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Valve-regulated lead/acid batteries for SLI use in Japan

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Abstract

Valve-regulated lead/acid batteries for automotive applications have been on the market in Japan for more than ten years. Initially, the batteries were used only for a small-size motorcycle. Today, however, they are widely employed in all sizes of motorcycles. In the meantime, VRLA batteries have also been used for agricultural machines, and even for some types of passenger cars. This paper provides an overview of the progress in the development and application of VRLA batteries for SLI (starting, lighting and ignition) use in Japan and discusses future expected trends.

Keywords: Lead/acid batteries; Valve-regulated lead/acid batteries; Motorcycle batteries; SLI batteries

1. Introduction

In the 1970s, the Gates Rubber Company developed the absorptive glass-mat (AGM) design of valve-regulated lead/acid (VRLA) battery. Since then, VRLA batteries have been used widely as stationary batteries for uninterruptible power supplies (UPS), securities, telecommunications, medical equipment, etc. Presently, most of the stationary lead/acid batteries in Japan are of the VRLA type.

For SLI (starting, lighting and ignition) applications, the motorcycle VRLA battery has achieved successful growth since Yuasa introduced dry-charged VRLA batteries in 1983. Automobile VRLA batteries were also developed in the early 1980s, but their usage has not grown appreciably. Nevertheless, attempts are being made in Europe to expand the use of VRLA batteries in cars. This paper reviews the progress that has been made on the development of VRLA batteries during the past decade, and offers a view on the future trends in this technology.

2. VRLA batteries for motorcycles

Before the advent of VRLA batteries, the needs of motorcycle manufacturers and retailers in terms of conventional batteries (flooded-electrolyte type) were as follows: (i) no acid spill; (ii) no need for topping up; (iii) able to be started after long idle periods, and (iv) extremely long shelf-life. Dry-charged VRLA batteries for motorcycles were developed in 1983 to meet these four needs and were installed on new motorcycles as original equipment [1].

2.1. Present uses

In the early 1980s, scooters with 50 ml engines were becoming popular amongst housewives and high-school students in Japan. VRLA batteries of 3 Ah capacity were installed in these scooters. At the same time, VRLA batteries of 10 Ah capacity were fitted to the buggy-type motorcycles that were rapidly becoming popular in the USA.

Later on, following an improvement in cranking performance, VRLA batteries became more widely used in middle-size motorcycles. More recently, VRLA batteries have been installed in large motorcycles of up to 1200 ml engine capacity, and even in water craft. The increased application of VRLA batteries in new motorcycles is shown in Fig. 1. At present, about 70% of new motorcycles are equipped with such batteries.

2.2. Battery design and development

The basic design of the VRLA batteries is shown in Fig. 2. The specific features are as follows:

1. absorptive glass-mat (AGM) separators;
2. reinforced containers to retain the compression of the AGM separators against the plates;
3. Pb–Ca–Sn alloys to minimize self-discharge and to aid recovery after overdischarge and long periods of standing;

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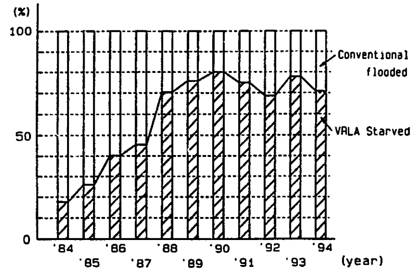

Fig. 1. Growth in the application of VRLA batteries as original equipment in motorcycles.

4. appropriate active material to acid ratio and an additive to assist recover after overdischarge and long idle periods;
5. posts and straps made from Pb–Ca alloys to provide superior physical strength and to avoid abnormal corrosion; cast-on-strap processing to ensure welding reliability between strap and lugs, and
6. container and cover made from polypropylene to withstand stress-cracking by gasoline or rustproof oils; heat sealing between container and cover to give high reliability against acid leakage; terminal wrapped in polypropylene to give a good seal with the cover.

In recent years, it has become necessary to make the battery size smaller in order to provide storage space for the helmet inside the body of the scooter. Also, it has been required to reduce the battery weight in motorcycles of middle size. Thus, efforts have been made to develop VRLA batteries of smaller size and lighter weight. It was also specified that the batteries in scooters should be placed sideways in the narrow space beneath the steps for the driver's feet and not, as in motorcycles, beneath the seat. To meet this change, the VRLA batteries were made slimmer, i.e. the width was reduced by at least one-third. Finally, the connection was changed from the troublesome method of bolt tightening to an easier means of connection or a patented plug-in system. The shift in design between the first and most up-to-date products is displayed in Fig. 2. The modern batteries (Generation III) are made slimmer by changing the cell arrangement, terminal configuration and material. Nevertheless, the basic materials and geometry remain as outlined above. A comparison of the performance of the Generation I and Generation III batteries is given in Table 1. The Generation III unit has about half the width and volume of the generation I counterpart.

