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MANUFACTURING TRENDS IN AUTOMOTIVE BATTERY MANUFACTURE

A. M. HARDMAN
Chloride Technical and Trading, Wynne Avenue, Swinton, Manchester M27 2HB (U.K.)

Introduction

The automotive battery in its present form can be said to be a mature product offering few opportunities to reduce manufacturing costs, especially with regard to material content against a given product specification requirement. A combination of intense international competition and environmental pressures has, however, brought about many changes in manufacturing methods over the past decade. These changes are continuing so that both labour and overhead costs can be further reduced. Such developments are reviewed in this paper.

Virtually all the automotive batteries manufactured worldwide, especially the lower ampere-hour/mass-volume types, are now made using polypropylene, heat-sealed containers and lids with through-the-partition extrusion fusion intercell connections. Also, the majority of these batteries is produced using either grain-refined, very low antimonial or lead–calcium alloys for grid production. Batteries using such grid alloys are, in the main, labelled ‘maintenance free’.

Grid casting

Throughout the world, whether casting in traditional or low-antimonial alloys, or the various calcium alloys, the grid casting machine (with individual moulds) remains the principal means of producing battery grids. The most advanced of these machines, however, now have automated control systems. These allow one operator to run several machines and, with the exception of spraying-up expertise, largely deskills the grid-casting operation. The self diagnostic, fault-finding capability and the automatic monitoring of the running parameters of these machines also help to ensure maximum output with minimum down time.

Alternative methods of grid production use either expanded-metal or continuous-casting techniques. Both of these procedures only become attractive once the output for a given grid type exceeds around 60×10^6 pieces/annum; this equates to approximately 2×10^6 batteries per annum (on the basis of using two grid thicknesses in each battery). Although the expanded-metal grid is now employed in commercial production in the U.S.A., Japan

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and Europe, its use still only represents a low percentage of all battery output worldwide. In the case of continuous grid casting, commercialisation of the process is relatively new. Nevertheless, the process is said to be suitable for working with both ultra-low antimony and lead–calcium alloys. With the expanded-metal technique, only calcium–lead alloys can be used, as the metallurgical properties of even low-antimony alloy are not compatible with the process. Also, the continuous cast grid has a complete frame and does not suffer some of the problems associated with expanded-metal grids. For the large-volume factory, this casting technique would appear to be a major contender in the not too distant future.

Oxide production

The ball mill and the reaction (Barton) pot remain the two manufacturing routes for the preparation of battery-grade oxides. Laboratory work indicates that mill oxide is the preferred powder type for ensuring product consistency and for battery applications in territories with a wide range of climatic conditions.

Experience gained by the author's company with the two alternative plant systems suggests that oxide produced by the ball-mill route is generally more consistent in quality. Also a mill is generally found to be mechanically less troublesome in both operational and maintenance terms. Nevertheless, the reaction-pot system is used quite satisfactorily by many companies for the production of automotive batteries. It is, as a process, cheaper to run, it occupies less space per ton of oxide produced, and the investment for a given tonnage output is significantly lower.

Whether produced in a mill or in a reaction pot, oxide is generally stored in bunkers and transferred directly to the batch weighers feeding the paste mixers. Modern systems are usually fully enclosed to eliminate hazardous manual operations; this is essential if environmental standards are to be met.

Paste mixing

The method of preparing pastes generally remains a batch process. Improvements in paste preparation have been made in the last decade, especially in maximising throughput and decreasing the handling aspects, for example, by the use of transveyors, batch weighers and paste dispensers. For both technical and quality reasons, it has not been possible, to date, to change to continuous processes. In attempts to produce paste on a continuous basis, it has proved difficult to achieve pastes consistently within the narrow tolerances necessary for the production of high-quality automotive batteries.

The most satisfactory paste-mixing option is still, therefore, a high speed, high efficiency, batch mixer. This procedure must ensure thorough and rapid mixing, as well as maximum throughput, without jeopardising paste quality by overheating (burning). Programmable logic control (PLC) guarantees high repeatability of mix and control of raw material inputs.

In the latest design of installation, the mixer is located at a high level directly over the pasting machine. Paste is fed, via a cone dispenser, directly into the pasting machine hopper. This arrangement eliminates the need for a separate paste handling system and its associated labour; at the same time, it also reduces environmental contamination, thus improving working conditions.

Pasting

For the pasting of soft, low-antimony or lead–calcium alloy grids, the latest designs of belt pasting machine, complete with horizontal drying oven and shingle-type takeoff conveyor, are almost universally employed. In up-to-date factories, the pasting machines are located directly below the paste dispenser of the paste-mixing installations. This arrangement minimises paste spillage and removes the arduous and tedious task of manually feeding paste to the machine hopper.

A new and developing trend is rapidly coming into favour, namely, that of pre-cutting grids before pasting. This is because the shelf life of wet batteries of the maintenance-free type has been greatly improved (over the products of the 1970s which used 6 wt.% antimonial alloys) and because there is mounting pressure from many outlets (such as supermarkets) to be supplied with wet batteries. This development eliminates plate cutting of green (unformed) plates as a separate operation which, in turn, both removes the adverse environmental aspects and reduces the high value scrap frequently associated with plate cutting. Pre-cutting of the grids before pasting does, of course, require the handling and curing processes to be changed to suit single plates rather than pasted castings.

