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CONTINUOUS PRODUCTION OF AUTOMOTIVE LEAD/ACID BATTERY PLATES FROM LEAD–CALCIUM–TIN STRIP

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Introduction

After decades of very slow development, the 1980s have witnessed an acceleration in the technology of automotive-battery manufacture. As part of the Component Branch of FIAT, Magneti Marelli concentrated on a new product based on a less traditional technology in order to comply with car manufacturers' requirements. These are:

Electrical performance. For an automotive battery, the main electrical performance requirement is obviously the cold-cranking ability. This differs for gasoline- and diesel-engined powered vehicles. In the case of capacity requirements, in Europe the number of different loads and the urban traffic and driving habits require an acceptable low-rate capacity (evaluated as a 20-h rating in A h, or as a reserve capacity in minutes at 25 A).

Weight. Weight reduction is one of the main goals for every car manufacturer. The relatively bulky battery is a particular target of the 'weight watchers' in car manufacturers' design offices.

Size. Compact and streamlined cars require battery sizes to be reduced but, at the same time, they must comply with dimensional standards for easy car exports. Therefore, it is necessary to solve this difficult problem through compromise, particularly regarding acid space and battery height.

Price. The car manufacturers are unwilling to pay extra for the improvements required for batteries. Therefore, the successful technologies are those that result in a reduction in cost (material and labour).

Reliability. The quest for a reliable car requires reliable components. The battery failure rate during car warranty must be at a minimum. The

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'bathtub-shaped' diagram for infant and age mortality should be kept in mind for design and production. Therefore, the goal is a battery having good reliability when new having components that wear at approximately the same rate.

Charge acceptance. Both car manufacturers and battery makers should research battery rechargeability while operating in a vehicle during both low temperatures and in urban traffic. Such operations will include frequent shallow discharges and occasional very deep discharges. The requirement is for a battery with low electrical resistance and a suitable current/potential curve.

Stand (open-circuit) loss. It is very important that the battery should start immediately, even after months of stand, not only when new but also after a couple of years' service, or more. This feature is equally important in sales distribution because dry-charged batteries pose many problems (from water pollution in production to filling with acid by the user).

Maintenance. Freedom from maintenance (for a new or an aged battery) is essential for a modern product and it is extremely important for owners of commercial vehicles, buses, and other fleet vehicles to save or reduce the labour costs involved in topping-up batteries.

Life. It appears that European car manufacturers are not unduly concerned about battery life. They are convinced (mainly on the basis of experience in the U.S.A.) that the life of batteries placed on the market by battery makers of good repute is more dependent on external conditions than on the component itself. Nevertheless, the battery, even after drastic reductions in both weight and size, must survive for as many years as the customer has come to expect.

Battery specifications

On the basis of the requirements listed above, a range of batteries based on expanded Pb–Ca–Sn grids for both positives and negatives was developed by Magneti Marelli during the 1980s (Fig. 1).

Weight saving was mainly achieved by employing grids of low weight. In general, FIAT cars use batteries containing about 5 kg of lead. The dimensions of the grid diamond structure have been investigated in depth using a programme for the optimization of potential distribution, as well as extensive field-testing to evaluate ageing in service. The negative plates are enveloped in microporous poly(ethylene). The production of Pb–Ca–Sn strip is based not only on a proprietary milling system (Continuous-Properzi), in joint venture with Magneti Marelli, but also on exhaustive metallurgical investigations of the mechanical quality, corrosion, and electrochemistry at the interface with the active material.

