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Sealed lead/acid battery for motorcycle use

T. Isoi, Y. Nakayama, S. Nakao and **H. Furukawa**
Product Engineering and Quality Odawara Plant, Yuasa Battery Co., Ltd., 4-5-1 Ohgimachi, Odawara, Kanagawa (Japan)

Abstract

Since the first dry-charged sealed lead/acid (SLA) battery was mounted on a motorcycle in 1983, millions of such units have been produced and sold for this application. Since that time, many efforts have been made to insure customer satisfaction and to improve the quality of the products by analyzing the batteries returned from customers. Simultaneously, the quality and productivity of the manufacturing process has been enhanced by the development of automatic welding equipment suited to Pb-Ca alloys. This latter advance has also given rise to a flexible manufacturing system.

Introduction

Flooded lead/acid batteries have long been used for motorcycles, but because of the inconvenience of handling such batteries, users have awaited the appearance of a battery with the following features.

1. Ability to start the engine without a recharge after a long period of disuse.
2. No leakage of electrolyte when a motorcycle overturns, and, obviously, when it is being transported or driven.
3. Maintenance of electrolyte, even when the battery is used for a long time.
4. No deterioration, even when the vehicle in which it is installed is stored for a long time.

A dry-charged, gas recombination, sealed lead/acid battery was developed and marketed in 1983 with the above features [1]. Since that time, this battery has held a prominent place in the market. In addition, during these years, much effort has been devoted to improving customer satisfaction, as well as to increasing battery reliability and reducing costs. This paper describes some of the improvements achieved by Yuasa. These have been effected in the hope that sealed lead/acid batteries will find even more widespread use.

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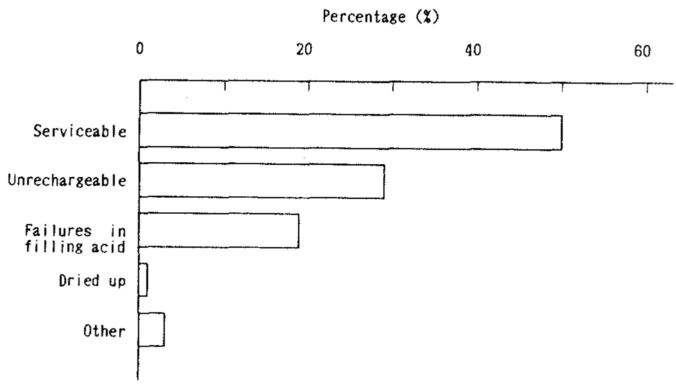


Fig. 1. Breakdown of customer complaints.

Improvements in battery use (improving customer satisfaction)

Figure 1 shows a breakdown of customer complaints at a certain time several years after beginning to market the battery. The following improvements were effected in response to the frequency of the complaints registered.

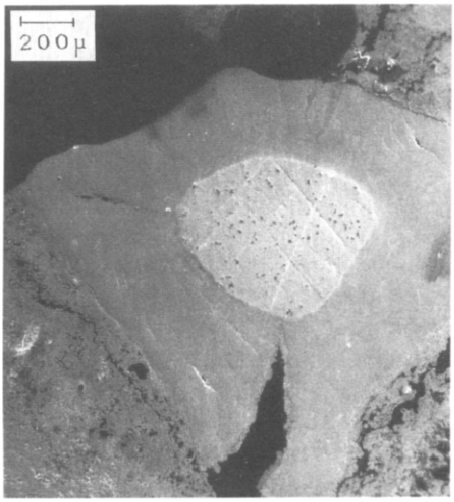
Clarifying the criteria for determining whether or not a battery is serviceable

The histogram contains an item entitled 'serviceable product'. This originated from the fact that (i) even though a given battery would have recovered to perform as new if it had been sufficiently charged, it was determined to be unserviceable because it was *not* charged sufficiently, or (ii) although full charge had been effected, the instruments used did not allow an accurate determination of battery serviceability. Thus, in order to preclude the possibility of insufficient charging, the battery charger was improved and a highly accurate battery serviceability tester was developed and put on sale.

