Journal of Power Sources, 48 (1994) 71-76

Modern technology for the preparation of battery paste

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Abstract

In 1985, Eirich started to introduce vacuum technology into the lead/acid battery industry (after having gained experience over many decades with more than 180 plants) for the preparation of lead paste. Despite higher investment costs, this process technology is becoming more and more established in Europe, and, starting with Japan, has seen growing acceptance in Asia since 1991. The major advantages are high paste quality (due to constant production conditions even under difficult climatic conditions), exact temperature and moisture control, as well as high mixing intensity.

Introduction

Competition in the battery industry becomes even keener and, therefore, calls for ever more economical production. At the same time, high quality is essential. In many cases, the economic efficiency of a production system cannot be assessed by the investment costs. For instance, a typical plant worth US$ 500 000 produces 230 000 tonnes of paste in ten years. If the investment costs are related to production, then they will only amount to some 0.3 cent per tonne. Thus, it is really worth considering new technologies, even if they seem to be more expensive than conventional systems at first sight. Higher product quality and smooth production can contribute a great deal to a cost-worthy manufacture. Due to a empirical horizon that has been gained over decades, Eirich has developed a mixing and plant concept that combines economical production and superior product quality.

The main components of such a plant are (Fig. 1):

- a lead-dust storage unit
- transport systems
- fully automatic weighing and batching units for all components of the formulation, including additives (dry or in form of suspension), fibres that are difficult to handle, and also the lead sludge recycled from waste water
- a mixing reactor
- a paste feeder for delivery to the pasting machine

Control system

The whole plant is controlled by hardware and software that have been tailored to this application. The sequential flow of the process is fully automized and ranges from the weighing, the mixing times (in conjunction with individually adaptable mixing intensities and viscosity control), up to the feeding of the paste feeders. This excludes human error and, at the same time, cuts personnel costs.

Elsevier Sequoia
SSDI 0378-7753(93)01858-F

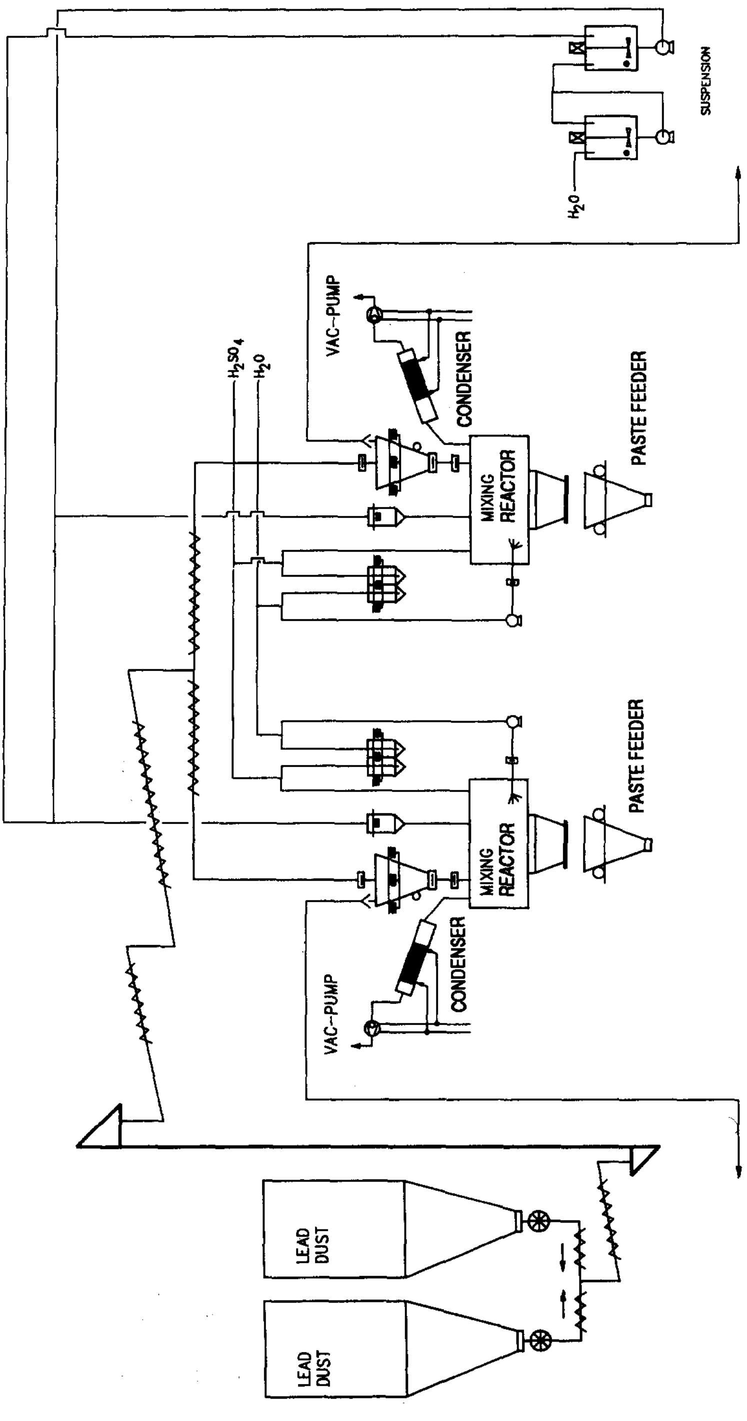

Fig. 1. Preparation plant for lead paste vacuum technology.

