Study of Dispersion Characteristics of Mercerized Pulp

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Mercerized pulp is widely used in the filter paper industry. But the major challenge facing users of the pulp is its difficult dispersion in water. It was found that by applying a suitable degree of beating it was possible to achieve better dispersion than the original pulp. The beating degree before and after beating was almost the same. But the properties of filter paper were greatly improved after beating, especially for the formation index and burst index. The morphology of beaten fibers was analyzed by SEM with both the freeze-drying and air drying sample preparation process. The results showed that the primary cell wall of the beaten mercerized pulp fibers were swollen and partly peeled from the fiber main body after beating, as revealed by micrographs obtained after freeze-drying. The results suggest that the improvement of the fiber dispersion in water was caused by these changes on the fiber surface.

Keywords: Mercerized pulp; Dispersion; Fiber morphology

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INTRODUCTION

Filter paper is an important specialty paper product for automobile and other industries (Li *et al*. 2008; Liang *et al*. 1998; Mei *et al*. 2001). The key properties of automotive filter paper are filtration efficiency and dust holding capacity. Both of these properties are functions of the porosity and structure of the paper. Mercerized pulp is widely used in filter paper; the pulp generally has high α-cellulose content and coarse fiber morphology (Harding *et al*. 2006; Phillips *et al*. 2001). But the mercerized pulp is difficult to disperse in the water. The properties of the paper can be greatly affected by the dispersion characteristics of the pulp. Few references about this field have appeared in the literature.

To get good dispersion and paper performance, the mercerized pulp should be pretreated before papermaking. The aim of this work was to study the pretreatment conditions, dispersion evaluation methods, and filter paper properties with mercerized pulp.

EXPERIMENTAL

Materials

Mercerized pulp was supplied by Buckeye Technologies Inc., USA. Polyethylene terephthalate (PET) fiber was supplied by Teijin Limited, Japan.

Methods

Beating

Mercerized pulp was beaten in a PFI refiner with either 5000 or 10000 revolutions at 10% consistency following TAPPI method T 248 (TAPPI standards 2008). The Canadian standard freeness (CSF) was tested by TAPPI method T 227 om-09 (TAPPI standards 2007).

Water retention value test

Determination of the water retention value (WRV) was according to ISO 23714 (ISO standards 2007).

Dispersion image analysis

Photographs of the pulp dispersion in water were taken 15 seconds after stirring the pulp in a beaker.

Handsheets formation and properties

Paper sheets were prepared with an ENJO-F-39.71 sheet machine by Metrotec Spain. The air permeability and burst index of paper sheets were determined according to Chinese standard GB/T5453 (Chinese standards, 1997) and TAPPI method T-494 (TAPPI standards 2007), respectively. Paper formation index was tested by Beta Formation Tester (Ambertec, Finland). The definition of formation is the small-scale basis weight variation in the plane of the paper sheet. A lower number indicates greater uniformity. The efficiency of the paper was tested by TSI-3160 (TSI Inc., US) according to EN 779:2012 (European Committee for Standardization, 2012) The equipment measures particle penetration versus particle size at a certain aerosol flow rate and face velocity. The particle size was 0.4 μm.

Sample preparation

The pulps were either air dried or freeze dried.

SEM observations

Scanning electron microscopy (SEM) was used to investigate the morphology of the different types of pulp fibers with a LEO 1530VP (LEO Gmbh, Germany) instrument. The specimens were coated with gold/palladium and observed using an accelerating voltage of 10 kV.

RESULTS AND DISCUSSION

Beating

The hydrophilic character of mercerized pulp decreases after mercerizing treatment (Kim and Netravali 2010), which can lead to poor dispersion in water. Therefore, increasing the exposure of hydrophilic groups (hydroxyl groups) on the fiber surface appears to be a good way to improve dispersion performance (Taipale *et al*. 2010). The common method is beating. In the present study the mercerized pulp was

beaten in a PFI refiner at 5000 or 10000 revolutions. Canadian standard freeness and WRV were used to evaluate the beating. The results are shown in Table 1, which indicates that Canadian standard freeness had no change after 5000 revolutions PFI refiner beating. The Canadian standard freeness decreased only a minor amount, to 730 mL from 750 mL, after 10000 revolutions of PFI refiner beating. But the WRV results for the pulps were very different. The WRV of the original mercerized pulp was only 5%. The WRV of mercerized pulp after beating at 5000 revolutions and 10000 revolutions could reach 15% and 23%, respectively. The observed increase in WRV was consistent with more hydroxyl groups becoming exposed during the beating. The trends of Canadian standard freeness and WRV were different.