Minimizing incidence of unrechargeable batteries

The second most common complaint was 'unrechargeable'. It was assumed that batteries reached this state because, during the long period of disuse (winter), vehicles were left with the ignition key turned on, so that the batteries were in an overdischarged condition, or even when the ignition key was turned off, a minute electric current drained through the regulator diode and the battery again existed in a discharged state.

An investigation of the failure mode(s) showed that, corrosion had occurred in the grid of the positive plate (Fig. 2). The corrosion products act as a resistor and thus make electrical conduction difficult. Another failure mode was the formation of large crystals of lead sulphate in the active material thus indicating that the plate was in an advanced state of 'sulphation' (Fig. 3).



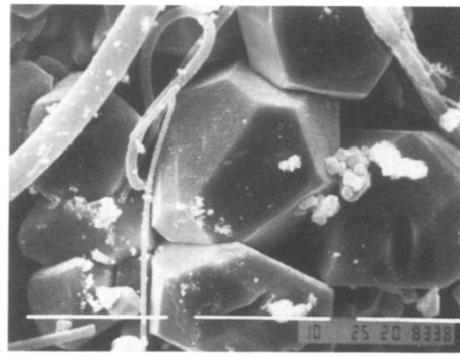


Fig. 2. Cross section of positive grid; corrosion observed in the unrechargeable battery.

Fig. 3. Positive plate surface showing 'sulphation'.

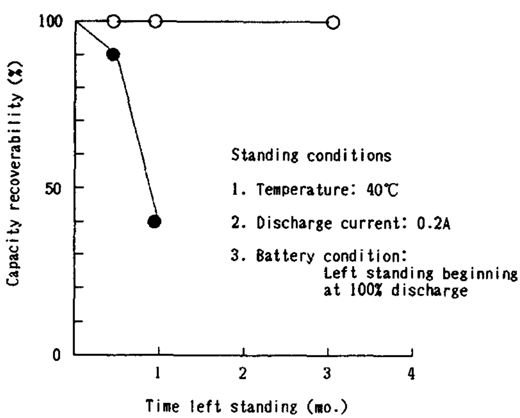


Fig. 4. Recoverability test results: ●: before improvement; ○: after improvement.

In order to deal with these problems, changes were made in the positive plates so that corrosion would not occur during overdischarge. At the same time, sulphate species were added to reduce the solubility of lead sulphate to a minimum. The results of these modifications are shown in Fig. 4 in terms of recoverability of battery capacity.

Improvements to acid filling device

When the battery was first developed, its design was such that acid was filled from a bottle of the type shown in Fig. 5 after cutting the top with a pair of pliers. According to the results of a customer satisfaction survey [2],

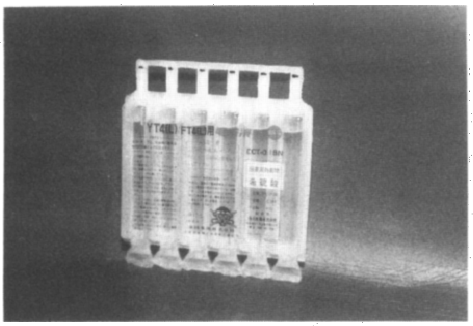


Fig. 5. The acid bottle first marketed.

Fig. 6. Improved design of acid bottle.

however, this arrangement caused problems such as acid shooting out when the bottle nozzle was cut, the air hole sometimes not being opened completely or being forgotten so that acid remained in the bottle, etc. For these reasons, several improvements were effected on the design of the acid bottle and the acid pour hole. This resulted in the present form of bottle (Fig. 6), which is known as the 'push and pour' system. The bottle opening is sealed with aluminum foil so that when the latter is pushed against the protrusion in the battery pour hole, the seal breaks and the acid flows into the battery. It is important that the air is replaced smoothly by electrolyte as the fluid enters the battery, and to this end, the principle of head pressure was used to create the optimum structure. This brought about a major reduction in the number of complaints regarding 'failures in filling acid.' Figure 7 shows a cross section of this acid pour hole. Efforts are continuing to perfect the acid-filling procedure. These include giving guidance to motorcycle dealers on the correct method to perform refreshing charges and to carry out battery service. At present, the customer complaint ratio is about one-fifth that experienced initially.

