START-/STOP-SYSTEM AND THE BATTERY

Meier-Engel Karl*, Iseli Felix, Kessi Andreas, Ruetschi Paul
Berner Fachhochschule TI, Automobiltechnik, Switzerland

KEYWORDS – start-/stop-system - battery management, acid stratification, aging detector, service life, shallow cycling

Abstract

In more and more applications, lead-acid batteries are subjected to shallow cycling. In recent years, the effects of shallow cycling on battery life have often been underestimated. Shallow cycling reduces the service life of the battery because of stratification effects. With start-/stop-systems these problems will even increase.
How can the service life under shallow cycling conditions be improved?
Another important question is: how can a battery failure be detected?

These two topics were the motivation for the work reported here.

We compared conventional (SLI) batteries against valve regulated (VRLA) batteries. The conventional batteries had pocket-type separators, the VRLA batteries had absorbent glass matt separators.
Two 12V-batteries of the same type were connected in series. One of these batteries was subjected to an external mechanical pressure, and the other was not. Both batteries were equipped with a center tap, which permitted to compare the sum of voltages of first three cells with the sum of voltages of the other three cells.

We already knew from tests in the past [2] and from other projects [4], that mechanical pressure on the sidewalls is a simple and efficient means to increase the cycle life. As shown in this paper, this is not always the case under shallow cycling conditions.

The center-tap connection is a useful means to detect defective cells. It permits the comparison of the voltages of the two battery half's. If the voltage difference between the two half's exceeds, for example, 2V, one can conclude that at least one cell is defective and is approaching its end of life. This technique is much more effective than the measurement of the total battery voltage, because the latter is the sum of six individual cell voltages, which tends to mask the effect of a single defective cell. Moreover, the total cell voltage depends on factors such as temperatures. In comparing the voltages of the two batteries half's, such factors are automatically compensated for. A disadvantage of this type of diagnostic system is however; that the battery needs a center tap.

First results indicated, that, under shallow cycling conditions, the life-limiting factor of the conventional automotive (SLI) battery (with pocket-type separators) is not anodic corrosion of the grid, but acid stratification. This battery type achieved only a modest number of cycles.
Valve regulated lead acid (VRLA) batteries with absorbent glass mat separators showed a much better result. Furthermore, with this type of battery, mechanical pressure had a positive effect on battery cycle life.

Introduction

Can conventional SLI batteries achieve the requirements of start-/stop-systems?
Could valve regulated (VRLA) batteries with absorbent glass matt offer a better service life?
Will batteries submitted to mechanical sidewall compression achieve a longer service life?
Is it possible to detect battery failures with a center tap?

These questions came up, when it became clear, that the start-/stop-systems will be used in the future because of fuel economy and reduction of exhaust gas.
We believe, that the lead-acid battery is actually the most interesting energy storage system for automotive applications.

The advantages of lead-acid batteries are:

- low cost
- low internal resistance
- recyclability
- safety

The aging mechanisms of lead acid batteries are (1):

- anodic corrosion of grids
- positive active mass degradation and loss of adherence to the grid
- irreversible formation of lead sulfate in the active mass
- short-circuits
- loss of water
- acid stratification

In the past, most batteries failed by grid corrosion.
Starting required only a very small fraction of the battery capacity. Most of the time the battery remained almost completely charged. When the engine was running, the battery was charged by the alternator, which resulted in permanent overcharge.

When using start-/stop-systems, the batteries will be subjected to shallow cycling.
This means, that during a stop, the battery must deliver the electric energy for the vehicle.
In the present paper "shallow cycling" means cycling to a depth of discharge of about 5 to 20 %, at a discharge rate of about 1C.

Starting an internal combustion engine means very high currents for a very short time. Therefore, a low internal resistance is a must.
Unfortunately, the service life of the conventional SLI batteries, under shallow cycling conditions, is reduced. The reason is acid stratification.

When batteries are subjected to a large number of cycles, one observes active mass degradation and loss of adherence to the grid [3]. Mechanical compression on the sidewalls of the battery, will reduce these processes.
We already knew from tests in the past, that mechanical pressure is a simple and efficient means to increase the cycle life. As shown in this paper, this is not always the case under shallow cycling conditions.

