

Fractionation of recycled pulp obtained from mixed paper

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SECONDARY-FIBER FURNISHES CONTAIN pulps of various kinds, typically mechanical and chemical pulps. The chemical composition and the morphology of chemical and mechanical pulps are quite different. The differences arise from the mixed nature of the particles in mechanical pulp and the amount of lignin present in each material (1, 2). Mechanical pulps retain almost all of the wood constituents, consisting of fiber bundles and fiber fragments with some whole individual fibers. In contrast, chemical pulp fibers consist primarily of cellulose. Chemical pulp fibers are also stronger, longer, more flexible, and thus more valuable than mechanical pulp fibers.

With the use of reclaimed paper on the rise, the mechanical-pulp fraction in furnishes obtained from mixed paper will continue to increase. The ability to separate secondary-fiber furnishes into chemical and mechanical fractions would give papermakers greater flexibility in using this fiber resource, allowing them to allocate the different fiber fractions to their most productive end use. Although pulp fractionation is not a novel concept, most procedures are based on the exploitation of differences in size and density (3–6). Only a very limited number of reports describe the fractionation of mixtures of fibers into components such as chemical and mechanical pulps or bleached and unbleached pulps (7).

Differences in the composition and morphological characteristics of

chemical and mechanical pulp fibers could be exploited to separate these fiber fractions. Compared with cellulose and hemicellulose, lignin has a low polarity and a low wettability when it interacts with water. The difference in lignin content between chemical and mechanical pulps thus translates to a differentiation in the surface polarity and wettability of these two pulps (8). Hence, flotation could be considered as a process of choice for separating fibers according to their surface characteristics.

In the present study, fractionation was accomplished by modifying and enhancing differences in the surface properties of the particles to be separated. The selectivity was achieved through the addition of surfactants to control the wettability of the particles in the pulp suspension.

EXPERIMENTAL

Materials

Pulp. Virgin and recycled pulps were used in the investigation. They included virgin groundwood (GW) and bleached kraft pulp (BK) and fibers recycled from laser-printed white office wastepaper (OW) and old newspaper (ONP). The weighted (by weight) average fiber length and the kappa number of the various pulps are listed in **Table I**.

Recycled fibers were obtained by pulping wastepaper for 10 min in a laboratory pulper (Formax 1800H, Adirondack Machine Corp., Glens Falls, NY). The pulping liquor was water containing sodium hydroxide (3.0%) and hydrogen peroxide (1.0%). The consistency of the slurry

RECYCLED FIBER

ABSTRACT

Past investigations of pulp fractionation have been directed toward classification of pulp fibers based on their physical dimensions. The present investigation describes a new method of segregating mixtures of wood pulp fibers into their mechanical and chemical pulp fractions. The technique exploits differences in the surface morphology and wetting characteristics of mechanical and chemical pulps. These differences were enhanced by adsorbing surfactants on the fiber surfaces, thus modifying their behavior in the pulp slurry. Fibers were then selectively separated into various fractions by flotation.

Application:

Flotation shows promise as a means of separating recycled pulps into chemical pulp and mechanical pulp fractions.

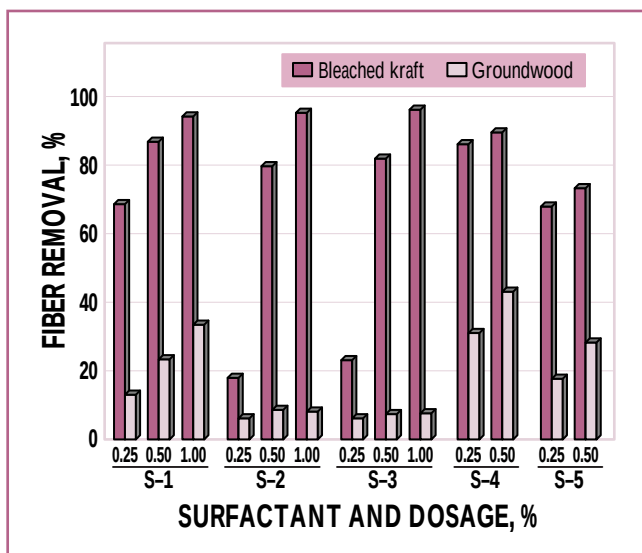
was 10%. Reclaimed fibers were washed in tap water.