Table 1. Properties of Mercerized Pulps

Sample	CSF (mL)	WRV (%)
Original pulp	750	5
Pulp 1	751	15
Pulp 2	730	23

Pulp 1 was beaten with PFI at 5000 revolutions; Pulp 2 was beaten with PFI at 10000 revolutions

Dispersion Image Analysis

Image analysis was used to evaluate the pulp dispersion character in water. The dispersion photos of different pulps are shown in Fig. 1. From photo A in Fig. 1, it can be seen that the fiber of the original pulp flocculated very quickly. The big flocs of fibers are very clear to see in the image. Photo B in Fig. 1 shows that the big flocs disappeared after the 5000 revolutions beating treatment. But the pulp fibers were also not very stable. The pulp fibers would flocculate again after about 1 min. When increasing the beating to 10000 revolutions, the pulp achieved good dispersion in water (photo C in Fig.1). There were no flocs in the system. The stability of the dispersion was greatly improved at the same time.

A B C

Fig. 1. Dispersion image of mercerized pulp at different beating condition. (An original pulp; B beating 5000 revolutions; C beating 10000 revolutions)

Morphology Observation

It is of interest to learn why the dispersion of mercerized pulp would tend to become improved after beating. In order to find the answer, SEM was used to observe the fiber morphology. The common sample preparation method used for plant fibers involves air drying followed by spraying of a gold metal layer to dissipate electrical charges during the observation. The results (photo A, C, and E in Fig. 2) showed that there was

almost no difference in the appearance of the mercerized pulp fiber surface before and after beating.

