The Rejuvenation of Valve Regulated Lead Acid (VRLA) Battery with Pulse Width Modulation (PWM) Charging and Ultrasonic

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Abstract

The objective of this research is to investigate the possibility of rejuvenation of the valve-regulated lead-acid (VRLA) batteries, which have been used. Because the performance degradation of batteries is strongly related to the accumulations of lead sulfate ($PbSO_4$) crystals at the battery cathodes, the rejuvenation of batteries could be achieved by removing the $PbSO_4$ crystals. We hypothesized that the pulse-width modulation (PWM) charging and ultrasonic cleaning might be able to eliminate the deposited $PbSO_4$ crystals at the battery cathode, resulting in better battery performance. Our results indicated that PWM cannot be used to rejuvenate the VRLA batteries with only two cycles of charging. Interestingly, while the ultrasonic can be used to clean the $PbSO_4$ crystals pre-deposited on the lead substrates in a liquid media, it is not possible to remove the accumulated $PbSO_4$ crystals at the cathodes in the gel media of VRLA batteries. It is expected that ultrasonic cleaning might be able to rejuvenate used flooded lead-acid batteries by specifically removing the deposited $PbSO_4$ crystals at the cathode.

1 Introduction

Electric power is the most needed to drive the command system for each operation in various industries. And including drilling rigs located far away from the ground or in the area of electricity. This is why renewable energy, such as solar cells. It is one of the suitable alternatives for using to generate electricity to drive various commanding systems within the oil rig. In which the solar panel relies on solar energy sources to store energy from the daytime in the battery to be used at night without sunlight. When the battery is used for a long time, the accumulation of lead-acid crystals at the polarity of the battery, which is one of the reasons for the deterioration of the battery performance. Usually, the internal reaction of the battery is crystalline lead-acid sulfate. The reaction can lead to the reaction of lead and lead oxide by charging, but due to the reverse reaction of lead sulfate crystals can only partially reverse. Causing irreversible crystals to accumulate in the negative polarity of the battery intensively. Due to the high crystallization of sulfate crystals, which can reverse the reaction via lead charging at the cathode and only some lead oxide at the anode resulting in reduced capacitance lost potential and increase internal resistance. The resulting crystalline sulfate has high crystallinity and large sizes may be caused by discharging for a long time or discharging by itself (Self-discharge) causing the formation of new crystals (Recrystallization) and the growth of crystals. Also, the growth of sulfate crystals depends on the concentration of sulfuric acid. Resulting in a reduced battery charge, losing more voltage and internal resistance. This disadvantage leads to the need to buy a new battery to replace the old one. And disposal of damaged batteries will incur additional costs for disposal. [1- 4]

The main point of this research is to describe the recovery of batteries caused by sulfate formation. From previous research [5-11], ultrasonic has helped to increase the amount of lead oxide. And reduce gas storage in the anode area Resulting in increased capacity of the battery.[12] Therefore, in this research, the ultrasonic performance of the VRLA battery was studied. This work aims at studying the VRLA batteries controlled by water that occurs during the discharge reaction. The liquid electrolyte can cause bubbles to affect the crystalline sulfate that binds to the polarity.

Restoring the effectiveness of valve-controlled lead-acid batteries can also be done with pulse width modulation (PWM) charging, which is generally high rate charging (High electric current) helps to convert lead sulfate into the lead. But can’t lead to large lead that high crystalline (Hard sulfate) completely into the lead and also causes hydrogen gas. According to the pulse, a charge will be charged with the frequency of the current, affecting the current concentration of the surface. Resulting in as much less hydrogen as possible because Faradaic resistance between the induced electrodes to lead sulfate into the lead. So, the VRLA battery can extend its life. [4]

Therefore, using the worn-out battery again, it will help reduce environmental problems and save charges by disintegrating the lead-acid crystals attached to the cathode. Because of the deterioration of the battery.

2 Experimental Methods

The VRLA batteries are the Sonnenschein A602 / 600 with an electrolyte as an acid gel that has been used. The research is divided into 3 parts: The first examine microstructure and chemical composition of element plates in VRLA battery by SEM (Scanning Electron Microscope) and XRD (X-ray Diffraction) respectively. The second and third study effect of the pulse-width modulation (PWM) charging and ultrasonic cleaning on the efficiency of the VRLA battery.