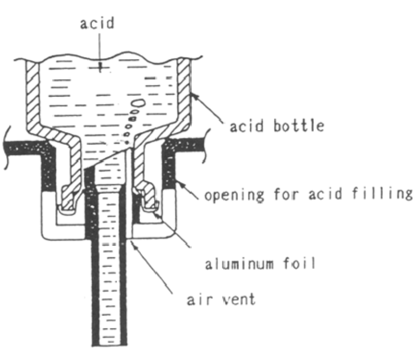


Fig. 7. Cross section of acid-filling device.

Improvements in battery manufacturing

It is the duty and role of battery manufacturers to produce and supply better and more cost-effective products. In the case of the motorcycle battery, a considerable number of innovative changes have been made, and much research and development effort expended. In particular, improvements have been effected in cooperation with a motorcycle manufacturer. The fundamental considerations have involved: (i) integration of differing models, and interchangeability of parts; (ii) a design that aims at high reliability and automatic assembly.

Integration of differing models, and interchangeability of parts

Close to one hundred kinds of conventional batteries are used in motorcycles. The parts are likewise substantial in number. These are a major cause of increased costs for both inventory and production. From very early on, Yuasa and a motorcycle manufacturer considered how best to achieve the integration of different models and the interchangeability of parts for the newly developed sealed batteries.

To achieve these objectives, battery sizes were standardized in two types with respect to vertical and horizontal dimensions; only the battery height was varied to provide units with different capacity. This approach made parts such as battery covers, separators, etc. interchangeable, thereby significantly reducing the number of these parts. Table 1 shows the example.

High reliability and automatic assembling

Since the introduction of the sealed motorcycle batteries a burning method has been used for welding the straps. This necessarily introduces disadvantages associated with welding difficulties, as well as limitations imposed upon automation with respect to producing many different models of batteries. Application of the cast-on-strap (COS) method was thought to be a means of overcoming these disadvantages.

Since the interior of a sealed battery presents a more severe corrosive environment than that of a flooded battery, the lead alloys employed must have no antimony. Examples of antimony-free systems include pure lead, lead–tin, and lead–calcium. On the other hand, because motorcycle batteries must be able to endure severe vibration, the strap alloy must have a certain degree of strength. Pure lead and lead–tin alloy cannot meet the latter requirement and, therefore, a COS method that uses a Pb–Ca alloy was ultimately developed.

The basic procedure for welding with the COS method involves melting solid lead (the lead of the plate lugs) with molten lead (the lead making up the strap), and joining the lugs and strap by contacting the molten metal from both elements. The plate lugs are generally covered with an oxidized film and if this prevents the two molten lead components from mixing, the lug and strap will not be joined. This problem is solved by finding a highly reductive flux.

TABLE 1

Sealed lead/acid batteries for motorcycle use

	YT4L-BS	YT5L-BS	YTX7L-BS	YTX7A-BS	YTX9-BS	YTX12-BS	YTX14-BS
Nominal capacity (C/10 rate) (A h)		3	4	6	6	8	1012
High-rate discharge (−10° C)							
Discharge current (A)	30	40	50	50	70	100	100
Duration (min)	1.5	1.5	2.3	2.3	2.2	2.3	2.8
Voltage after 5 s (V)	9.9	10.1	10.4	10.5	10.4	10.1	10.3

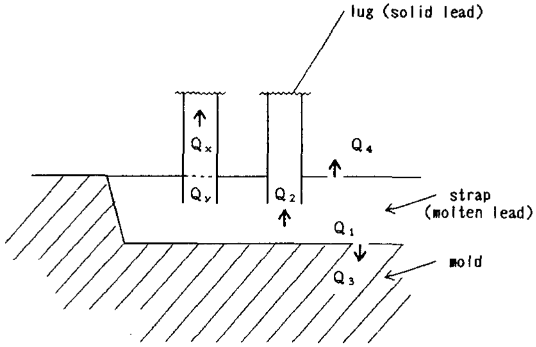


Fig. 8. Schematic diagram of heat transfer in COS. $Q_1 = Q_2 + Q_3 + Q_4$; $Q_2 = Q_x + Q_y$. Q_1: q.o.h. of molten lead; Q_2: q.o.h. transferred to lugs; Q_3: q.o.h. diffused into mold; Q_4: q.o.h. diffused into air; Q_x: q.o.h. diffused into lugs; Q_y: q.o.h. used for melting lugs. (q.o.h. = quantity of heat.)