Failure detector
Regarding start-/stop systems, it would be useful for the driver to know, if the battery is capable to provide the necessary energy for the next starting operation. Modern automobiles should be equipped with an onboard diagnostic system, indicating any battery failure.

From many battery tests we learned that normally one single cell is responsible for battery failure. One defect cell can cause problems with engine start.
For a failure diagnosis one simple means is, to measure separately the voltages of the two battery half’s. A difference of 2V ore more between this voltages indicates, that there is a defect battery cell.
We used a microprocessor to measure and compare these voltages. This allowed to measure the voltage difference also during very short discharge pulses.
The idea described above was already patented in 1983 [5].
Today, small and cheap microprocessors are available.
However, measurements of half-battery voltages require a center-tap, which results in additional costs.
For 24V or 36V electrical systems, the described failure detector can be easily installed at the connection between the 12V blocs.

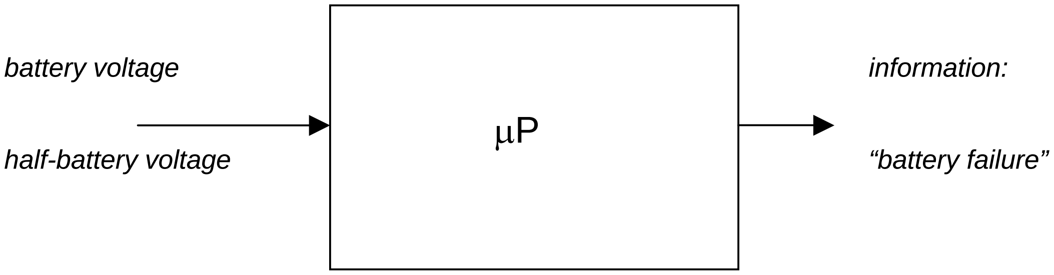

Figure 1: Principle of the battery failure detector. A microprocessor is used for the measurement and it compares the half-battery voltages.

Methods

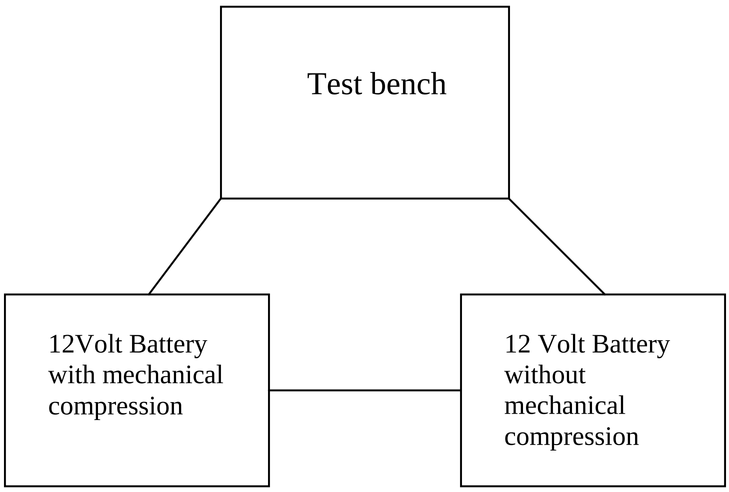

Figure 2: principle of the test arrangement

A test programme, according to figure 4 was carried out with two 12 V batteries connected in series. One battery was subjected to mechanical compression on the sidewalls, and the other was not. We tried different values of compression, between 10 and 100 kPa.
We used either conventional automotive (SLI) batteries (having pocket-type separators) or valve regulated lead acid (VRLA) batteries (having absorbent glass matt separators).

Specifications of the batteries:

Conventional (SLI) battery:	nominal voltage:	12V
	capacity (C20):	54Ah
	internal resistance:	6mOhm
	elektrolyte:	liquid
	dimensions (l/w/h):	226/166/180mm
	weight:	13,5kg

Valve regulated (VRLA) battery:	nominal voltage	12V
	capacity:	44Ah
	internal resistance:	6mOhm
	electrolyte:	in absorbent glass matt
	dimensions (l/w/h):	196/164/171 mm
	weight:	13,5 kg