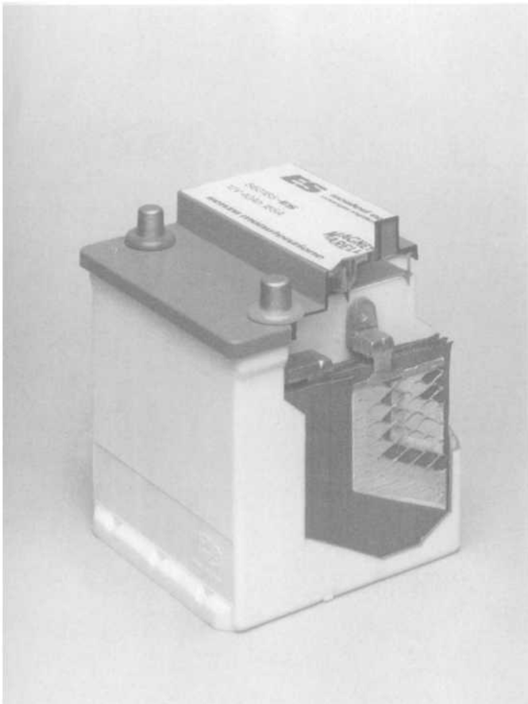


Fig. 1. Battery for FIAT cars, 40 A h, 185 A.

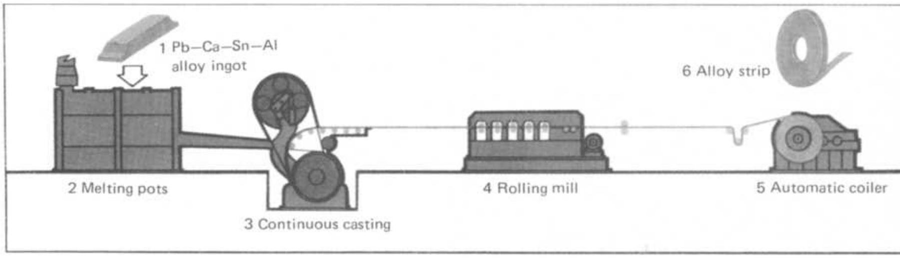
The range for starter batteries goes from 34 A h (6 plates) to 200 A h/ 1000 A. The -18 °C starting ability test (on car size) gives about 20 A kg^{-1} of filled battery (more than 200 W kg^{-1}). The water consumption, evaluated according to International Electrotechnical Commission Recommendation (95-1) is less than 1.5 g $(A\ h)^{-1}$. By comparison, a battery with a Pb–1.8wt.%Sb grid alloy gives a value of 4.5 g $(A\ h)^{-1}$. The battery can therefore be regarded as 'absolutely maintenance free'.

Technology for battery production

Figure 2 shows the main stages for the continuous production of the battery (at a plant in Romano Lombardo). At present, the output is 3 million batteries per year.

Strip production

The continuous Properzi system has a capability of 4 million batteries per year (on 3 shifts). Currently, the line is running for about 3 weeks per



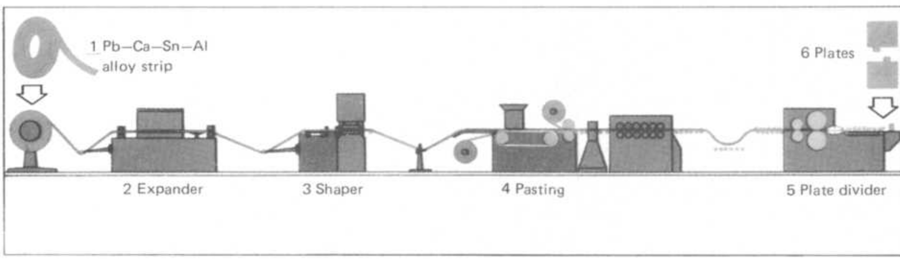


Fig. 2. Technology of battery plate production: (a) strip production; (b) plate production.

month with 2 - 3 men/shift, including alloy preparation. The alloys, of different tin content (higher for positive), are spectrographically batch-analyzed.

The main features of the system are:

(i) a furnace using two melting pots (one for melting, the second to keep the alloy at temperature);

(ii) a Properzi wheel, casting a continuous 10 mm-thick ingot;

(iii) a belt conveyor with a sensor to synchronize the ingot production and the mill;

(iv) a rolling mill, Fig. 3, with six rolling stands and continuous thickness and width monitoring (0.8 mm min. - 1.1 mm max., and from 50 - 100 mm, respectively). The final stand is adjustable for thickness;

(v) a slitter handling a maximum width of 90 mm;

(vi) a finishing unit equipped with a washing and drying tunnel and a slitter;

(vii) trim and scrap recycling to the oven;

(viii) an automatic coiler that includes a discharge device to handle coils up to 900 kg.

