Glass-fibre separators for valve-regulated batteries

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Abstract

Recombining battery mat separators for valve-regulated lead/acid batteries must: (i) prevent shedding of active material from positive plates; (ii) retain the whole of the electrolyte for flexibility of battery positioning; (iii) have fine pores to eliminate the need for maintenance. The relationships between these requirements and the diameter of glass microfibres are discussed with respect to the design of a new cost-effective recombinant battery mat separator, brand name: M Sepa. M Sepa products have been introduced to the market to meet the special requirements of valve-regulated lead/acid batteries.

Introduction

In recent years, there has been rapid progress in the development of valve-regulated lead/acid batteries. This technology eliminates the need for maintenance, and allows greater freedom of battery positioning.

The authors' company has kept pace with changes in the manufacture of lead/acid batteries and has constantly developed new and improved battery separators that are based on proven glass technology. A notable product is the glass microfibre material that is supplied to the battery industry under the 'M Sepa' brand name. There are various types of this separator, i.e., the MS, MH, MSW and MFC varieties. Of these, the MS type is the main, and most widely used, material.

The main roles of the M Sepa in a valve-regulated lead/acid battery are as follows. First, the separator should prevent the shedding of active material from the positive plates. Second, the material is required to retain the whole of the electrolyte and thus provide flexibility in battery positioning. Finally, the very fine pores of the M Sepa will facilitate the passage of oxygen that is generated at the positive plates through to the negative plates where the gas is recombined with hydrogen to form water and thus remove the need for maintenance. Later in this paper, it is shown how a cost-effective MS separator has been developed to meet these requirements.

General properties of MS separator

The main feature of the MS separator is that it is made from 100% glass fibres, without any organic binders or organic fibres. The material has a high mechanical strength, even though the density is lower than any of the other commercialized glass-

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TABLE 1

Properties of MS battery separator

Basic weight (g/m^2)	140
Maximum pore size (μm)	20
Average pore size (μm)	10
Tensile strength ($g/10\ mm^2$)	400
Absorption speed (mm/min)	50
Acid extractables (%)	1
Electrical resistance ($\Omega\ dm^2/mm$)	0.0005

TABLE 2

Properties of glass types E and C

	E glass	C glass
Acid extractables[a] (%)	31.4	1.4
Main application	Plastic reinforcement	Battery separator

[a]At 80 °C, 10 days, 10% aq. H_2SO_4.

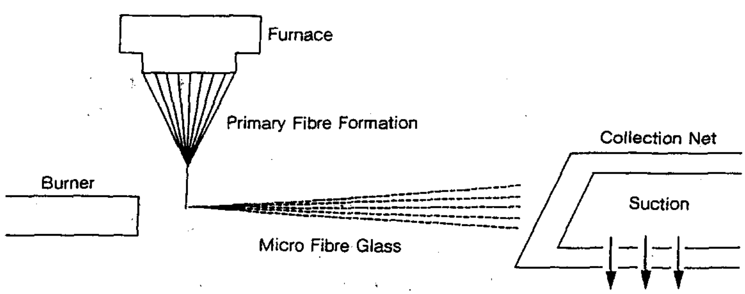


Fig. 1. Manufacturing process for glass microfibres (flame attenuation process).

mat separators that have been designed for valve-regulated batteries. The properties listed in Table 1 are accepted fully by many of the leading lead/acid battery manufacturers. It is thought that glass fibre is the best medium for lead/acid battery separators because of its higher acid resistance and lower cost than alternative materials.

Table 2 provides a comparison between E and C types of glass that are popular glass compositions for well-established industrial applications. E glass, because of its physical and electrical properties, is used in large quantities for the reinforcement of plastics. The glass shows, however, a serious weight loss of more than 30% after 10 days of immersion in sulfuric acid at 80 °C.

By contrast, C glass has a much higher acid resistance (1.4%) under similar conditions, and is widely accepted as a cost-effective material for battery separators.

Production processes

The essential manufacturing process for the glass microfibres that are used to make M Sepa material is presented in Fig. 1. The raw glass materials are melted in a furnace at around 1000 °C. Molten glass is then drawn from bushings to form primary coarse glass-fibres with diameters of a few hundred microns. These are then converted by a combustion gas into fine fibres. The latter are collected on a moving conveyor net by the action of a vacuum applied below. This manufacturing method is known as the flame attenuation process.

