulator has been made using Zn-C as an electrode which composes of three cells with sulfuric acid electrolyte. Two setups were used to assembly the cell namely series setup and parallel setup. Three types accumulator will be tested for charging and discharging characteristics to know the energy efficiency of Zinc-Carbon Accumulator with series configuration, Zinc-Carbon Accumulator with parallel setup and Standart Accumulator Model 6N4-2A-4. Operational voltage 1.39 – 7.96 V, 1.06 – 2.69 V and 1.73 – 7.55 V was applied to the charge and discharge process. Charging and discharging performances were measured and analyzed using three cycles for 36 hours. The results showed that Standart Accumulator Model 6N4-2A-4 is better than both the accumulators regarding the average energy efficiency. The average energy efficiency for Standart Accumulator Model 6N4-2A-4 is 67.9 % whereas Zinc-Carbon Accumulator with series configuration and Zinc-Carbon Accumulator with parallel configuration resulted in 35.3 % and 63.3 %, respectively.

Keywords: *Accumulator, Electrode, Energy Efficiency*.

1. INTRODUCTION

Electrodes Zinc - Carbon is a constituent material of alkaline batteries that have the nature of non-rechargeable batteries or primary cell battery, it is designed to be fully discharged only once, and then discarded [1]. People usually use and throw it carelessly so that it gives a very bad impact on the environment, it is because the content of the spent primary cell batteries generate specific residues such as mercury, zinc, manganese and other heavy metals [2], which is very susceptible to damage the environment and threaten public health [3]. Increased environmental awareness and consumption of raw materials led to tightened regulations on primary batteries worldwide. These rules and various things of issues - environmental issues pushed to collect the spent primary battery aimed at recovery of further use of metal [4]. One is in Turkey; the regulations on the Control of Spent Battery and Accumulators was published on August 2004 [5]. In Indonesia, regulations on environmental pollution by dry cell batteries have been published by the decision of environmental state minister and provincial regulation in Yogyakarta No. 2 of 2012 on the management of hazardous wastes and toxic [6,7].

Based on the regulation on environment ministers, Zinc is one of the hazardous heavy metals that pollute the environment [6]. So in this study, zinc metal developed to be active material as a concept of energy storage technique that is shaped like an accumulator. In the previous studies have been developed as an active material of a secondary battery design [8,9]. Likewise with carbon electrodes are also used previous studies as an inert material that has an influence as the good collector current behavior in the lead acid battery system [10,11]. Electrode system design uses a sandwich models, as is done on the research [12,13].

2. METHODS

In this study, using Zinc as the negative electrode made with levels of 72% with dimensions of 7 x 4.5 cm^2 total of 24 plates, while the carbon material as a positive electrode with a 94% level with dimensions of 7 x 4.5 cm^2 up to 12 plates. Connecting process at zinc plate bonded with a tin trunk that has dimensions of 28 x 4.5 cm^2 as well as carbon plate with the same connecting treatment. Both electrodes are stacked into one like a sandwich model and between the two sides were given a separator made of insulator material so that the two are not in contact with each other as is done in research [12,13]. This pile is composed of three layers with the configuration Zn | C | Zn. This electrode layer configuration was put into a cell with dimensions of 6 x 5 x 32 cm^3 in which there is a solution of sulfuric acid.

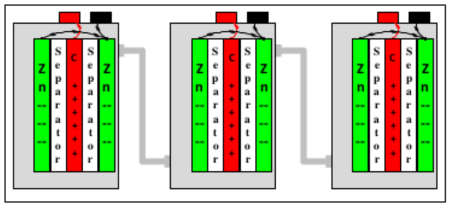


Figure 1. The Design Of Cell System.

Figure 1 shows an accumulator cell system block diagram[14]. Three cell system in which each one cell system connected in series with the pipe.

3. RESULTS AND DISCUSSION

In this study consists of two electrodes that is Zink electrode and inert electrode. Zink is as the anode electrode and inert electrode is carbon as the cathode. While the electrolyte used is sulfuric acid (H_2SO_4) at concentration of 0.1 M. The discharge and charge reaction on both electrodes is as follows [16,17]:

Cathode : $O_2\,(g) + 4H^+\,(aq) + 4e \rightarrow 2H_2O\,(l)$ $E^o = +1,23$ V

Anode : $2Zn\,(s) \rightarrow 2Zn^{2+} + 4e$ $E^o = -0,76$ V

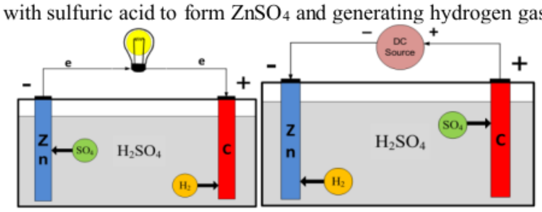
Discharge Reaction Cells : $2Zn(s) + O_2\,(g) + 4H^+(aq) \rightarrow 2Zn^{2+} + 2H_2O\,(l)$ $E^o_{Cell} = +1,99$ V