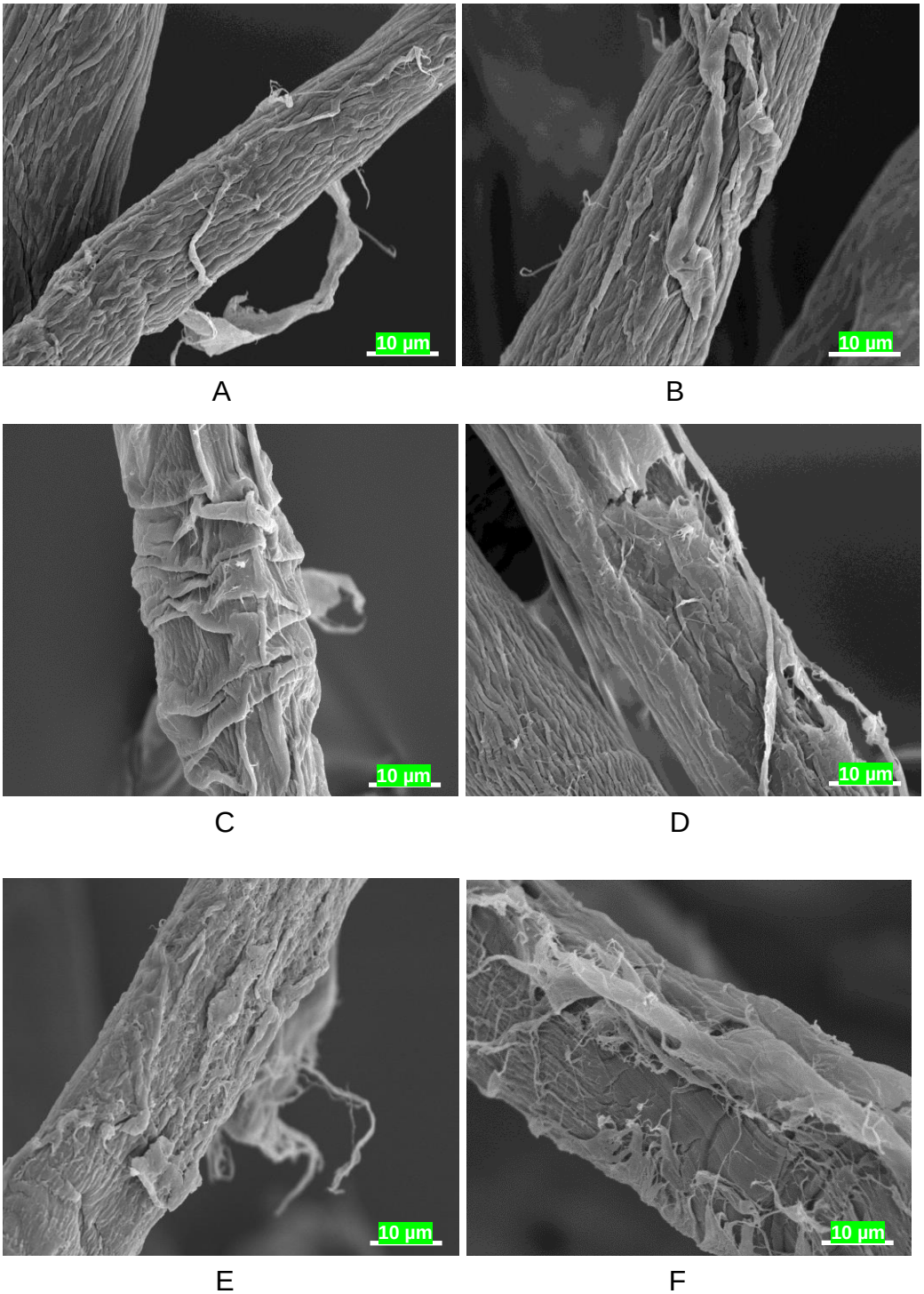

Fig. 2. Pulps morphology at air drying and freezing drying conditions. (A and B original pulp; C and D beating at 5000 revolutions; E and F beating at 10000 revolutions. A, C, E were with air drying; B, D, F were with freezing drying)

Freeze-drying is used for sample preparation for SEM in biology and nano-science (Abdelwahed *et al*. 2006; Inoue and Osatake 1988; Zhang and Ma 2000). The specimen would have no artifacts after freeze-drying. The fibrils would not aggregate and the primary cell wall of the fiber would keep its original shape by this method (Duchesne *et al*. 2001). So the freeze-drying was used to prepare the samples for SEM.

The SEM results with freeze-drying are shown in Fig. 2 (photo B, D, and F). From Fig. 2, it can be seen that the diameter of fibers subjected to freeze-drying conditions (right column in Fig. 2) were much bigger than those of fibers subjected to air drying conditions (left column in Fig. 2). The pulp fibers at 10000 revolutions beating had the largest diameter (photo F in Fig. 2). The primary cell wall of the original fiber was undamaged and twined closely to the main body (photo A and B in Fig. 2). But the primary cell wall of the beaten pulp was destroyed and partly peeled during beating. The secondary cell walls of the fibers were swelled and shifted at the same time. These changes were clearly apparent at the freeze-drying condition (photo D and F in Fig. 2). Most of the primary cell walls of the fibers were destroyed after 10000 revolutions beating (photo F) and were partly destroyed after 5000 revolutions beating (photo D). The microfibrils were split from the second cell wall of the pulp after 10000 revolutions beating in photo F. The fibers were rendered more easily swollen after these changes. Swelling would affect the surface chemistry and hydroxyl availability of the fiber (Tze and Gardner 2001). The primary cell wall fibers were delaminated, and fine pore structures were created on the surface during beating. So the WRV of pulp would increase after beating. But under the air drying conditions, these changes of primary cell wall were not easy to find. When exposed to air-drying conditions, the fibers were shrunk (photo C and E in Fig. 2). So the freezing-drying procedure was judged to be suitable for sample preparation.

Properties of the Handsheets

The properties of handsheets with different pulp are shown in Table 2. It was indicated that the burst index was increased and formation index of the filter paper was greatly decreased after beating. The burst index increased from 2.51 kPa·m^2/g to 3.54 kPa·m^2/g. Also the formation index reached 2.5.

Table 2. Properties of Handsheets

Sample	Air permeability (mm/s)	Burst index (kPa·m^2/g)	Formation index	Filtration efficiency (%@0.4 μm)
Original pulp	350	2.51	3.5	4.2
Pulp 1	320	3.12	3.4	5.3
Pulp 2	255	3.54	2.5	6.2

The formula of the handsheets: 140±5g/m^2; 60% softwood pulp; 30% mercerized pulp; 10% 1.0dtex PET (polyethylene terephthalate) fiber

After refining, the big flocs were gone from the handsheets. The improvement of the paper properties showed that the better dispersion could improve the papermaking ability. The filtration efficiency was increased with the improvement of fiber dispersion, from 4.2% to 5.3% and 6.2%. But the air permeability of the handsheets was sharply

decreased after 10000 revolutions of beating. The air permeability decreased nearly 100 mL from 350 mL to 255 mL. That means that the resistance will increase and dust capacity will decrease during filtration. Suitable beating conditions should maintain a balance between good dispersion and low resistance to flow for filter paper. The right beating condition was judged to be 5000 revolutions.

CONCLUSIONS

1. The mercerized pulp was difficult to disperse in water. It was found that the pulp could achieve better dispersion after suitable beating with a PFI refiner than the original pulp. The results showed that the properties of air filter paper were also greatly improved after beating, especially for the paper formation index and burst index.

2. The morphology of pulp fibers was analyzed by SEM with freeze-drying and spraying gold sample preparation process. The results showed that the primary cell wall of the mercerized pulp fiber was swollen and partly peeled from the fiber main body after beating. The second cell wall of the fiber was swollen.

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