The experimental work on the separation of pulps into their constituent fractions was carried out by using bicomponent mixtures prepared by suspending two different types of pulps in water. Two combinations of mixtures were evaluated: virgin BK-GW and recycled OW-ONP. The initial bicomponent mixtures contained 50% of each kind of material.

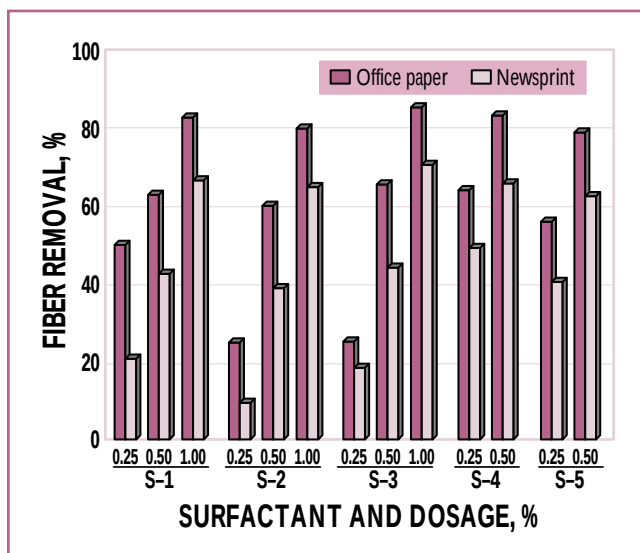
Chemicals. Five commercially available surfactants were used in the flotation experiments. The surfactants are described in **Table II**. All surfactants were dissolved in water (5 g surfactant per 500 mL water). Polyvinyl alcohol was dissolved in water maintained at 95°C under vigorous agitation for 30 min.

Procedure

Methodology. Flotation was carried out using individual pulps and mixtures of fibers of different origins. Individual pulps were used to



1. Removal of virgin BK and GW fibers from single-component slurries (after three-stage flotation) as a function of surfactant type and dosage



2. Removal of recycled OW and ONP fibers from single-component slurries (after three-stage flotation) as a function of surfactant type and dosage

Pulp type	Fiber length, mm*	Kappa number
Virgin fiber		
Bleached kraft (BK)	2.90	1
Groundwood (GW)	0.70	124
Recycled fiber		
Office waste (OW)	1.72	2
Old newspaper (ONP)	1.52	128

*Weighted average length by weight

1. Fiber length and kappa number of pulps

determine the type and dosage of the surfactant that yielded the optimum pulp separation in the experimental conditions selected for the study. In the screening trials, surfactant was added in amounts of 0.25%, 0.5%, and 1.0%, based on the weight of oven-dry (o.d.) pulp.

Pulp (20 g o.d.) was dispersed in water (2000 mL) and then disintegrated in a British standard disintegrator at 3000 rpm for about 16.5 min ($\approx 50,000$ rev). After disintegration, the stock was diluted to 5000 mL by adding water to make a slurry of 0.4% consistency. The suspension

was then poured in a flotation cell (model D-12, Denver Equipment Co., Colorado Springs, CO). The impeller was run at 1200 rpm for 10 min to introduce air bubbles in the pulp slurry. Then a fresh solution of surfactant was added to the tank, and the aeration rate was increased by changing the speed of the impeller from 1200 rpm to 1500 rpm to produce a stable foam. The froth containing fibers was collected for 10 min. The solid collected with the foam was recovered by filtration, and the liquid was recirculated to the flotation cell. This operation was car-

ried out three times for a total froth-collection time of 30 min. At the end of this period, the fibers remaining in the flotation tank were separated from the aqueous solution by filtration. The fibers recovered from the foams and the slurry were dried at 60°C, and weighed. Then, the ratio (in percent) of the weight of pulp reclaimed from the foam to the initial weight of the pulp in the slurry was calculated. This quantity was considered as a measure of the pulp removal for the process.

