A New Intense Pulse-charging Method for the Prolongation of Life in Lead-acid Batteries

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Abstract

Prolonging the life of lead-acid batteries which are used for vehicles is an important research project for the further development of motorization and because of the finite nature of resources. Based on the assumption that the deterioration of batteries is caused by sulphating at the anodes, a method of charging a large current in a short period of time in order to activate Pb-ions at anodes is possible. But if the electric charge of a large current is conducted simply by using direct current, it will cause a large amount of thermo genesis in batteries, and this will hasten the deterioration of the batteries. In order to prevent this, a pulse-charging method with a high duty cycle was considered. Batteries (28AH) for starting vehicles were used for this experiment, and the deterioration of the batteries was evaluated from the discharge time at approx. 0.3C charge and discharge time. An experiment was conducted by equalizing the average charge current between cases using direct current and cases using a pulse. As a result, pulse charging prolonged the possible discharge time of the batteries.

Keywords

pulse charging, prolongation

1. INTRODUCTION

Annually, 40,000,000 lead-acid batteries are produced in Japan, and this is creating a market of approx. 1.5BUSD. And vehicles account for approx. 1BUSD of this. The global market size is approximately ten times larger than this. Because of the wealth of resources, the ease of manufacturing and safety, the demands on batteries are likely to increase. Especially, if we consider how many batteries are needed in the world as battery cars and hybrid cars spread, we are in the situation where the use of lead batteries is inevitable. Prolonging the life of lead-acid batteries is a very important research project when we think about environmental issues and energy problems in production.

Many studies have been conducted in order to prolong the life of lead-acid batteries. These studies are categorized into: (1)study in relation to the handling and the environment of using batteries, (2)methods using additives [Kozawa et al., 2002, 2003], and (3)methods to control the electric current in charging and discharging. Historically, it has been thought that the main cause of the deterioration of batteries was softening. But sulphating occurs at the anodes. This mechanism is not completely understood. The main factor in deciding the performance of lead-acid batteries is the increase of inner resistance rather than the sulphating at anodes. In this kind of situation, the charged current does not accumulate at electrodes as chemical energy, but it only generates heat. $PbSO_4$ is made at anodes at the discharge. If $PbSO_4$ is crystallized, the effective surface area of the anode becomes small, the electric current will be limited, and the discharged energy will not be removed from the batteries. This phenomenon at the anodes is called sulphating. This study aims to prolong the life of batteries by removing sulphating at anodes. If the life of batteries is prolonged because of a large charged current acting at the anodes, this will mean that the assumption of deterioration at anodes is verified. Based on this theory, the physics of sulphating was studied.

Until now, generally, it was recommended not to discharge a large current, not to discharge deeply and not to charge excessively in order to use batteries for a long period of time. If we consider the life of batteries from the point of view of sulphating, it is important to have a lot of lead available on the surface at the anode. If the discharge of a large current is conducted, or if discharge is repeated at the normal rate of 5C-10C, a nucleus of $PbSO_4$ occurs at the surface of the anode, and the crystallizing of a non-conductor is likely to occur. As a way of prolong the life, a method of conducting a minute charge in order to improve the main features as long as possible by separating the lead from the inside of the electrode to the surface has been carried out. [Minami et al., 2003] The method of putting a minute high frequency-wave charging current into batteries belongs to this category. [Battery Enhance Systems, 2003; Pulse Tech. Products Corp, 2003]

On the other hand, charging with a large current makes it possible to bring the fresh lead inside to the surface, and it has been reported that overcharging will increase the discharge performance of batteries. However, this overcharging causes an excessive release of hydrogen and puts the charging spot in danger, and at the same time it causes the sulfuric acid, which is an electrolyte, to erupt. This is not kind to the environment. Furthermore, because the temperature increases, the moisture in the electrolyte evaporates and if it is not refilled, the battery will be damaged.

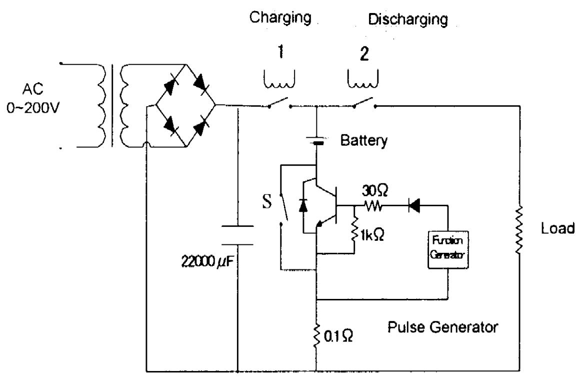
Therefore, a charging current at a large current was put into the batteries for a short period of time. Furthermore, by charging an average time of 5 to 10 hours, the problems discussed earlier should be solved; and while preventing excessive heat, pulse charging at a large current and the replacement of fresh lead to the surface of the anode would be managed. This should be able to stop sulphating. Until now, the pulse charging method has been studied for the following uses. (1)To maintain batteries for trickle charging, (2)To excite electric oscillation of electrodes by a minute pulse current, (3)To complete charging effectively in a short time by reducing the decrease of the charge current in the latter half of charging of mainly lithium-ion batteries or Ni-H batteries. [Lam, 1995].