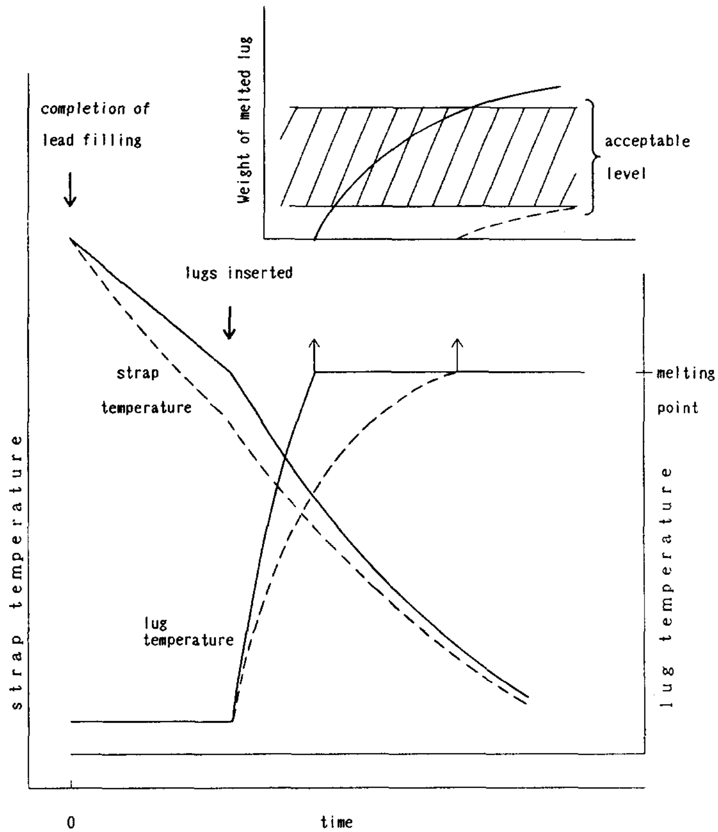


Fig. 9. Simulation of lug melting: —, type A; - - -, type B.

A model for melting the lugs is shown in Fig. 8. The quantity of heat transfer was measured on completion of the successive stages of lead filling to lug insertion, and lug insertion to the conclusion of melting. The actual heat conductivity was then calculated.

Next, a number of factors were varied, such as lead temperature, lead amount, volume of lug immersed, and the mould temperature. Changes in the lead temperature with time, and the amount of lug melted, were estimated by trial calculations. Figure 9 presents the results of the simulated processes. These calculated values match the actual acceptable upper and lower values for welding. The simulation curve indicated the tolerance to variation in the production process for features such as the depth of lug immersion, thickness of the straps, timing of the lug insertion, etc. This made it possible to take measures in advance to design production facilities for those characteristics that are important in guaranteeing accuracy in mass production. Such progress has made a major contribution to enhancing the quality of the production process.