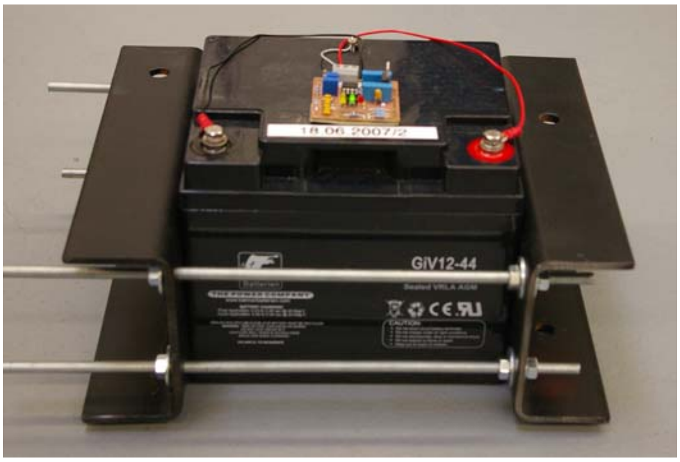

Figure 3: Device to maintain a sidewall mechanical compression, using disc springs. On the top of the battery one recognises the failure detector.

The test programme (figure 4), simulating conditions in a vehicle, consisted of 25 shallow cycles. We used a discharge current of 40A during 5min. (except the first discharge, which had a duration of 10min.) and a charging current of 40A for 5min. This means a depth of discharge of about 10%. (Today, the average electric power for a vehicle electrical system will be more then 500 W [6])

The charge voltage was limited to 14,4V and the duration of charge was limited to 5min. Following this programme, a full charge and a capacity test was carried out, using a discharge current of 40A.
This specification represents, in a simplified manner, the behaviour in a vehicle with a start-/stop-system.
After every test cycle the battery capacity was determined by a full discharge.

After failure of one battery, it was replace by a new one and the test was continued until the second battery would also fail.

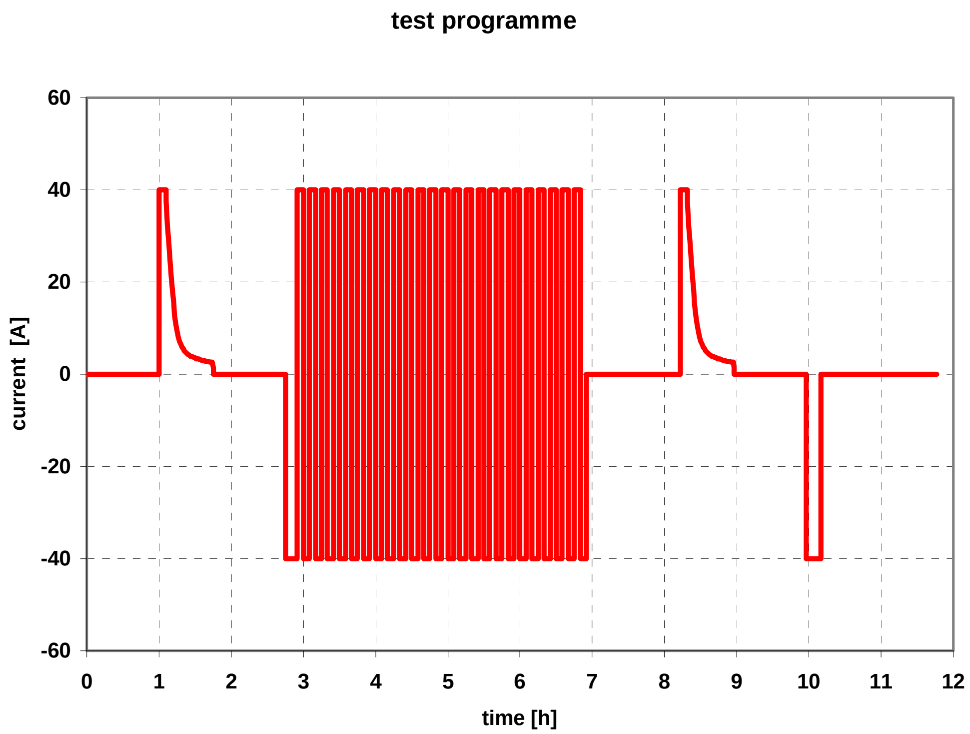

Figure 4: The test programme starts with a full charge, followed by 25 partial discharges and 24 partial charges, and finally a full charge and a full discharge. The charge and discharge current was 40 A.