So, study of effect PWM charging on battery performance, which tests the discharge efficiency of the batteries before and after charging with PWM according to IEC 60896-21:2004-02 standards. The test conditions controlled by valves are as follows: Control current is 22 amps, the temperature is 20 ± 2 degrees Celsius, discharged to the voltage equal to 1.80 volts. For testing with the pulse width modulator of the Morning Star Model PS-30, the current frequency range of approximately 271 Hz, connected to the circuit with the battery. In which connecting the battery to the pulse width modulator charger, it is necessary to series connect at least 12 volts batteries by connecting all 6 units.

To study the ability of lead sulfate crystals removal on negative plate of VRLA battery by ultrasonic cleaning in sulfuric acid liquid and sulfuric acid gel (obtained from the inside of the battery) at the frequency of 40 kHz, electric power at 100 watts for 20 minutes, 40 minutes and 60 minutes. Then, conducting an electrochemistry experiment, which is similar to the process of crystallization of lead sulfate, which has changed the voltage to no more than 2 volts. And examine the surface with SEM and analyze the percentage of weight difference of the negative plate before and after the ultrasonic cleaning testing.

3 Result and discussion

3.1 Effect of pulse-width modulation charging to VRLA battery

The results in the discharge test after the battery has passed both pulse width modulation charging in 2 times. It can be seen in Figure 1 and Table 1. It is found that the battery No.1 and No.2 used discharge time for the 1st discharge (2nd discharge) are 29 hours 14 minutes (30 hours 16 minutes) and 31 hours 5 minutes (30 hours 56 minutes) or all show in electric capacity are 643.13 Ah (655.87 Ah) and 683.83 Ah (680.53 Ah). Which have the similar values between the 1st and 2nd discharge (less than 1-hour difference), and when comparing the graphs of the 1st and 2nd decay tests, the graph lines in the 2nd discharge tend to discharge with a constant slope than the 1st test. When considered to be able to predict that pulse width modulation charging, can improve battery performance. For charging and discharging of VRLA batteries, directed by a valve to control the charging voltage and discharging. It is expected that pulsed charging will cause the reaction to be entering the porous area of the lead plate. Constant high current which makes the reaction of the crystal formation has a large crystal on the surface of the lead plate. Causing discharging to be unstable as with pulse charging. [3-4]

In general, if the pulse charge is used for a long time, it can be seen that the battery connected to the pulse width adjustment can charge higher than batteries that use a normal turn-off. Around 70-80%. Charging of pulse width adjustment helps to prevent overcharging or lack of capacitance of the polarity. Resulting in the polarity not decaying itself and not causing sulfate on the polar surface.

PWM charging	Discharge time (Hour: minute)	Electric Capacity (Amp-hours; Ah)	Efficiency (Percent)
Standard of battery's performance	37.57	826.50	100
PWM 1st battery No.1	29:14	643.13	77.81
PWM 1st battery No.2	31:05	683.83	82.74
PWM 2nd battery No.1	30:16	655.87	79.36
PWM 2nd battery No.2	30:56	680.53	82.34

Table 1: PWM charging results

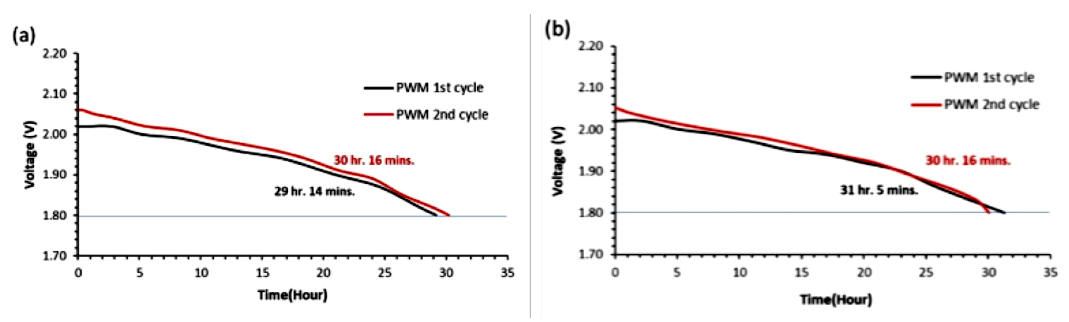

Figure 1: (a) The result of the 1st battery discharge test and (b) The 2nd battery discharge test result