Cathode : $2Zn^{2+} + 4e \rightarrow 2Zn\,(s)$

Anode : $2H_2O\,(l) \rightarrow O_2\,(g) + 4H^+\,(aq) + 4e$

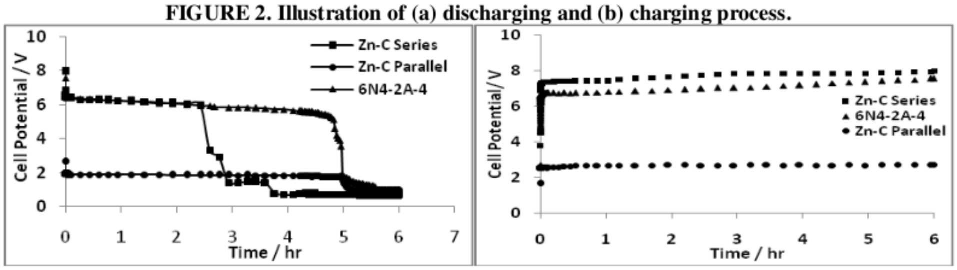
Charge Reaction Cells : $2Zn^{2+} + 2H_2O\,(l) \rightarrow 2Zn\,(s) + O_2\,(g) + 4H^+\,(aq)$

The discharging and charging process illustrate in figure 2, the chemical reaction at the discharge process is indicated by the formation of hydrogen bubbles (H_2 gas) at positive pole and oxygen gas in the anode when charging.On the negative pole Zink metal at room temperature have a solid form and has a negative standard potential ($E° = -0.76$ V), it means that zinc metal is easily oxidized by releasing two electrons forming Zn^{2+} ions. Zn^{2+} ions will react with sulfuric acid to form $ZnSO_4$ and generating hydrogen gas [15,17].



(a) (b)

FIGURE 2. Illustration of (a) discharging and (b) charging process.



(a) (b)

FIGURE 3. Constant current 0,5 A (a) discharge and (b) charge characteristics.

Figure 3 shows that the cell energy generated Standart Accumulator Model 6N4-2A-4 is greater than the Accumulator Zn-C series, but the time span discharge process between Standart accumulator 6N4-2A Model-4 and Accumulator Zn-C parallel has span time is almost the same. Based on the curves in Figure 3, the operational voltage Standart Accumulator Model 6N4-2A 4th is 1.73 Volt to 7.55 Volt. Accumulator Zn-C series is 1.39 volts to 7.96 volt, accumulator parallel is 1.06 Volt to 2.69 Volt. The chemical process that happens is the opposite of the process of discharging. At the anode occurs oxidation reaction, the water will form oxygen gas. Furthermore, the zinc cathode $ZnSO_4$ is reduced forming solids Zinc. This happens because the carbon electrode is an inert material, which means it will not dissolve in acidic or alkaline solution so that there is no reaction. Because the electrolyte used is a sulfuric acid electrolyte that has negative ion SO_4^{2-} then water reacts at the anode. While on the cathode metal ions Zn^{2+} has a smaller potential than water reducible form a solid metal [16]. In Figure 3b shows the charging energy consumption in the Zn - C Accumulator series is bigger than all the graphs voltage charging performance accumulators Zn - C parallel and Standart Accumulator Model 6N4-2A-4.

Test of charge/ discharge cycle is done to look at the performance of each type of Accumulator. Based on the reference to the technical specifications data of Standart Model 6N4-2A-4 states that discharging duration required for 0.5 Ampere [19]. The data can be used as a reference for comparison with Zn-C Accumulator. The cell parallel circuit configuration can add the sectional area of the metal electrode so that Zink can reproduce Zink metal oxidation reaction and increase the amount of formation of the Zn^{2+} ion to react with sulfuric acid to form $ZnSO_4$.

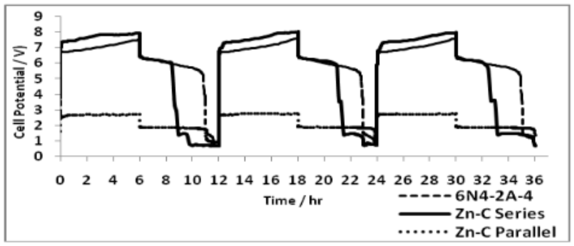


FIGURE. 4. Cell voltage vs. time response to three charge/discharge cycles at constant current 0.5 A.

In Figure 4, shows the test result of charge/discharge cycles in each accumulator of three cycles for 36 hours. Zn - C Accumulator parallel has the best performance. The longer carried out the process of charge - discharging for 3 cycles, the curve of surface area during discharge is getting bigger. Based on testing 3 cycles of charging-discharging by using equations energy efficiency[18], the value of the average energy efficiency of each accumulator is 35.3% (Zn - C series), 63.3% (Zn - C parallel), and 67.9% (Standart Model 6N4-2A -4), respectively.

4. CONCLUSIONS

Operational voltage for each accumulator were 1.39–7.96 V (Zinc–Carbon series configuration), 1.06–2.69 V (Zinc –Carbon parallel configuration) and 1.73–7.55 V (Standart Accumulator 6N4-2A-4). The process of charge - discharging is performed 3 times over 36 hours on each type of accumulator. As a result, Standart accumulator Model 6N4-2A-4 has the best performance. The average energy efficiency for Standart Accumulator Model 6N4-2A-4 is 67.9 % whereas Zinc-Carbon Accumulator with series configuration and Zinc-Carbon Accumulator with parallel configuration resulted in 35.3 % and 63.3 %, respectively.

5. ACKNOWLEDGMENTS

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