Result of Lead-acid Battery Life Prolongation Experiment with Low-level Charging

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Abstract

Lead-acid batteries have long been used providing inexpensive access and stable performance. Starter batteries can be obtained very inexpensively due to mass production, however, rapid deep discharge drastically reduces its performance. If starter batteries can sustain performance even after deep discharge, they have a greater potential for use in electric automobiles. Our experiment tested the battery's life prolongation by charging at a low level when not in use under an environment of repetitive deep discharging. The experiment also included the comparison of the batteries with and without charging while idle. Four timers were used. One set of two timers controlled the duration of charge and discharge, and the other set of timers controlled the time for charging and discharging. The experiment was conducted based on a simulated electric vehicle running pattern. The cycle of three hours of charging and discharging for 10 minutes each and three hours of inactivity was repeated for about 300 hours. During the experiment, battery voltage and charge/discharge currents were measured. The two test batteries are connected in series with only one of them charged at 0.5A to compare with the other battery for performance, and 2C-level currents were used for charging/discharging. After 300 hours, a full discharge test was conducted for a performance comparison. As a result, the battery with low-current charging sustained 85% of its performance, however, the battery without charging had a reduced performance level of 25%. As shown, low-current charging enables significant conservation of battery capacity. For the practical use in automobiles, a self-activated low-current charging circuit will enable the use of this system.

Keywords

low-level charging, lead-acid battery, prolongation

1. INTRODUCTION

Lead-acid batteries have traditionally been used as auxiliary power for automobiles. When deep discharging of the starter battery is repeated, the battery life is shortened. This is a well-known fact. Battery life varies per application but averages about 2-3 years. If a method to sustain battery life with deep discharging were to be discovered, it would be effective for electric vehicles as well as internal combustion vehicles during the summer months, when heavy battery load causes deep discharging. To discover this method, an experiment was conducted based on the hypothesis that battery sulfication can be suppressed by charging the battery at a low level.
Internal combustion vehicles use electric to run the lights, some accessories and the air conditioner. The generator is powered by the internal-combustion engine while the vehicle is in motion and charges the battery.
This experiment tests a way to charge the battery at a low level while idle utilizing the supplementary power source of the internal combustion engine. For electric vehicles, separately charged electric power is utilized for low-current charging of the battery while the vehicle is stopped at a traffic signal.
Lead sulfate is generated due to battery discharge. The lead sulfate remains at the deep electrodes and crystallizes over time leading to the deterioration of the electrodes. To transform the remaining lead sulfate at the deep electrodes into lead metal or lead dioxide, low-current supplemental charging over time at the level of voltage that does not start water electrolyzation was considered. [Kozawa et al, 2002] While the internal combustion engine is idling, no currents are generated by the generator or auxiliary, which enables idealistic supplemental charging.
The objective of this experiment is to verify the validity of the low-level charging method by comparing the batteries with and without low-level charging under conditions similar to an automobile during operation.

2. EXPERIMENTAL METHOD

The experiment was conducted based on a simulated charging pattern of an automobile and electric vehicle running pattern. Two new commercially available 28 AH starter lead-acid batteries were charged with the same charge/discharge current and a low current was continuously sent to only one of the two batteries. The cycle of three hours of charging and discharging for 10 minutes each and three hours of inactivity was repeated for about 300 hours. During the experiment, battery power voltage and charge/discharge currents were measured. The two test batteries are connected in series with only one of them charged at 0.5A to compare with the other battery for performance. The experiment used 2C-level currents for charging/discharging. After 300 hours, a full discharge test was conducted for a performance comparison.

A circuit diagram of low level charging used for this experiment is shown in Figure 1. Four timers were used to control the waveform of charge/discharge currents, though not shown in the diagram, low current at about 0.5A was fed to only one battery parallel to the main charge/discharge current. The absolute value of this current is so low that it is insignificant. Figure 2 shows the waveform of charging/discharging currents. Time in the figure indicates the hours elapsed from the start of the experiment.