The characteristics under review in this study aim to prolong the life of batteries by enlarging the duty cycle and activating the flow of Pb-ions. Pulse duration to cause the flow of a large current was approx. 1ms. This is because the Pb-ions can be released easily over this level of duration. The duty cycle is decided by the ratio of the average current to the pulse current.

2. EXPERIMENT

2.1 Experiment-1

Lead-acid batteries (38B, nominal current capacity 28AH), which are the starter batteries for vehicles, were used in this study. The charging device is shown in Figure 1. When the switch S is on, it is a normal circuit for the charging and discharging of direct current. When the switch S was off, charging was performed by a duty cycle which was controlled by the function generator. Figure 2 is a sample of the current waveform used in the experiment. The charging current is 45A, and the average current is approximately 7.5A. As a load resistance, 1[Ω] was used. A 22,000 μ F condenser was equipped to the power source in parallel. This enabled the accumulation of a large current for the pulse current.



Change the charge/discharge by on/off of two contact points 1 and 2, which switch on /off exclusively

Fig. 1 Schematic diagram of experimental setup of the charge/discharge system

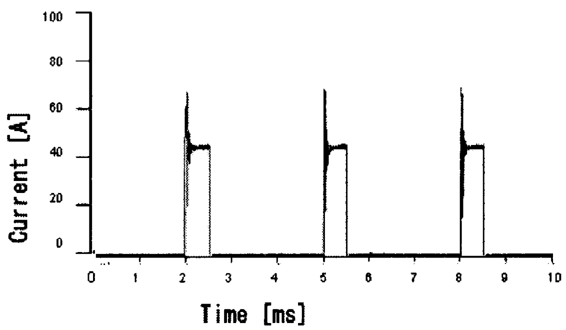


Fig. 2 Typical current form of the pulse charging

Two kinds of current waveform, which simulate the actual travel pattern of vehicles, were used in this experiment. One method is to stop the charging when charging the electric voltage becomes 14.5V, and to switch over to charging when the electric voltage decreases to 10.5V while discharging. New batteries were used for the experiment.

Figure 3 shows the method of switching between discharge and charge.

Time Sequence

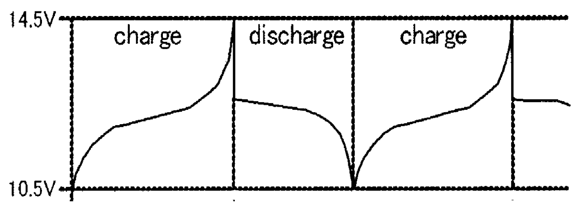


Fig. 3 The time sequence of charging and discharging

In this experiment, the inner resistance rose because of the deterioration of the batteries and the charging stopped at a battery tension of 14.5V; the charging was not done enough. As a result, the discharge duration of batteries

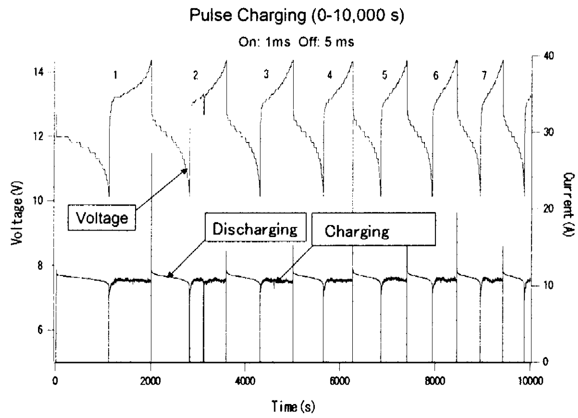


Fig. 4 The results of the charge/discharge experiment conducted at a peak current of 45A (1ms pulse width), an average current of 8A (till 10,000 seconds after the experiment began)

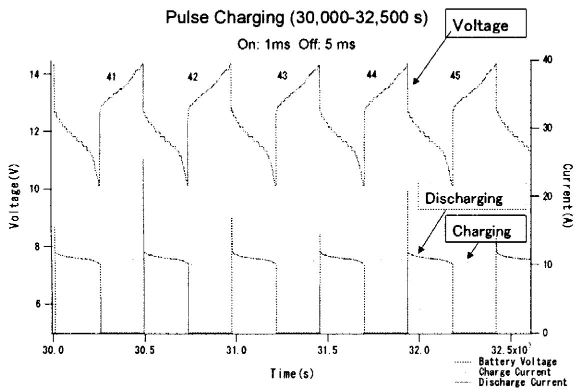


Fig. 5 The results of the charge/discharge experiment conducted at a peak current of 45A (30,000 to 32,500 seconds after the experiment began)

was shortened in both cases. It appeared that the deterioration of batteries was hastened.