The subsequent manufacturing process of the M Sepa is illustrated in Fig. 2. The fine microfibres are dispersed in water, laid in a uniform mat on a moving conveyor net, and then dried in an oven. The process is similar to a paper-making process. The authors' company is unique in that it manufactures both the glass microfibres and the separator material. This arrangement ensures a product of consistent quality.

Comparison between coarse and fine glass-fibre separators

First, an investigation was made of the proposition that a mat with flexible thickness is more effective in the prevention of active-material shedding. That is to say, a recombinant-battery mat separator with a higher thickness change between low and high pressure will have better conformity with the plates. The thickness changes of glass-fibre mats of various diameters and compared in Fig. 3. It can be seen that the

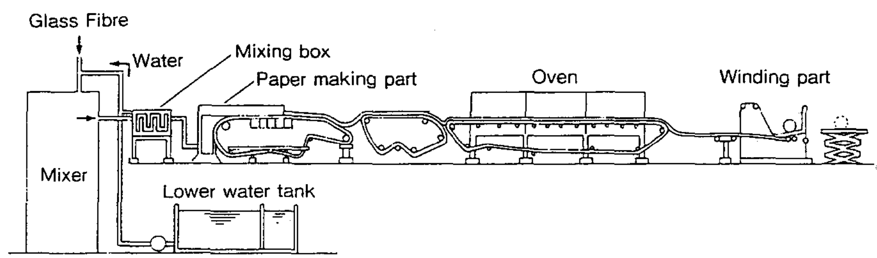


Fig. 2. Manufacturing process for M Sepa.

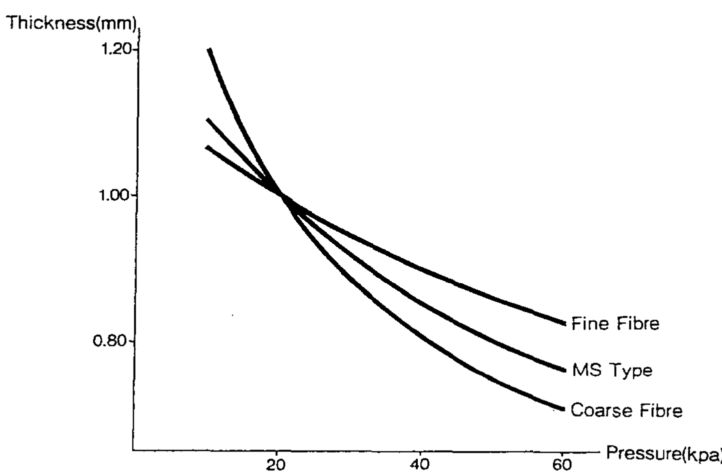


Fig. 3. Thickness curves for various glass-fibre mats.

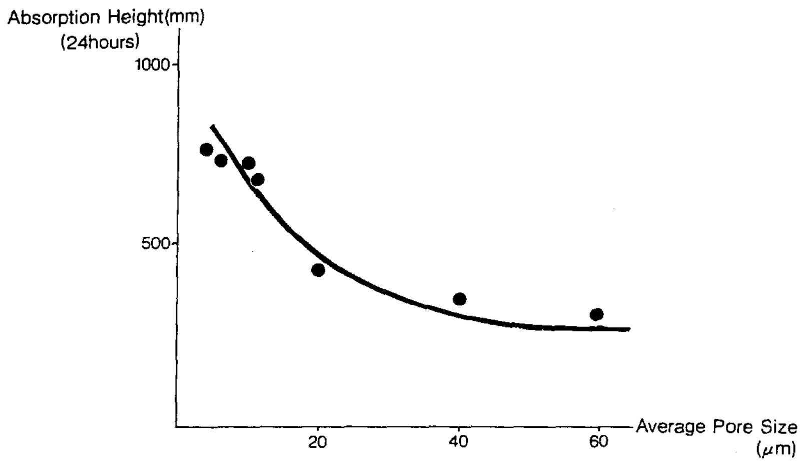


Fig. 4. Electrolyte retention ability of a glass-mat separator.