Results and Discussion

The conventional SLI batteries (with pocked-type separators) achieved 23 test programmes. Compression resulted in a slightly decreased capacity and slightly decreased cycle life. Post mortem analysis showed effects of acid stratification. The upper part of the positive plates showed a loss of the adherence of the active mass, because this upper part had to work harder.
The lower part of the plates showed signs of sulfation.

A second set of conventional SLI battery was tested using a charge voltage of 15 V instead of 14.4 V. These batteries achieved 33 test programmes, whereby again the compressed battery failed before the uncompressed battery.
Post mortem analysis showed strong signs of acid stratification.

Regarding the valve regulated batteries, the battery without compression achieved 124 test programmes (see figure 5) and the compressed battery (100kPa) 157 test programmes.
Using a compression of 20kPa we achieved 265 test programmes. Apparently, 100kPa is to much.

VRLA batteries require a stronger battery case, because they are mounted with absorbent glass matt separators under pressure.
Using a compression device one could possibly utilize polypropylen as battery case material, which would be considerable cheaper then ABS-cases.

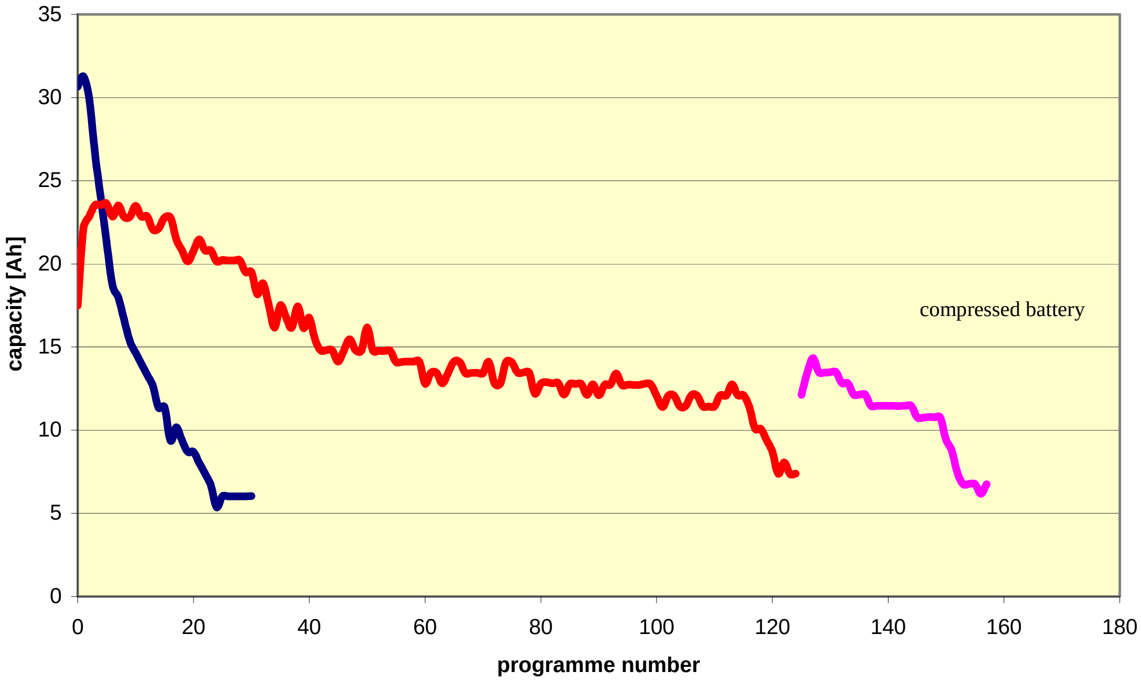

Figure 5: This diagram shows the (poor) result with a conventional battery (with pocket-type separators) and a charge voltage of 15 V, at left, and the (much better) result of the valve regulated battery with glass mat separators.
The compressed VRLA-battery achieved more programmes than the uncompressed battery.