The software package 'Akkuexpert' serves to log the operation results, e.g., formulation and mixing records can be printed out. This allows quality assurance to be achieved according to ISO 9000 ff. This is becoming indispensable in the automobile industry. As a result, the final product gains a higher customer acceptance.

Mixing reactor

The mixing reactor is the heart of the plant. It is specifically designed for high shearing forces and quick and thorough mixing of the whole paste body. This is absolutely necessary for the short cycle-times of today. Between the main mixing tool and the paste, shearing speeds of up to 30 m s^{-1} are possible. The whole paste body is mixed thoroughly several times per minute. Thus, an instantaneous and absolutely homogeneous dispersion of the acid is achieved, even at high addition rates. The sulfates are evenly dispersed right from the time of their formation, and thus produce a very constant paste quality. Moreover, the formation of burned grit and inactive material is minimized.

Independently of whether air cooling or vacuum cooling is used, this mixing principle provides for a very effective cooling that works in the whole paste body within seconds. The resulting homogeneous temperature distribution has a positive effect on an evenly high paste quality — a pre-condition for good battery quality.

The mixers that are applied nowadays (Fig. 2), the so-called R-models, always consist of a pan that revolves on vertical axes and mixing tools that work inversely to the rotation sense of the pan. Eighteen times per minute, the pan guides the complete paste volume to the tools for homogenizing.

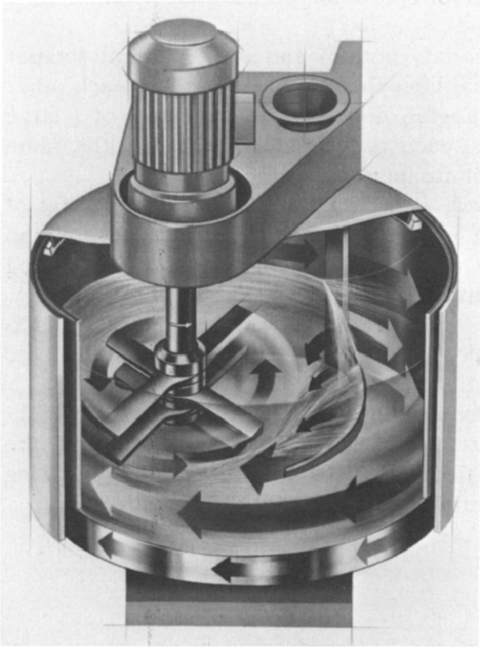

Fig. 2. Principle of the intensive mixer.

Fig. 3. Material streams in the intensive mixer.

A mixing tool, the agitator, is positioned eccentrically to the pan centre. It provides the so-called micromixing of the raw materials, especially of the small components, and a fine dispersion of the liquids. The agitator speed can be adapted within a wide range to the requirements of the mix.

Together with the rotating pan, a stationary bottom and wall material scraper generates the macromixing in form of motional lines that cross and overlap each other constantly. This leads to a continuous re-arranging, dividing, and collecting of a large number of material streams (Fig. 3). Hence, each particle of the mix has the same probability to meet the other, a requirement for perfect mixing.

There are no dead-mixing zones, not even at the pan wall or bottom; cakings of stickings and drying material that burst off gradually and cause difficulties on the pasting machine are prevented. Due to this virtual self-cleaning effect, one cleaning per week on three-shift operation is sufficient.

The discharge gate is positioned in the centre of the mixing pan bottom and is operated via the hydraulics of the mixer. For discharge, the blended shape of the bottom scraper conveys the paste to the outlet.

Special importance is attached to the prevention of corrosion by choice of high-quality materials and the sophisticated construction. These developments are both the result of a close cooperation with the lead/battery industry for many decades. Cleaning and maintenance costs are thus minimized and a long service life is guaranteed.

Cooling

In most present conventional equipment, the heat generated by the reaction of lead oxide and sulfuric acid is mostly extracted by air cooling. An air stream strikes over the intensively agitated paste body. The cooling effect is mainly achieved by the evaporation of the water contained in the paste. For effective cooling, it is essential that three conditions are met, namely:

(i) cool and dry air is available in sufficient amounts:
(ii) a sufficient amount of water for evaporation is available in the paste, and
(iii) the paste offers a sufficiently large surface for evaporation.

All over the world, large numbers of these systems have operated successfully for years. By virtue of the functional principle, however, the air cooling has its limits.