The content of each type of fiber in the pulp mixtures was determined in accordance with the following procedure. First, the kappa number was measured for the pulp recovered from both the froth and the slurry. Then, the content of each type of fiber in the pulp mixture was determined by extrapolation on the calibration curve of kappa number vs. pulp fiber content.

Calibration curve. The calibration curve was constructed by plotting known compositions (in percent) of one type of fiber present in the bicomponent mixtures of pulps as a function of the kappa number.

	Trade name	Description	Supplier
S-1	Armak 1027	Vegetable-derived fatty alkyl primary amine containing ethylene oxide moieties	Akzo Chemicals (Chicago, IL)
S-2	Airvol 107	Fully hydrolyzed polyvinyl alcohol	Air Products and Chemicals (Allentown, PA)
S-3	Airvol 325	Fully hydrolyzed polyvinyl alcohol	Air Products and Chemicals (Allentown, PA)
S-4	Trycol 5956	Polyoxyethylene alcohol with with decyl alcohol moieties that functioned as hydrophobes	Henkel Corp. (Ambler, PA)
S-5	Trycol 6968	Ethoxylated alkylphenol containing nonylphenol groups	Henkel Corp. (Ambler, PA)

II. Surfactants used in the experiments

The proportion of the two types of pulps were varied from 10% to 90%. The kappa number of each mixture was measured in accordance with TAPPI T 236 cm-85. Because of the low lignin content in the chemical pulp and OW samples, 5-g specimens were needed for each determination. A relatively small specimen (0.4 g) was required for GW or ONP because of the high lignin content in these materials.

RESULTS

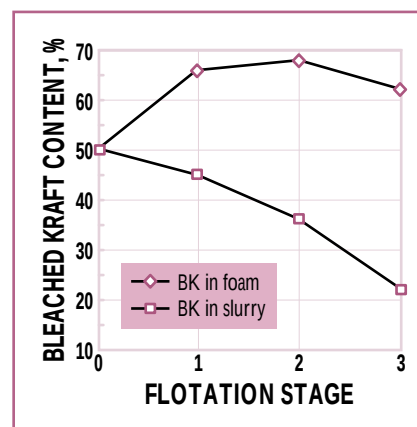
The initial screening experiments were carried out on slurries of individual pulps. **Figure 1** shows the proportion of the bleached kraft (BK) and groundwood (GW) pulps removed by flotation as a function of surfactant and dosage. All five surfactants removed a high percentage of BK from the slurry. The amount of GW removed from the slurry was much smaller. For example, at dosages of 0.5% for surfactants S-2 or S-3, removal of GW was less than 10%, while BK had a removal of more than 80%. In both cases, the removal ratio of BK to GW was greater than 10.

Figure 2 shows the results for the recycled fibers. The amount of office waste (OW) removed by flotation was greater than that for old

newspaper (ONP), but the removal ratio of OW to ONP was not as high as the ratio for virgin BK and GW.

The results for the single-component slurries show that the chemical pulps (BK and OW fibers) are more easily removed from the slurry than the mechanical pulps (GW or ONP fibers). The pulp removal also depends on the type and amount of surfactant. Increasing the surfactant dosage improves pulp removal. Dosages of 0.5% for surfactants S-1, S-2, and S-3 or 0.25% for S-4 and S-5 were necessary to obtain a high removal of chemical pulps.