3.2 Effect of ultrasonic cleaning to VRLA battery

The SEM images showing the accumulation of dense lead sulfate crystals are characterized by a random layer across the surface. When examining crystals with X-ray diffraction analysis. It was found that the lead-acid crystalline structure at planes 210 102 220 and 221 according to JCPDS No. 89-3750. Lead crystal structure with the substrate at planes 211 202 and 303 JCPDS No. 87-0663 and the peaks listed as the peaks of the lead oxide group shown as in Figure 2.

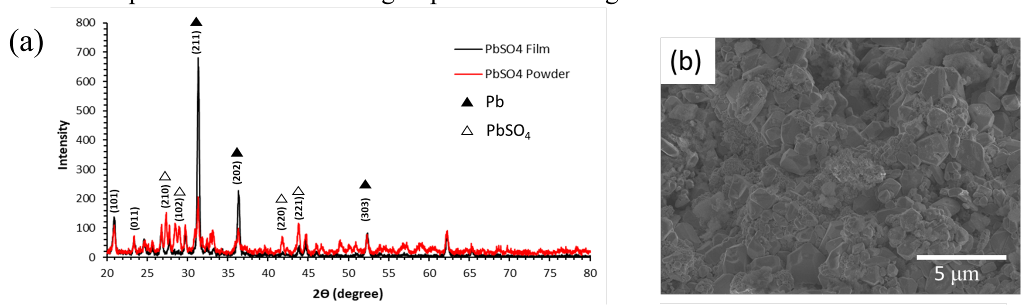

Figure 2: (a) The X-ray diffraction pattern of the lead sulfate crystals and (b) Morphological from SEM of the lead sulfate crystals from the cathode plate of the VRLA battery

Next, the study of the removal of lead-acid crystals from the negative plates of the VRLA battery by analyzing the weight loss. Found that the negative plates have been ultrasonic in the sulfuric acid gel electrolyte (which is a semi-solid), so after the ultrasonic does not change the weight as in table 2.

Time of ultrasonic	Weight before ultrasonic (g)	Weight after ultrasonic (g)	Loss Weight (g)	Efficiency (%)
20 min	6.188	6.188	0	0
40 min	6.341	6.341	0	0
60 min	6.487	6.487	0	0

Table 2: Ultrasonic test results in the sulfuric acid gel electrolyte

And the results of the negative plates have been ultrasonic in the sulfuric acid electrolyte, which found that efficiency of detachment removal of lead-acid crystals after ultrasonic according to the ultrasonic duration of 20 minutes, 40 minutes and 60 minutes were 0.06%, 0.26%, and 0.39% respectively as in table 3.

Time of ultrasonic	Weight before ultrasonic (g)	Weight after ultrasonic (g)	Loss Weight (g)	Efficiency (%)
20 min	5.0601	5.0573	0.0028	0.06
40 min	5.1618	5.1485	0.0133	0.26
60 min	5.7441	5.7217	0.0224	0.39

Table 3: Ultrasonic test results in the sulfuric acid electrolyte

The ultrasonic waves help break down the lead sulfate crystals at the negative plate in the case of sulfuric acid electrolytes. It cannot cause the lead sulfate crystal to escape from the element sheet because removing lead-acid sulfate crystals requires bubbles form ultrasonic waves. Therefore, electrolytes that form in semi-solid intermediates cannot transfer that air bubble, and it also reduces the power of the wave that is generated.

4 Conclusion

- The ultrasonic waves help break down the lead sulfate crystals at the negative plate in the case of sulfuric acid electrolytes.
- Pulse width modulation charging cannot restore the performance of valve-regulated lead-acid (VRLA) battery with a single charge.

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