TABLE 3

Characteristics of battery separator types MH, MSW and MFC

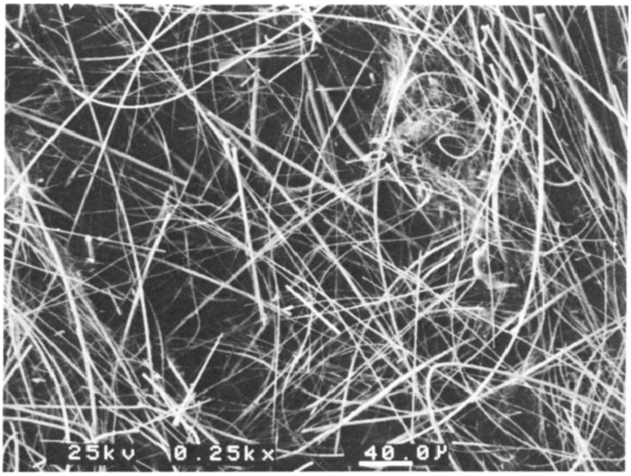
	MH	MSW	MFC
Basic weight (g/m^2 mm)	150	160	150
Tensile strength (g/10 mm^2)	700	900	1800
Loss on ignition (%)	0.0	0.0	2.0
Absorption speed (mm/min)	43	53	53
Average pore size (μm)	8	9	9
Application	Stationary	Cycle use	Automotive
Feature	Fine pore	High compression retention	High processability
Composition		100% glass	+ organic fibre

mat made from coarse fibres exhibits the largest thickness change over the selected range of pressures. This indicates that coarser fibre is more effective for the prevention of active-material shedding.

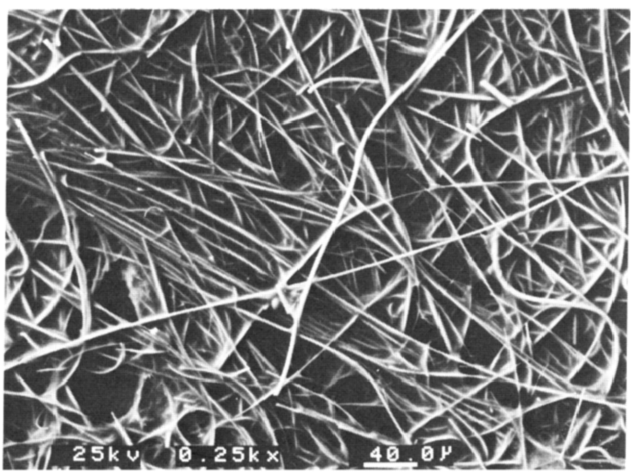
With regard to electrolyte retention and the facility for free positioning of batteries, the authors believe that retention ability is closely related to the absorption height achieved over a 24 h period. Figure 4 shows the relationship between absorption height and average pore size of a recombinant-battery mat separator. The data clearly confirm that finer pores show higher electrolyte retention.

The transfer of oxygen gases from the positive to the negative plates is best achieved through a mat with large pores. Electron micrographs of the structure of M Sepa material in a dry and a wet condition are given in Fig. 5(a) and (b), respectively. The average pore size of the MS type separator is about 10 μm. This value meets the requirements of valve-regulated lead/acid batteries.

The structure of the M Sepa material is shown at a greater magnification in Fig. 6. As mentioned before, the finer pore size of the MS type separator provides good wettability and, thus, high retention of electrolyte.



(a)



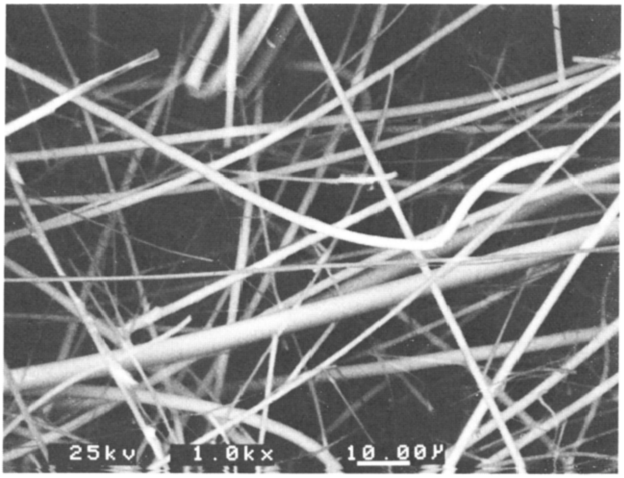
(b)

Fig. 5. Scanning electron micrographs of M Sepa: (a) dry; (b) wet. Magnification ×250.