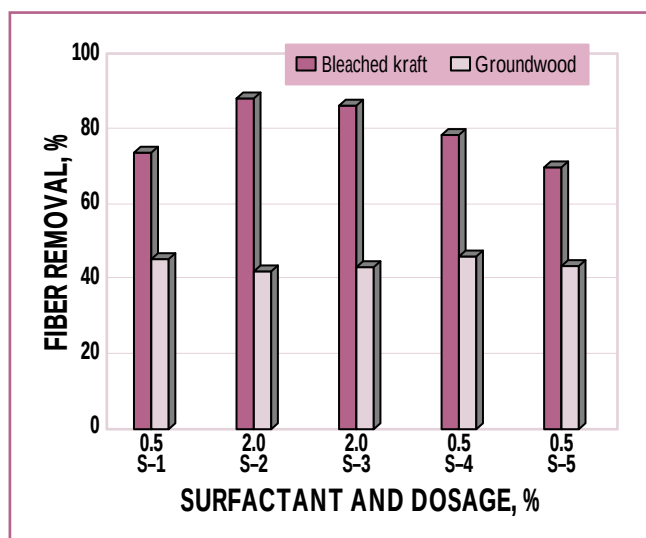
Bicomponent mixtures—consisting of virgin fibers (BK and GW) or recycled fibers (OW and ONP)—contained 50% of each type of fiber. During flotation, the compositions of the pulp removed in the foam fraction and the pulp remaining in the slurry suspension diverged. The foam fractions became rich in chemical pulp, while the proportion of GW in the slurry increased. **Figure 3** shows the content of BK in the foam and slurry fractions at the various flotation stages at 2.0% dosage for surfactant S-2. Under these conditions, the foam fraction contained 64.0% BK, while the content of BK in the slurry decreased from 50% to 22% after three stages of flotation.



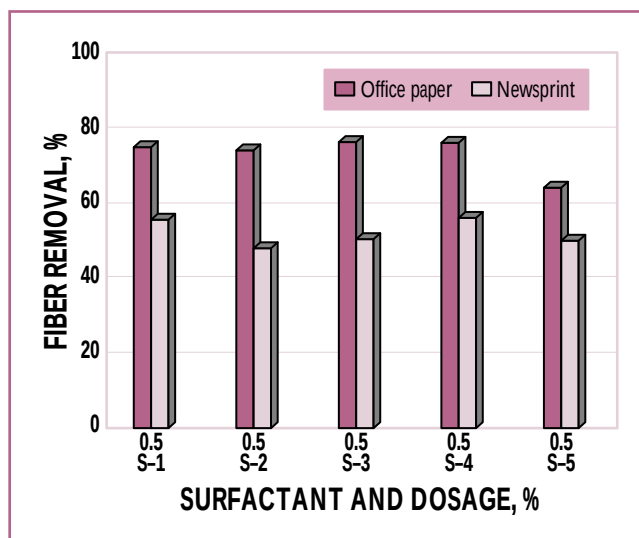
3. BK content in the foam and slurry fractions from the bicomponent mixture of BK and GW during three-stage flotation (S-2 surfactant applied at 2.0% dosage; total pulp removal = 60.8%)

Figure 4 shows the proportion of BK and GW fibers removed in the foam fractions after the three flotation stages. The amount of BK in the foam fractions increased steadily over the three flotation stages, while the amount of GW remaining in the slurry fraction increased steadily, indicating the effective separation of the two pulps by flotation.

The recycled pulps were prepared from OW and ONP. The OW pulp was made from laser-printed



4. Removal of virgin BK and GW fibers from bicomponent slurry (after three-stage flotation) as a function of surfactant type and dosage



5. Removal of recycled OW and ONP fibers from bicomponent slurry (after three-stage flotation) as a function of surfactant type and dosage

white sheets that were produced from bleached chemical pulp. The OW pulp thus contained a low amount of lignin. The ONP pulp was composed of mechanical pulp with a high lignin content. The proportions of fibers removed from the bicomponent mixtures of recycled OW and ONP are shown in Fig. 5. Clearly, flotation preferentially removed recycled OW compared with the recycled ONP fibers.

