Demands on automotive battery performance, what is the best alloy?

G. Richter
Robert Bosch GmbH, Robert-Bosch-Strasse 200, 3200 Hildesheim (F.R.G.)

Abstract

Modern automotive batteries represent a compromise between starting performance and power handling. Being designed for high starting currents, their capacity amplitude for frequent cyclic loads is relatively small, compared with their nominal capacity. Considering the category of high-class passenger cars, the two-battery concept better meets requirements and at the same time improves the reliability of the starting system. It is expected that for both the starter battery (in the engine compartment) and the power-handling battery (in the boot), the lead–calcium–tin system will be the most appropriate choice for the grid alloy.

Battery requirements

Considering the increase in electrical equipment and its growing importance for the safe operation of modern passenger cars, priorities have to be set regarding the corresponding improvement required in relevant battery properties. The developments considered important are shown in Table 1. By introducing them, the battery will ameliorate considerably the situation in the car's electrical network.

It will not be possible to raise simultaneously the starting performance and the capacity of the battery since these two properties are coupled with increased weight and volume, which would, in turn, increase CO_2 emissions. Nevertheless, more attention has to be paid to reliability, i.e., reduction of engine-starting failures. By maintaining an ever-ready (fully charged) battery, the portion of the batteries capacity (this means the portion of the batteries weight) required for the 'starting reserve' can be reduced drastically. During the intervals of negative charging balance, a better availability of power can be achieved by increasing the 'cycleproofness'. This, in turn, leads to an increase of energy-throughput per unit weight and, in the end, to smaller batteries.

Extension of the lifetime of the battery is one of the most important goals. This includes a further reduction in maintenance and increased battery durability to temperature effects.

Only approximately 5% of automobile users would be interested in a possible rise in battery voltage to levels above 12 V. These consumers, however, can be supplied with the required power by a separate part of the car's electric system not involving the battery. Further demands, mainly in

0378-7753/91/$3.50

TABLE 1

Required improvements for automotive batteries

Increased capacity
Reliable cranking ability
Better availability of energy ('cycleproof')
Longer service life/less maintenance
Increased voltage (i.e., >12 V)
Stable voltage in the electrical system

the field of reliability, require stabilized voltage instead of voltage increases. This measure will mainly effect sensitive electronic equipment in the system, particularly during the starting procedure.

Dual-battery concept

The present single-battery concept (SBC) cannot meet all the above demands at the same time, viz.,

- high starting power with a high energy-throughput and low battery weight
- high reliability from an ever-ready, fully charged battery and a stable system voltage
- long lifetime and greater availability

Particularly the demand for reduced weight and volume requires a change from present principles of construction (Fig. 1). Therefore, there are advantages for the introduction of a dual-battery concept (DBC) of the type shown in Fig. 2.

A comparison of the properties of the specialized battery with a dual-battery concept (high-performance automotive battery and energy-throughput battery) and those of the present universal battery are given in Table 2. More effective battery performance with approximately the same or less weight and reduced volume, along with an extended lifetime, are the main reasons why the DBC is an economical solution.

With the single battery there are two (statistically independent) events that are responsible for failed starts: (i) complete battery failure due to improper handling (probability P_1); (ii) insufficient energy at the starting time due to a negative charging balance (probability P_2). The relative increase in the reliability (the reduced probability of failed starts) of the DBC (Fig. 3) compared with the SBC works out to be $(1 + P)$ to $(1 + 2P)$, depending on wiring and charging priorities.

Alloy requirements

When designing an advanced battery for increased starting performance, as well as the energy-throughput battery, certain parameters have to be considered. These are shown in Table 3.

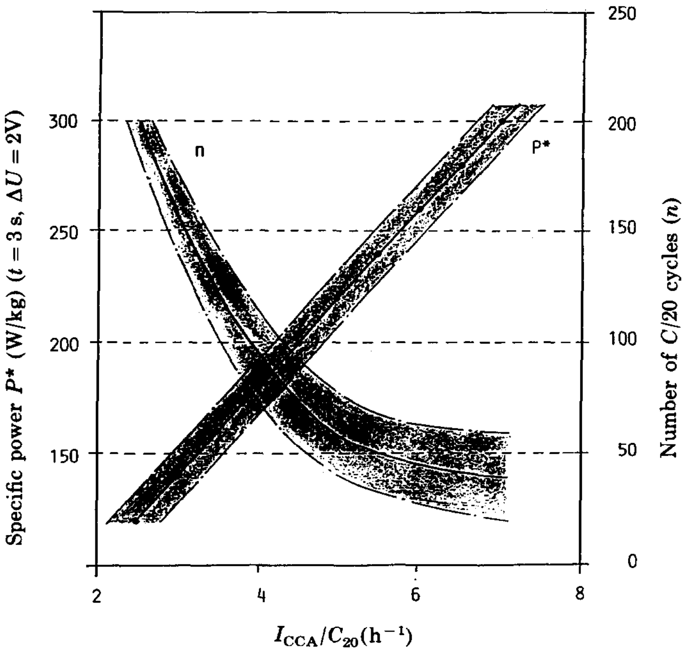


Fig. 1. Performance of present automotive batteries.