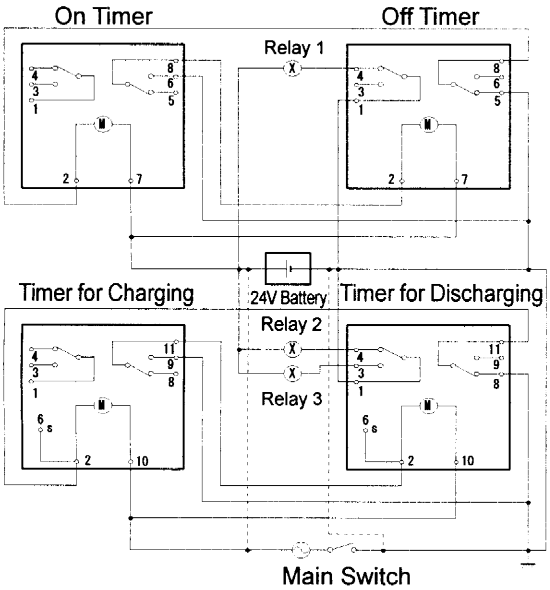

Fig. 1 Circuit diagram for the experiment

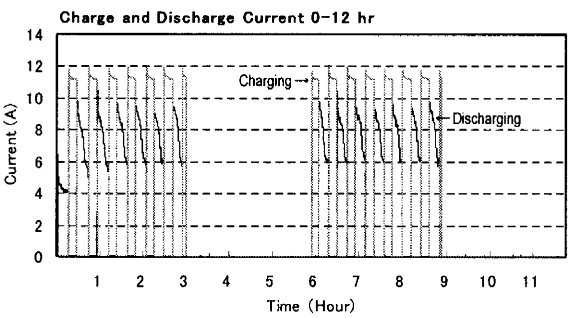

Fig. 2 Waveform of the charge and discharge current at 0-12 hr

3. RESULTS

Charging/discharging was continued for about 300 hours. Voltage and charging currents of these batteries were measured during the experiment. Voltage fluctuation of the batteries is shown in Figure 3 through Figure 6. The battery voltage level with low level charging is indicated with thin lines and battery voltage level without charge is shown in thick lines. The low level charging is not enough to fully recover the battery energy (about 0.02 C charge). After repeating the charging/discharging five times, the voltage of the battery charged with low-level current showed a slight increase. The overall battery voltage level is also high.

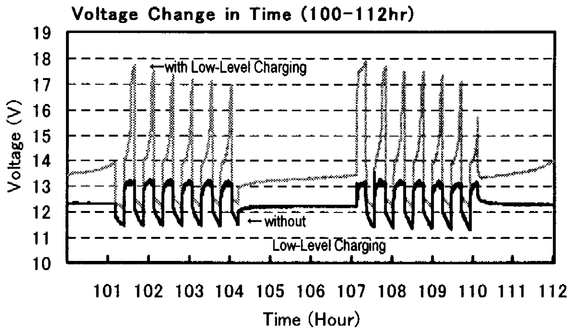

Fig. 3 Battery voltage change in time (100-112 hr)

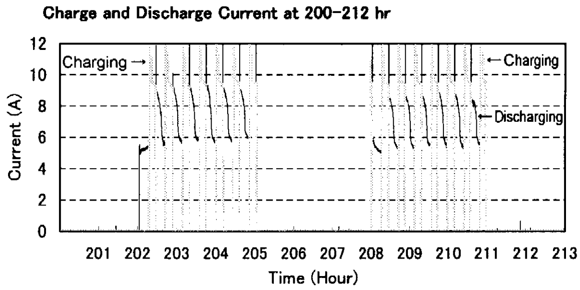

Fig. 4 Battery voltage change in time (200-212 hr)

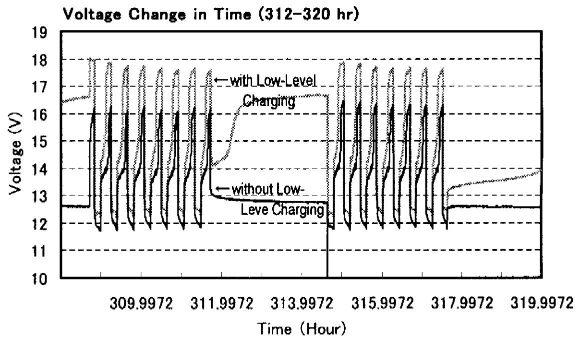

Fig. 5 Battery voltage change in time (312-320 hr)

It is evident that the battery charged at a low level remained in good condition for use at the final stage of the experiment. Figure 6 shows the charge/discharge current waveform after 200 hours. Figure 7 shows the current waveform just prior to the end of the experiment. The decreased level of current at the time of discharge shows the deterioration of the non-charged battery, which is not able to supply enough current.