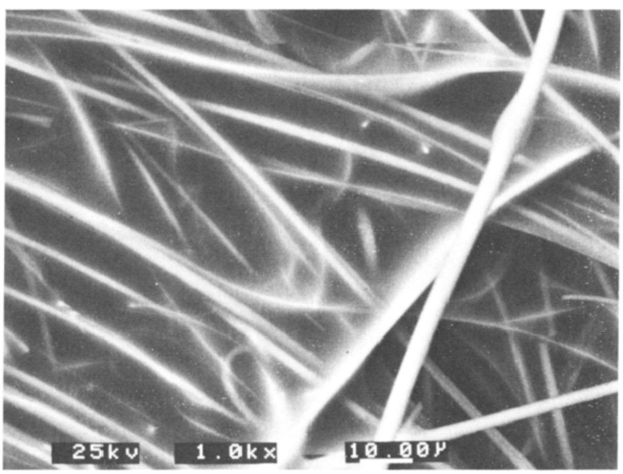
In summary, the first and third requirements for M Sepa, viz., prevention of shedding and facilitation of oxygen transfer are achieved by coarser fibres. The second requirement, viz., electrolyte retention, is achieved by finer fibres. These test results show that it is difficult to satisfy all three requirements at the same time, and that cost performance must also be taken into account.

Figure 7 gives the relationship between glass-fibre diameter and average pore size, and also between fibre diameter and production costs. Production costs depend on fibre diameter, but the relationship is exponential rather than proportional. In other words, costs increase at a greater rate than the fibre diameter decreases.

If coarse fibre was used in the production of recombinant-battery mat separators in order to reduce costs, it would not be possible to achieve a successful cost/performance relationship. It is clear that the battery industry would not accept an average pore



(a)



(b)

Fig. 6. Scanning electron micrographs of M Sepa: (a) dry; (b) wet. Magnification ×1000.

size larger than 15 μm due to the risk of short circuits. For this reason, the MS type separator has been designed within the required parameters, as shown in Fig. 7.

The properties of the MS type separator are as follows. The thickness change is about 200%, the absorption height is more than 600 mm after 24 h and the average pore size is about 10 μm. Market experience has shown that these properties are wholly acceptable to designers of valve-regulated lead/acid batteries.

The specifications of newly developed M Sepa products for valve-regulated lead/acid batteries, designed to meet the special requirements of battery manufacturers, are listed in Table 3. The MH type is specially designed for large stationary batteries;

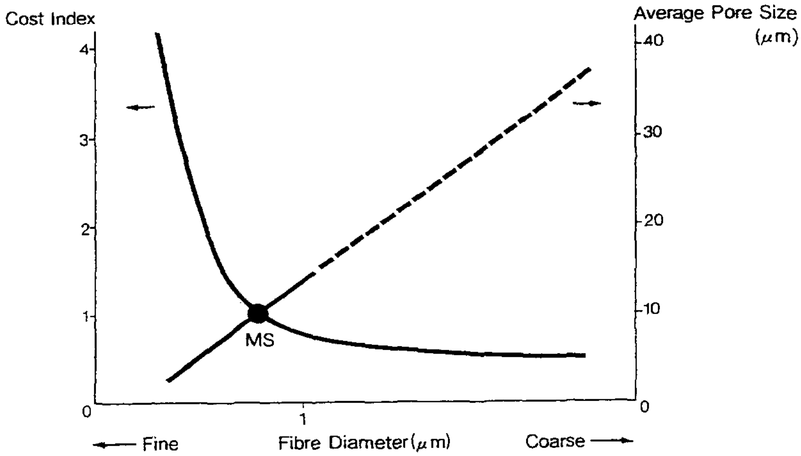


Fig. 7. Design of a cost-effective glass-mat separator.

MSW has high compression retention, and MFC has high machine processability on the production line by virtue of its high mechanical properties.

At present, the authors' company is conducting research programmes aimed at: (i) a low-cost separator; (ii) an envelope type of separator; (iii) prevention of acid stratification; (iv) good retention of compression to plates after filling with electrolyte.