Therefore, a different experiment was conducted. The discharge of direct current was done for a certain period of time, and it was changed according to the pulse charging; then the discharge duration was measured. Figure 6 shows an example of the experiment. At the point of the arrow in the figure, the change to pulse discharging occurred. As a result, the inner resistance of the battery lowered, and the charge duration was prolonged till the 14.5V point. The discharge time was prolonged, and the life of the battery was prolonged. The direct current charging current and the average current of pulse charging was set the same.

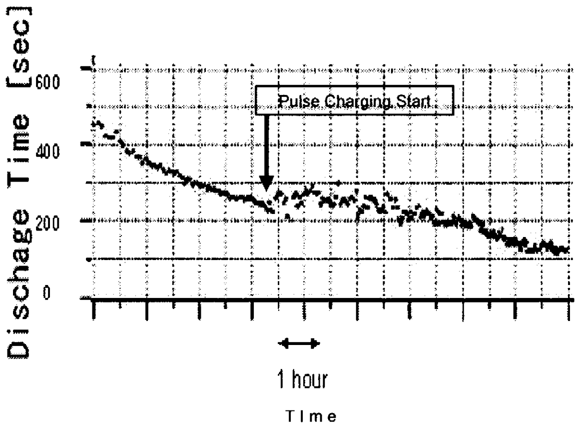


Fig. 6 An example of the result of life prolongation dur to the pulse charging

2.2 Experiment-2

In order to avoid the impact made by the increase of resistance inside the batteries, the charge time was made constant. Furthermore, discharging was performed at a resistance of 1[Ω] until an electric voltage 10.5V, and this was repeated. This is shown in Figure 7. In this experiment, batteries which had not been used for nearly one year were utilized, and the batteries were at a nominal current capacity 28AH, which is the same for as the batteries in experiment 1. These batteries contain ITE additives. [Kozawa, 2002, 2003].

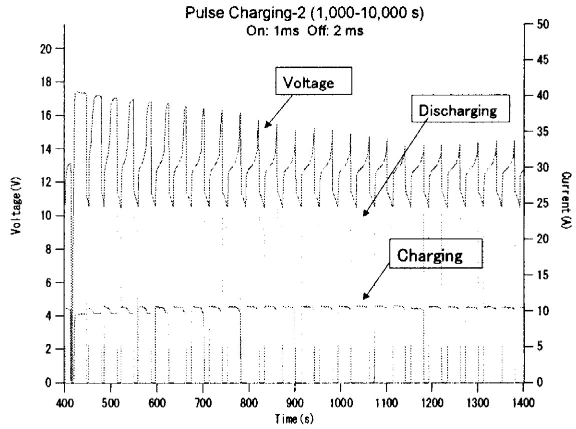
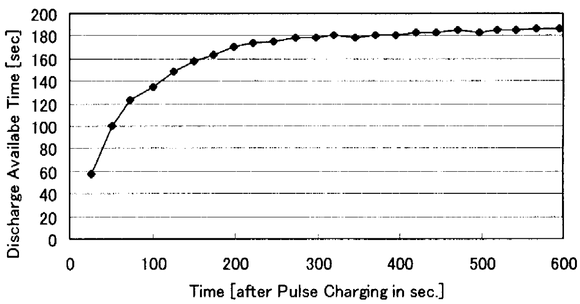


Fig. 7 Battery's charge/discharge current and the time change of the battery voltage, when the pulse charge was performed with a used battery which contained additives



Charge current: 30A 1ms
Average current: 10A
Discharge current 20A loaded by 0.5[Ω]

Fig. 8 Available discharge characteristics before and after pulse charging

This experiment shows that if the pulse charge was repeated, the discharge time was prolonged, and the inner resistance of battery also deteriorated. Figure 8 shows the discharge time as well as the time after the pulse charging started.

3. DISCUSSION AND CONCLUSION

In this experiment, as a method of prolonging the life of lead-acid batteries, a charge with an intense pulse current, and the removal of sulphating which is generated at the anodes, was proposed. In order to check whether this method is possible, experiments were conducted using lead-acid batteries which are used for starting vehicles. The charge current was set to approx. 3C, and the discharge current was set to approx. 1C. The setting was quite a heavy burden for this type of starter battery, which is not for the prolongation of deep discharging. But they were suitable to test whether such batteries could be used for a long period of time as batteries for EV, if a pulse charge was applied.

As a result, it was found that even if the duty ratio was in the range of 3-5, pulse charging prolonged the discharge current of batteries, and this was useful for removing sulphating. This experiment confirmed that the problem caused by excessive charging was avoided and that battery life could be prolonged. This means that the effect of the pulse method, in which the merits of large-current charging could be effectively used, was proved. This paper is a first report on this result. More experiments in order to optimize the parameters relating to the value of pulse current, duty ratio, and pulse width in relation to the current capacity of batteries, will be conducted.

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