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COPPER-STRETCH-METAL TECHNOLOGY AND APPLICATIONS

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Copper-stretch-metal technology

Cell impedance

One of the most important properties in determining the performance of a battery is its impedance. Generally this includes the phenomena of polarization and electrolyte resistance on the one hand, and the sum of the grid resistances on the other Considering standard lead/acid batteries, the first component might be called horizontal resistance (R_h) and the second, vertical resistance (R_v).

Despite the fact that polarization follows the Tafel equation, it is a good approximation to assume that within normal applications of industrial batteries of the tubular-plate type, polarization can be treated as an ohmic resistor As found by Euler [1], the impedance for a vertical cell segment covering one positive tube and the corresponding part of the negative plates is given by·

$$R = \sqrt{R_v R_h} \coth(\sqrt{R_v/R_h} X) \quad (1)$$

where X is the total plate length The same calculation also provides information on the current distribution, j, as a function of the plate length, L, i e ,

$$j = aX \cosh(aL) \sinh^{-1}(aX) \quad (2)$$

where

$$a = \sqrt{R_v/R_h} \quad (3)$$

Cell design

In Europe, cycling lead/acid batteries are basically of the tubular-plate type The positive grids are comb-like and are prepared by a process similar to die-casting. The casting pressure is lower than that recommended for either zinc or aluminium. The advantage compared with gravity casting is a much smaller grain size and therefore increased corrosion resistance The current-bearing lead spines are surrounded by the tubes and the annular space is filled with the active material The negative grids are gravity cast and then pasted in the usual way.

Cell sizes are defined either by the British or German standards The German standards (PzS according to DIN 43595) use a cell width of roughly 200 mm and a plate pitch of 18 mm The minimum service life is 1500 labora-

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tory cycles at 80% depth-of-discharge Copper-stretch-metal (CSM) technology follows the same general design and standards. This means that the dimensions, the weight, and the terminals of the cell remain unchanged. The positive plates are almost the same as those used for PzS having 19 tubes However, the tube diameter is increased by 0.3 mm The main difference from CSM lies in the negative plates. Polarization and electrolyte resistance cannot be improved appreciably, and with the present state-of-the-art there is no possibility of improving the conductivity of the positive spines by application of a more suitable metal than lead Nevertheless, the total impedance can be reduced by using copper for the current transport in the negative grids The Pourbaix diagrams [2] for lead and copper show that

(i) copper should not be dissolved in the electrolyte of a lead/acid cell without the presence of oxygen,

(ii) copper might be cathodically protected by lead

Negative-plate processing

With the above electrochemical background, the main steps for the processing [3] of the negative plates are

(i) copper sheet (from coils) is expanded on standard machines (CSM = Cu-Streck-Metall), the width of the sheet will define the length of the plates,

(ii) the expanded metal is electroplated, firstly with a lead–tin alloy, and secondly with pure lead,

(iii) the length is trimmed to the size(s),

(iv) a plastic bottom bar is injection-moulded to the grid,

(v) a lead alloy top bar is cast on,

(vi) pasting, curing, and formation are carried out in the normal manner

It should be noted that both the adherence to the copper and the crystal sizes and shape of the galvanically-applied layer are important quality criteria In general, the coating should completely cover the surface, although slight imperfections are tolerable

Applications

Traction

Because batteries using the CSM technique are more expensive than traditional ones, they are used whenever maximum energy content, high power demand, and long service life are important selection criteria.

A comparison of the energy contents of PzS and CSM can be made using the nominal loads of PzS as a base This is acceptable as the design of fork-lift trucks is made according to the standardized batteries The energy content (in W h) of CSM is 172, 142 and 129% for the 0 5, 2 and 5 h rates, respectively, when compared with corresponding data for a battery of the popular size 6 PzS 720 (Note, the latter battery has 6 positive PzS plates per cell with a capacity of 720 A h at the 5 h rate.)

In state-of-the-art batteries, the polypropylene containers and lids are heat-sealed together With CSM batteries, the terminal feed-throughs are made perfectly tight in order to ensure a good insulation of the battery to the ground throughout its lifetime In explosion-sensitive applications, such as chemical plants or underground coal-mines, flexible cable connectors with contact protection have become standard. Most of the batteries are equipped with plugs for automatic topping up with water

A notable application of CSM batteries is in conventional submarines In fact, the demand for higher capacities (both under low and high discharge rates) throughout the years, combined with an increase in the physical height, initiated the development of CSM technology The volumetric and weight energy densities of CSM batteries are significantly greater than traditional types Further, the increased physical strength of the copper grids results in an improvement in shock resistance The service life of CSM batteries is extremely long For example, one of the first batteries to be built was in operation for nine years After this time, randomly selected cells showed 101 and 90 5% of the nominal capacity at the 5 h and 100 h rates, respectively

Stationary batteries

A separate paper at this Conference discusses the use of CSM batteries in load-levelling applications The batteries are more suited to this type of stationary application than to, say, UPS systems The latter are becoming progressively smaller as progress in electronic componentry and circuitry reduces power demands

Standardized stationary tubular batteries are termed OPzS, and the copper versions OCSM The plate designs are identical with those used for traction batteries Again, the cell dimensions and weight are the same for OPzS and OCSM The performance of OCSM technology normalized to that of OPzS technology is given in Table 1 It should be noted that in this comparison the discharge current *and* the ampere hours are increased simul-

TABLE 1

Performance of OCSM batteries, setting OPzS (100 A h plate) technology to 100%

Discharge time (min)	Final voltage (V/cell)	Performance (%)
10	1 80	146
10	1 70	142
30	1 80	139
30	1 70	132
60	1 80	126
60	1 70	126

taneously. Under this condition, the improvement does not appear to be as impressive as that seen with traction batteries

For situations requiring high power demand over a short period, the required batteries will be significantly smaller when CSM technology is used Not only is the number of plates reduced, but also the containers and the floor space requirements, including the racks, will be smaller Thus, although the negative grids are more expensive, the battery will be significantly cheaper

Conclusion

Although the batteries described here are of the tubular design, CSM technology is not restricted to this type. The application of CSM technology to flat-plate batteries requires only minor redesign

Generally speaking, there is an increasing world-wide demand for large, reliable, low-cost batteries with a high performance Thus, further development of the mature lead/acid system is necessary. It is our understanding that CSM technology will contribute to this requirement

References

1 K J Euler and W Nonnenmacher, *Electrochim Acta, 2* (1960) 268
2 M Pourbaix, *Atlas of Electrochemical Equilibria in Aqueous Solutions*, London, 1966
3 *West German Patents DP 2 241 368* and *DP 3 312 550*