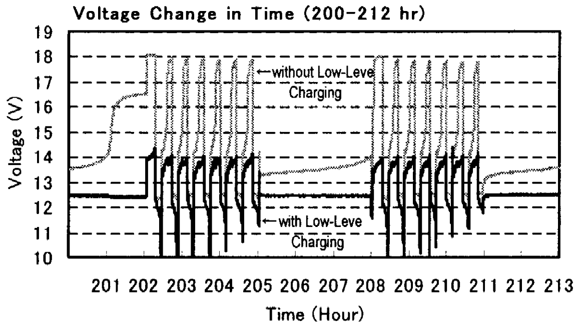

Fig. 6 The charge and discharge current at 200-212hr

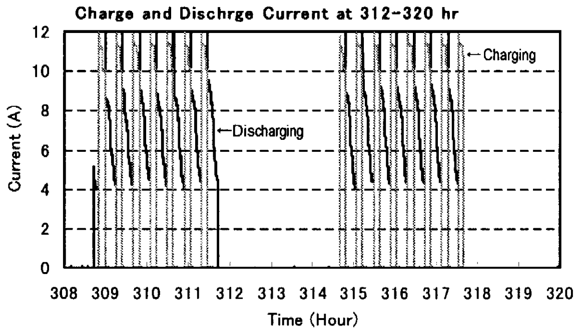

Fig. 7 Charge and discharge current at 312-320hr

4. DISCUSSION AND CONCLUSION

After 320 hours of experimentation, both batteries were removed and each was fully recharged. They were then completely discharged with 2C-level current. Figure 8 shows the attributes of discharging current. By integrating this current, the capacity of each battery at the final stage can be assessed.

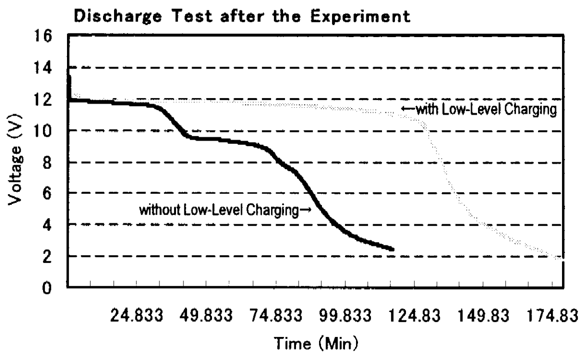

Fig. 8 Discharge current attributes after the final full charging

Table 1 shows the results. It comes out to be 300 hours of charging/discharging with 2C-level current during the test. The low-current charged battery maintained its new condition. However the battery without low-level charging was at the final point of its life cycle.

Table 1 Final state of each battery under the test

	Capacity (AH)
With Low-Current Charging	23.9
Without Low-Current Charging	7.3

This experiment used an external source of low level current. In more realistic situations, automobiles can charge a separate battery or capacitor while an automobile has a generator running to charge the starter battery at a low level when the engine stopped. This will enable increased battery life as shown in this experiment. Figure 9 and Figure 10 shows the specific current diagram.

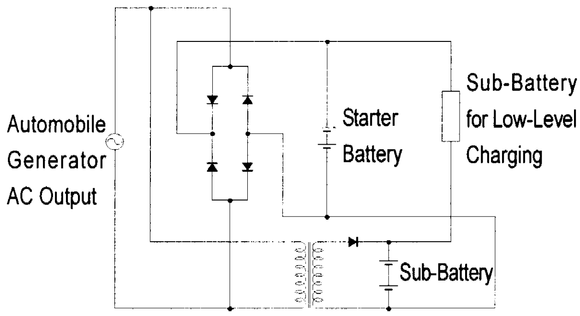

Fig. 9 Example of low-current charging system (A)

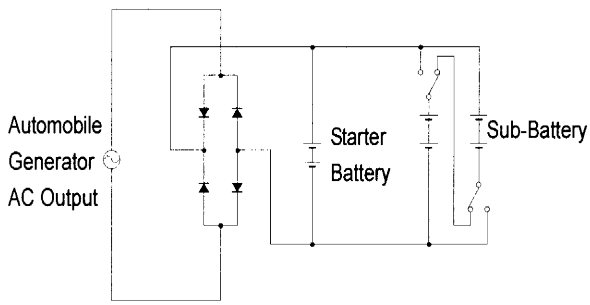

Fig. 10 Example of a low-current charging system (B)

The possibility of a drastic extension of battery life in automobiles has been proven by this experiment based on the established theory in today's world where effective utilization of resources is necessary.

References

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(Received September 17, 2003; accepted November 5, 2003)