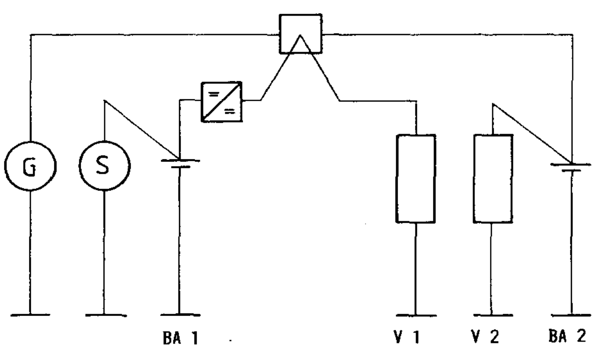


Fig. 2. Dual-battery concept.

The high-performance starter battery containing a fluid electrolyte should be a maintenance-free type. This makes it possible to choose the most convenient location inside the car, no matter whether easy access is provided for or not.

The energy-throughput battery (cycle-proof battery) should also be maintenance-free with thick plate application, fluid or starved electrolyte (SLA) and deep-discharge proof. How significant are these requirements for the alloy system of future battery grids and what kind of conclusions can be made considering the experience and know-how available already?

TABLE 2

Comparison of dual-battery (DBC) and single-battery (SBC) concepts

	DBC		SBC 58814
	I	II	
Capacity $C/20$ (A h)	12	60	88
$E^* = n \times C/20$ E^*/G (kW h kg^{-1})		0.6	0.27
Max. power P^* ($t = 3$ s, $\Delta U = 2$ V) P^*/G (kW kg^{-1})	0.75	0.2	0.25

TABLE 3

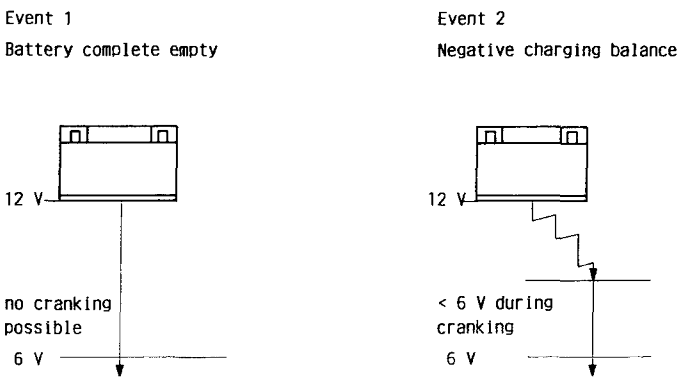
Parameters affecting design of dual-battery concept

High-performance starter battery
Optimized grid design
Temperature stabilized negative paste
Fluid electrolyte
Energy-throughput battery ('cycleproof' battery)
Thick plate application
Fluid or fixed electrolyte
Deep-discharge proof

TABLE 4

Corrosion, electrical and economic considerations for lead–calcium–tin grids

Parameter	Grid type	
	Cast	Expanded metal
Corrosion type		
Erosion	+	–
Pitting	–	+
Stress cracking	–	+
Electrical properties		
Cold-cranking	+	–
Reserve capacity	+	+
Time to 6 V	+	+
Rechargeable after deep discharge	+	+
Economic factors		
Plate production for filled and charged batteries	+	+
Plate production for dry charged batteries	+	–
Assembling	+	–
Mechanical reliability	+	–



SBC: $R_S = 1 - P_1 - P_2 + P_1 \cdot P_2$

DBC: $R_D = 1 - P_2/F \qquad 1 \leq F < \infty$

$$(1 + P) \leq \frac{R_D}{R_S} \leq (1 + 2P)$$

In case of $P_1 \approx P_2$

Fig. 3. Reliability study of dual-battery (DBC) and single-battery concepts (SBC).

Besides being maintenance-free, the well-known lead–calcium–tin alloy system used for cast and expanded grids provides: (i) resistance against corrosion; (ii) good electrical properties; (iii) economical production processes along with a very low failure-rate. The abovementioned criteria, also have to be considered when searching for the correct production process for these battery types. Consideration of the following requirements could help discover correct answer (refer Table 4).

Corrosion resistance

The high-performance starter battery requires a permanent high charging level with a high acid density, and has to operate in a high-temperature environment since it is located in the engine compartment. By contrast, the energy-throughput battery undergoes frequent deep-discharge with low acid density, and experiences only moderate temperature since it can be placed outside the engine compartment (e.g., in the boot).

Electrical properties

The high-performance starter battery has to supply high currents during a relatively short period; that means thin plates and separators. The energy-throughput starter battery must exhibit a good voltage level at average currents during longer periods. It must also withstand frequent cycles. The latter can be achieved by using large and thick plates.

Economic considerations

Both battery types require: (i) economic plate production with subsequent box- or tank-formation; (ii) quick and easy battery assembly; (iii) reliable, reproduceable and well-known production processes in order to maintain low failure-rates and to avoid subsequent claims.

Conclusions

It can be concluded that the lead–calcium–tin alloy system, already offering a number of advantages when used for grids in present-day batteries, will also meet the requirements of the dual-battery concept. In particular, the alloy will: (i) comprehensively meet technical requirements and conditions; (ii) allow various production procedures offering possibilities to optimize costs and expenses. It has therefore become necessary to revise some of the existing battery test standards in order to accommodate this system.