Table 1
Performance of VRLA motorcycle batteries

No.	Characteristic	Generation I	Generation III
1	Nominal voltage (V)	12	12
2	Nominal capacity (Ah)	3	2.3
3	Battery weight (kg)	1.3	1.1
4	Battery size		
	Width (mm)	70	38
	Length (mm)	113	113
	Height (mm)	85	85
5	C_{10} capacity (Ah)	3.0	2.3
6	30 A discharge at −10 °C		
	5 s volts (V)	9.8	9.8
	Time lapse (min)	1.3	1.3
7	Cold-cracking ampere at −10 °C (A)	45	45
8	Specific cranking power (A kg^{-1})	34.6	40.9
9	Cranking power density (A l^{-1})	66.9	123.3

As mentioned earlier, an extremely long shelf-life (at least more than four-to-five years) is required for motorcycle batteries. In order to meet this criterion, the VRLA batteries have been supplied in the dry-charged state since the first products appeared on the market. Moreover, since the performance and cycle life of the batteries depend largely on the accuracy of the acid volume poured into the cells, great efforts have been made to improve the acid bottle and filling system. The progress in design is shown in Fig. 3. At present, a 'push in' system is used. This allows easy and accurate acid fill to each cell and, consequently, decreases significantly the probability of misfilling.

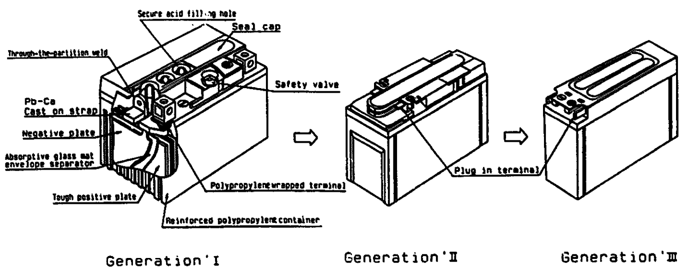

Fig. 2. The evolving design of VRLA batteries for motorcycles.

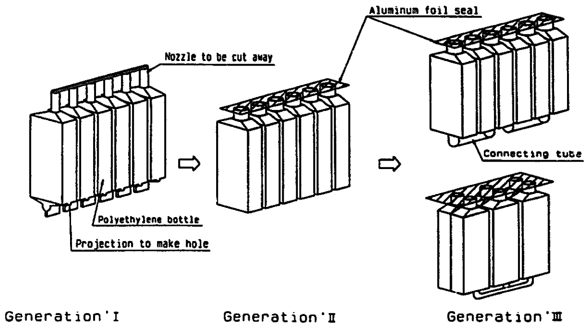

Fig. 3. Development of acid bottle design. (The bottles are turned upside-down to dispense the acid.)

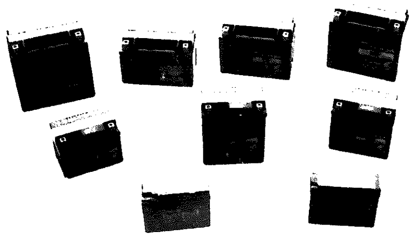

Fig. 4. Modern VRLA motorcycle batteries.

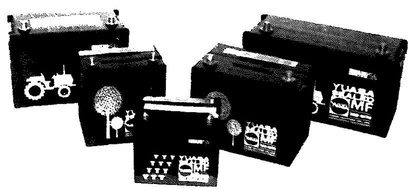

Fig. 5. VRLA batteries for agricultural machinery.

During the past decade, VRLA technology has given motorcycle batteries superior maintenance-free characteristics, as well as reduced size and lighter weight. In future, efforts will focus on improving active-material utilization, as well as on total production efficiency from receiving an order to delivery of the battery. Examples of modern motorcycle VRLA batteries are shown in Fig. 4.