Condition (i) is dependent on the climatic conditions. With increase in air temperature and air humidity, air cooling becomes less effective. Air conditioners for air drying and cooling do not always bring about the desired success. As a consequence, preparation cycles and temperature curves of the paste vary according to time of day, or season and, thus, quality fluctuations become inevitable.

Condition (ii) can be met by adding a surplus of water when starting the preparation process. This approach, however, leads to a certain formulation inaccuracy as, at the end of the process, the water content can only be determined by a measurement of penetration or weighing of the complete mixer still containing the paste. Both methods are not accurate. When weighing the mixer, more than 95% are tare, i.e., constant material mass that consists of the mixer itself and the paste except for the water. The higher the tare, the less accurate the weighing. Vibrations of the mixer that cannot — even electronically — be filtered away completely add to the problem of inaccuracy.

Condition (iii) namely, a sufficiently large paste surface, is dependent on the mixing intensity which reaches its optimum in the Eirich mixer where the paste is quickly agitated and circulated.

Vacuum cooling

The cooling of paste under vacuum is a relatively new process technology. The first plant based on this principle was delivered to Bosch in 1985. Since then, the vacuum technique has gained increasing acceptance in Europe. Meanwhile, 25 plants have been put into operation and in Asia, too, one manufacturer has started to appreciate the vacuum technology. Already in 1991, the Eirich Vacuum Technology has entered on the Japanese heavy industry.

The principle of vacuum cooling is as follows. At normal pressure, boiling water has a temperature of 100 °C. An infinite amount of energy can be added, as long as there is still liquid water, the temperature will not exceed 100 °C. All energy introduced will be consumed to evaporate the water. If the pressure is lowered, the water starts to boil at a lower temperature. For instance, at a pressure of 200 mbar, the boiling point of water is 60 °C. If the pressure is kept constant, it is physically impossible for the temperature to rise in the system as long as the water is not completely evaporated.

The vacuum cooling takes advantage of this correlation. As soon as the paste reaches the boiling point of water (which is adjusted beforehand by creating a defined depression), the complete amount of energy, generated by the chemical reaction between lead oxide and sulfuric acid, is consumed to evaporate the water in the paste. The steam produced is condensed in a heat exchanger. The heat exchanger returns the evaporation heat extracted from the paste. The condensed water flows back into the paste to evaporate again. This process is therefore called vacuum backflow cooling.

Being a closed system, the vacuum cooling offers many advantages, as follows:

(i) The air process is completely independent of climatic conditions. Air temperature, air humidity as well as raw material temperatures (e.g., temperature of water) have no impact on the preparation and cooling process. Different cooling times and adaption of the formulation to time of day and season are no longer necessary. Due to constant production conditions, absolutely reproduceable paste properties and, consequently, evenly high battery quality is achieved.

(ii) No components are extracted from the formulation as only minor air quantities are exhausted during the evacuation procedure. The flow velocity produced at this stage is negligible; whereas with air cooling, velocities of more than 80 km h^{-1} may occur.

(iii) The water content of the finished paste corresponds exactly to the amount batched at the beginning since all the water evaporated for cooling is condensed and returned to the paste.

(iv) As soon as the plant is commissioned and the properties of the lead dust remain constant, only minimal amounts of correction water are necessary for the automatic control of viscosity. This accurately adjustable water content provides active material with a reproduceable porosity and, thus, constant electrical and mechanical properties (e.g., capacity and mechanical resistance).

(v) Absolutely reliable temperature control is one of the most important properties of the vacuum cooling. Even if the acid is added very quickly (i.e., if large amounts of heat are generated), it is impossible to overheat the paste due to the physical regularities. As a result, constant and reproduceable processing properties of the paste are achieved and this minimizes rejects on the pasting machine.

(vi) Due to the vacuum technique, it is possible to cool down the mix by, for example, 20 or 30 °C within seconds. This guarantees the exact adherence to predefined temperature curves and thus permits an exact control of the reactions. The desired proportions of crystal phases, such as tribasic and tetrabasic lead sulfates are safely achieved in conjunction with the reliable moisture control and the independence of the process of ambient conditions. This contributes largely to achieving the predefined battery properties (e.g., initial capacity, service life).

(vii) The vacuum system can supply final paste temperatures that are lower than those achieved in air-cooled plants. Uncontrollable changes in viscosity that are connected with the evaporation of water during the storage period after mixing, and that create processing difficulties, are thus minimized.

The future

The Eirich Vacuum System is a progressive technology that renders the production of high-quality battery paste economical. It represents the success of a careful research and development work in close cooperation with the battery industry. Since the lead dust does not leave the vacuum plant, the system also meets more stringent future regulations as to environmental protection and working safety. Due to the possibility of almost instantaneous temperature control, even complex temperature/time curves are controllable. This offers a necessary flexibility for future developments in the field of lead/acid batteries.