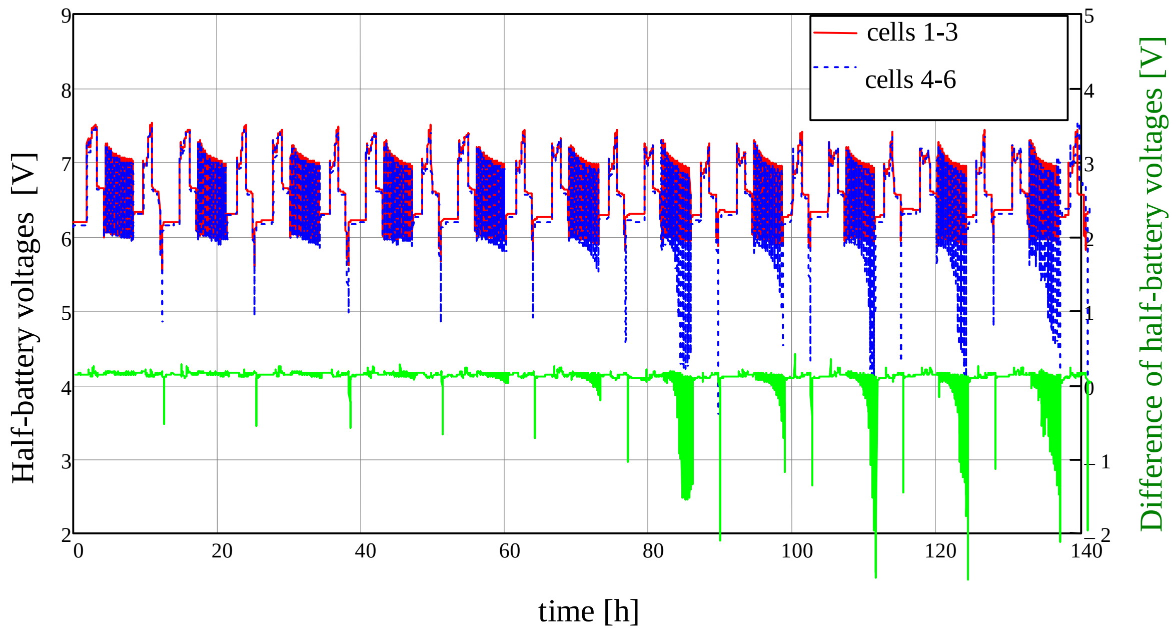

Figure 6: Comparison of the half-battery voltages. The difference between the two half-cell voltages (lower curve) increases drastically at the end of life.

Conclusions

Under shallow cycling conditions, conventional automotive (SLI) batteries achieved only a low number of cycles. Post mortem analysis showed signs of strong acid stratification. Acid stratification is the life-limiting factor. Therefore, compression does not improve cycle life. The compressed batteries even failed before the uncompressed ones.

On the other hand, valve-regulated (VRLA) batteries showed a much better cycle life. Post mortem analysis indicated no signs of acid stratification. But the active mass of the positive plates was relatively soft. Active mass degradation is a life-limiting factor. With compression, cycle life was improved.

The aging detector proofed its effectiveness. It is a simple tool for failure detection.

In start-/stop-systems it is preferred to use VRLA batteries.
The use of a battery-fixing device, allowing sidewall compression, seems to be of interest.

Acknowledgements

The speaker expresses his thanks to:
Paul Ruetschi, who has been a battery consultant for BFH-TI for many years.
Reto Gasser, Felix Iseli, and Andreas Kessi, who have collaborated at the test laboratory.
Berner Fachhochschule, University of applied sciences, for the use of the laboratories and the test benches.

REFERENCES

[1] Ruetschi Paul; “Aging Mechanisms and Service Live of Lead-Acid Batteries”, 2002, J. Power-Sources 127 (2004) 33-44
[2] Meier-Engel Karl “OPAL Optimierung der Antriebsbatterie eines Elektrofahrzeuges”, 2004
[3] Meier-Engel Karl, “ALBOCA Anhalten von Linienbussen und Speisung der Verbraucher mit BOOSTCAPS”, 2004
[4] L. Torcheux, P. Gagnol, J.F. Sarrau: “InnovativeLead Acid Battery Development for electric & Hybrid Vehicle applications”, EVS-22 Yokohama, 2006
[5] Kahlen Hans: “Control Device for Battery” EEP 0080164
[6] BOSCH; “Autoelektrik Autoelektronik” ISBN 3-528-23872-0