Expander

Using a progressive die of in-house design at a speed of about 12 m min^{-1}, one person plus one supervisor per shift can run 5 lines. Temporarily, the factory is coiling to conform with pasting programmes. It is worthwhile noting that the two operators are unskilled, but casting of thin, low-antimony grids requires some skill and/or sophisticated controls for the

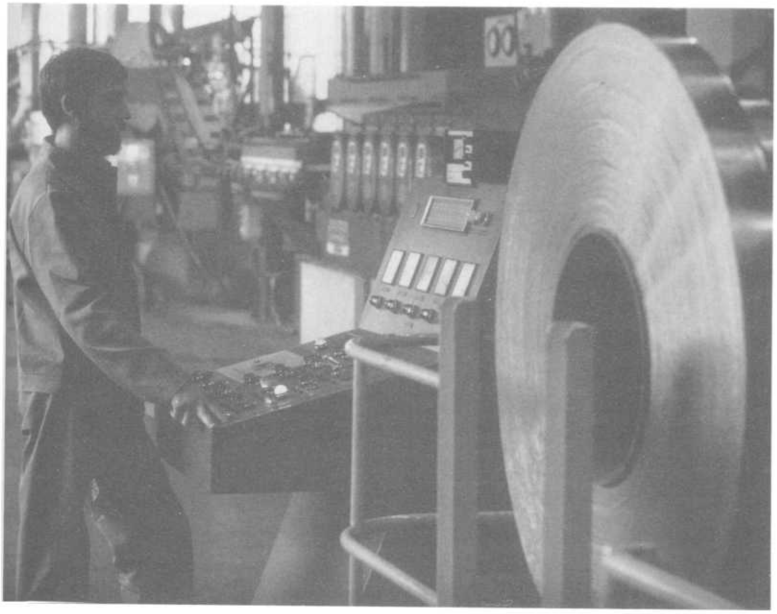


Fig. 3. Rolling mill.

moulds. New and faster machines are under development to match the output from the paster when running at twice the present speed.

Continuous pasting line

The line operates at a speed of 25 m min^{-1}. A rotary cutter divides the plates which then enter a flash-drying oven with special protection against overdrying (the surfaces of the plates are protected with thin sheets of paper, pasted together).

A unique and automatic stacking system avoids damage in plate handling. An automatic palletizer stacks four pallets of 8000 plates each. Weight is monitored in real time with a radioactive isotope system.

Curing system

Special chambers (ovens) with controlled temperature and humidity (maximum temperature 60 °C; 5 - 85% relative humidity) provide excellent curing in 24 h.

Group production

The negatives are first enveloped in a stacking, enveloping machine (150 negatives processed per minute). The plate groups are obtained using a cast-on strap (COS) system. For 8-plate groups, an in-line COS system produces groups (12 at a time) to match the assembly line. Groups of more than

8 plates are assembled on rotary COS units producing 12 groups per revolution.

Assembly line

After group production, the inter-cell connections are made by an extrusion–fusion system with a conveyor pitch of 10 s (~2200 batteries/shift).

Welding is electronically controlled, not only for current, time, and squeezing power but also for energy. Modern electronic controls are used to examine for short circuits, connection resistance, and tightness of connections and cover.

Dumping line

After formation (using low-gravity acid), the battery is dumped and refilled twice to reach a stable and consistent final gravity without the need for a further mixing charge. A high-current test is automatically made and values recorded for each battery. Each line handles 2500 batteries/shift.

Conclusions

With the above technology, savings have been achieved in both cost and scrap. Also, there has been an appreciable reduction in the lead dust in the ambient and external atmospheres, as well as in the effluent water. The levels are below the stringent rules of the law.

Production started gradually in 1980 and is now over 3 million automotive batteries. Car manufacturers (FIAT, Iveco, Renault, Peugeot, SEAT) are very satisfied with the weight reduction and reliability of the batteries. The overall production cost is more than 20% below that of an equivalent cast-grid battery. Finally, average life, after 8 years of appraisal, is longer than that obtained with low-antimony batteries.