3. VRLA batteries for agricultural machinery

In Japan, VRLA batteries for agricultural machinery have been developed since 1987 [2] following the success of the motorcycle application. This is because the operating conditions of such equipment are similar to those for motorcycles, e.g. long (off-season) idle periods, short driving distances, heavy vibration, etc. The vehicles in question are combine-harvesters, tractors and rice-planting machines. The number produced per year is about 219 000, and the total number in service is 3.67 million. At present, the manufacturers are not eager to equip these machines with VRLA batteries, mainly because of the higher cost of the technology compared with conventional flooded-electrolyte batteries. In the replacement market, the share taken by VRLA batteries appears to be less than about 1% of the total battery sales for agricultural equipment. Some of the present designs of VRLA batteries that are being used in agricultural applications are shown in Fig. 5.

4. VRLA batteries for cars

In 1989, Mazda adopted VRLA batteries for its sports cars. Recently, Nissan has also used the technology in a passenger car for which good manoeuvrability is one of the selling points. It is said, however, that the purpose of adopting VRLA batteries is to balance the weight of the car. Less than 1% of new cars are equipped with VRLA batteries and no further increase in this percentage has been observed to date. The main advantages of the VRLA battery are considered to be: (i) maintenance-free service; (ii) flexible positioning (no acid spillage); (iii) increased cycle life, and (iv) smaller size and lighter weight.

Table 2
Characteristics of conventional and VRLA car batteries

No.	Characteristic	Conventional (hybrid)	VRLA
1	Nominal voltage (V)	12	12
2	Nominal capacity (Ah)	28	28
3	Battery weight (kg)	9.5	10.0
4	Battery size		
	Width (mm)	127	127
	Length (mm)	195	195
	Height (mm)	223	190
5	C_{10} capacity (Ah)	34.0	33.9
6	150 A discharge at −15 °C		
	5 s volts (V)	9.7	10.4
	Time lapse (min)	3.7	3.9
7	Cold-cracking amperes at −18 °C (A)	300	370
8	Specific cranking power (A kg^{-1})	31.6	37.0
9	Cranking power density (A l^{-1})	54.3	78.6
10	Cycle life (SAE J240 at 40 °C)	4000	8000

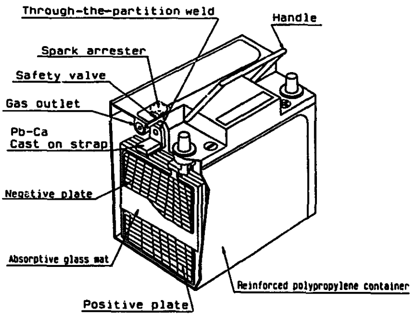

Fig. 6. Design of VRLA battery of cars.

A schematic of an up-to-date VRLA car battery is shown in Fig. 6 [3]. The features of the latest VRLA and conventional flooded-type batteries are compared in Table 2. With VRLA batteries, the specific cranking power increases by 17%, the cranking power density increases by 45%, and the charge/discharge cycle life is almost doubled. Also, the battery size has become larger with increase in the electric consumption of cars.

In addition to the original functions, i.e. starting, lighting and ignition, the battery is now required to support increasing electrical and electronic functions, such as the engine control system, the manoeuvrable balance system, safety and security systems, and comfort and convenience equipment. At the same time, it has become rather difficult to provide the necessary space for the battery in the engine compartment. This is not only because of the increasing space required for the increasing amount of electrical/electronic equipment, but also because of the reduction in the hood height to give enhanced aerodynamic performance. Moreover, the battery must have a longer life, must be lighter, and must guarantee engine starting. In order to meet these requirements, a dual battery system has been proposed [4]. In this system, one battery handles the starting function and the other fulfils the service function. VRLA technology is suitable for use in dual-battery systems, provided appropriate conditions of charging voltage and environmental temperature are maintained. By virtue of its operational advantages (see above), a VRLA battery will increase the electrical system and will lessen the weight of the car. Consequently, the demand for VRLA batteries in this application will increase.

5. The future

Although the sales volume of VRLA batteries for cars is still low at this time in Japan, demand will expand as the electric consumption of cars increases and the battery space in the engine compartment decreases.

The demand for VRLA batteries in motorcycles is nearly saturated because the production of motorcycles has been gradually decreasing in Japan. In Asian countries, however, motorcycle production has grown from 2.1 million in 1983 to 7.3 million in 1993, and is expected to exceed 14 million in 2000. Thus, the requirement VRLA batteries, which are the most suitable batteries for motorcycles, will increase substantially.

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