Curing

For many years, curing or plate setting has been carried out either by using separate cubicles or by simply covering pallets or stillages of freshly pasted grids with canvas sheets. These methods require between 72 and 96 h to provide cured and dried plates ready for further processing. Furthermore, due to climatic changes during the year, considerable product variability can be experienced.

Curing procedures of increasing control, using special ovens having preset humidity and temperature profiles, are being incorporated into automotive battery factories. The advantages of these systems are improved product consistency and quality as well as a major saving in work-in-progress (WIP) since the turnround for cured plates is reduced to under 48 h.

Formation

Possibly the single most important manufacturing option is whether to make dry-charged or jar-formed (wet-charged) products. Although plates using 4 to 6 wt.% antimonial grid alloy can be made into either dry- or jar-formed products, those with low-antimony or calcium grids are preferentially processed into jar-formed products. The reason for this is that dry-charged negative plates produced in low-antimony or calcium alloys are very soft and difficult to process without having excessive scrap rates and reduced productivity in both the plate cutting and assembly operations. If there is a genuine market need for dry-charged, maintenance-free products, then it is possible to produce a hybrid battery using low-antimony or calcium alloy positive plates and a higher antimonial alloy for the negative plates. Naturally, this will require at least two different alloys in the grid-casting department.

If jar-formed batteries are produced, then all grid manufacture would be from one alloy. The main advantages for the manufacturer of such batteries are a reduced number of processes compared to the dry-charged route and, because of the simpler manufacturing route, lower overall levels of factory scrap are generally experienced. A further benefit of the single-shot, jar-formed production route is that virtually no liquid acidic effluent is involved as a by-product. This saves both revenue costs in treatment chemicals and reduces the capital cost of the effluent treatment plant.

Because of the reduced number of processes, the simpler alloy situation, the environmental advantages and the more favourable economics of manufacture, it is self evident that the production and marketing of jar-formed batteries (especially in domestic markets) should be the preferred option.

Regarding the process techniques employed for both jar- and tank-formation, developments have been, and continue to be, made especially with a view to reducing WIP. The latest jar-formation chargers are becoming quite sophisticated, having at least PLC controllers. Through the introduction of stepped programmes, temperature sensing, and customised charging bays complete with forced draught cooling arrangements, car batteries can be turned around in under 24 h. In the case of tank formation, tackless formation is now almost universal. By the use of higher currents and the inclusion of cooling systems, it is now possible to achieve at least two formation circuits per 24 h, compared to one using the traditional 20-h formation schedule.

Plate cutting

For the production of dry-charged batteries from plates formed as castings, it is still necessary to include a plate-cutting and lug-brushing operation prior to battery assembly. For jar-formed batteries, on the other hand, the cutting of unformed (green) plates will be most likely carried out prior to pasting (see above). Until this technique becomes commonplace, however, the combined lug brushing and parting machine, complete with shingling conveyor, will remain the most common plate-cutting method.

A recent development is to provide auto stacking of the brushed and cut plates rather than using a shingling conveyor and associated labour. Such a development reduces operator exposure to lead and also removes a highly repetitive and tedious task. At this stage, this procedure appears to be only used by a few major manufacturers.

Assembly

Since the advent of the through-the-partition polypropylene automotive battery, increase in the mechanisation and automation of assembly lines has proceeded continuously right up to present day. Modern assembly lines producing automotive batteries of up to ~80 A h have throughputs of between 600 and 800 batteries per eight-hour shift and generally comprise the following key operations:

(i) stacker/enveloper using either reels of polyethylene or synthetic wood pulp as a separator feedstock;

(ii) cast-on-strap machine with automatic case out, that is, the burnt-up groups are placed mechanically into the container;

(iii) fully automatic through-the-partition squeeze welder, complete with automatic lid-placing facility;

(iv) fully automatic heat-sealing machine;

(v) fully automatic burning machine for both types of taper post (standard and small).

In between some, or all, of these key assembly functions may be included fully automatic testing units complete with auto accept/reject facilities. At the end of the assembly line, depending on whether dry-charged or jar-charged products are being manufactured, a range of other machinery may be incorporated, *e.g.*, vent plug placing, labelling, shrink wrapping, powered conveyors leading to acid-filling machines for jar-formed production, etc. After jar formation, batteries can now be high-rate discharge tested with automatic accept/reject facilities, followed by automatic acid topping up/levelling, vent plug placing, washing/drying, and labelling.

Future developments

The continuous further development of individual machines can be expected, particularly in the area of control systems. PLCs will be used for monitoring and controlling processes and raw material inputs and for assisting in breakdown prediction and maintenance planning.

The pressures and concerns for environmental aspects will continue to grow on a worldwide scale. The capital element for environmental control will continue to increase in percentage terms *vis-á-vis* the total productive assets.

The small-to-medium sized factory will continue to manufacture product generally along the lines outlined in this paper. Methods using expanded or continuous cast grids, followed immediately by plate cutting, pasting and sharp (flash) drying will only be employed by a handful of very large factories most probably located in the U.S.A., Japan and Western Europe.