DISCUSSION

This preliminary study shows that it is possible to separate different types of pulp fibers by flotation. The frac-

tionation is based on the selective adsorption of surfactant. The mechanical pulp contains a large amount of lignin, as indicated by the high value of kappa number (Table I). The BK is almost a lignin-free material. Compared with cellulose and hemicellulose, lignin has a low polarity and will adsorb the apolar end of the surfactant through chemical affinity. This increases the wettability of mechanical pulp fiber. For chemical pulp, the hydroxyl groups on the fiber surfaces interact with the polar end of the surfactant. In this case, the apolar part of the surfactant is oriented away from the fiber surface. This leads to the development of sites that facilitate bonding of fibers to air bubbles. The mechanism of adsorption of surfactants explains the fractionation of pulp mixture into its various components. Adsorption of surfactants improves the selectivity of the separation.

Nevertheless, the exact mechanism of fiber flotation is not yet well understood. In a previous report, Lindström and Glad-Nordmark (7) suggested that flocculation is the

main mechanism that explains differences in the behavior of wood fiber during flotation. In our investigation, no attempt was made to verify the existence of a flocculation mechanism.

The efficiency of the pulp separation, as determined by the ratio of the pulp removal, was predicted to be high during the flotation of individual pulps. However, this ratio was found to be relatively small for the fractionation of mixtures. It is speculated that fiber entanglement is responsible for the observed decrease in separation efficiency. Lower pulp consistency would probably help in decreasing the entanglement.

Particle size also affects the selectivity of the flotation. Two explanations of the influence of particle size on the selectivity (9) are

1. The balance between the hydrodynamic and surface forces acting on the particles
2. The fulfillment of the conditions for the preferential capture of particles by a bubble.

KEYWORDS

Additives, chemical properties, chemical pulps, documents, fiber structure, fibers, flotation, fractionation, mechanical pulps, mixed waste papers, news media, newspapers, periodicals, physical properties, properties, pulps, reclaimed fibers, separation, surface properties, surfactants, waste papers, wettability.

Moreover, chemical pulp fibers are usually longer than mechanical pulp fibers. Hence, in addition to the differences in morphology and chemical composition, the difference in fiber length between the chemical and mechanical pulps probably has a positive effect on the selectivity of the flotation.

Foaming is also an important factor in flotation. Foam separates the more floatable fibers from the pulp slurry by entrapping them in a froth layer. Hence, sufficient foaming is necessary to promote good pulp fractionation. However, excessive foaming can cause overflow of the process and decrease the efficiency of the separation. The foam formation is affected by the amount of surfactant utilized. Similarly, surfactants with a high hydrophilic:lipophilic balance (HLB) will have a high foaming ability. Therefore, the separation efficiency will be affected by the amount and HLB of the surfactant.

CONCLUSIONS

This preliminary study shows that it is possible to separate pulp fibers based on their morphological and chemical characteristics. The separation

process may rely on the selective adsorption of surfactant molecules. Pulps with higher lignin content exhibit poorer floatability than pulps with low levels of lignin. Consequently, mixtures of pulp can be separated into their components by flotation. The fraction that is removed in the foam is richer in chemical pulp fibers, while the slurry that remains in the flotation cell contains more mechanical pulp fibers.

However, the fractionation of pulps by flotation is a complicated process because of the complex interactions among fibers, water, surfactant, and air bubbles. Further work is needed to explore the appropriate and optimum conditions for pulp fractionation by flotation. **TJ**

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This article is based on work supported by the Minnesota Agricultural Experiment Station, University of Minnesota.

sity of Minnesota.

Received for review Jan. 19, 1996.

Accepted June 9, 1996.

Presented at the TAPPI 1994 Recycling Symposium.

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