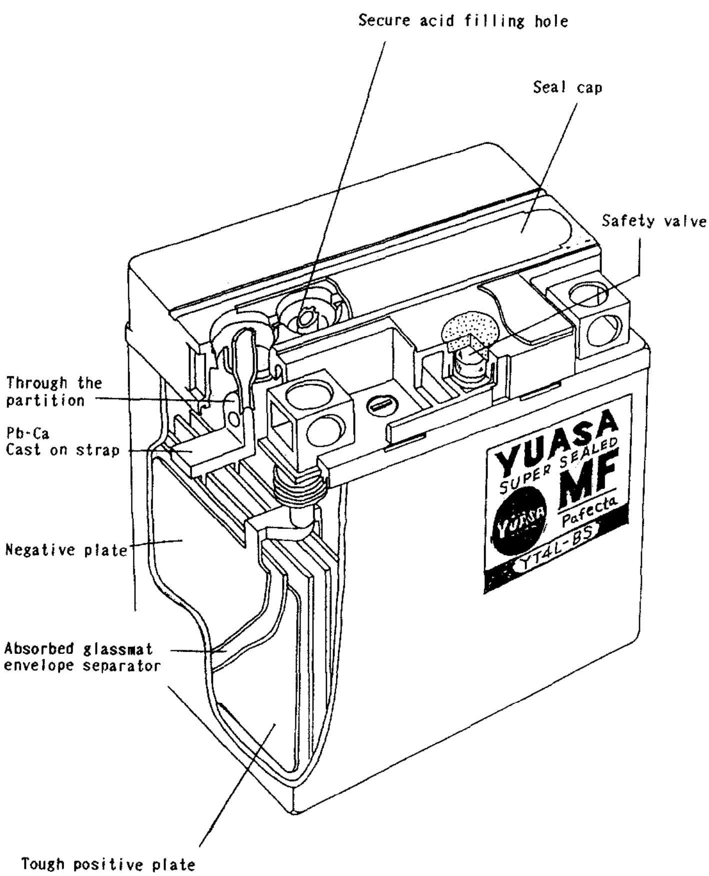


Fig. 10. Design of SLA battery for motorcycles.

Finally, automated equipment has been introduced in the assembly line through the stages of plate and separator stacking, COS, TTP, heat sealing, and sealing the electrolyte pour hole for the purpose of maintaining dry-charged battery activity. This technology allows many different battery models to be assembled on the same line, thereby bringing closer to reality the development of a flexible manufacturing system, and achieving more efficient production. The design of the latest SLA battery is shown in Fig. 10.

Conclusions

Since producing and selling dry-charged SLA batteries for motorcycles, two aspects have been addressed in order to advance the market. First, improvements have been sought in battery usability so that the batteries can be used more easily and without concern over reliability. Second, improvements in battery manufacture have been attained. This has given rise to a significant decrease in user complaints, as well as to a greater variety of highly reliable products. As a consequence, the rate at which these SLA batteries are being adopted for new vehicles has increased from year to year. Data from a major vehicle manufacturer, Fig. 11, shows that the acceptance rate for SLA batteries has recently surpassed 70%. In response to the continually increasing demand, still further improvements are being sought in the manufacture and performance of sealed batteries for motorcycle applications.

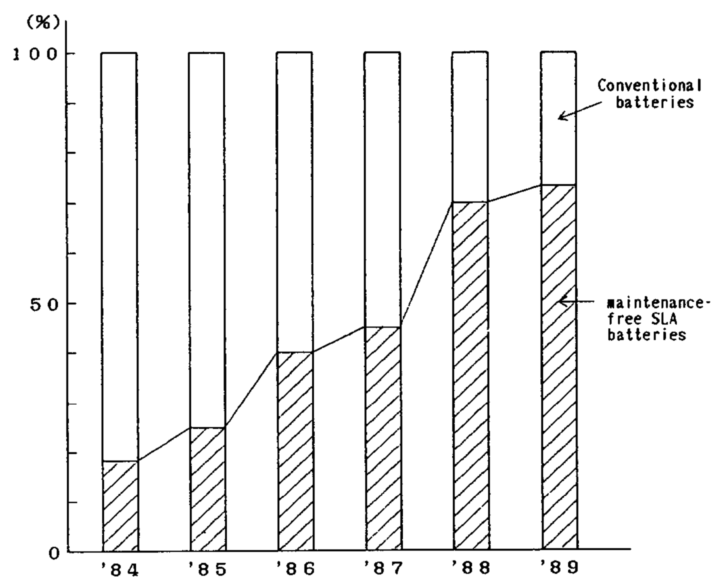


Fig. 11. Adoption of SLA batteries in new vehicles by a motorcycle manufacturer.

Acknowledgement

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