EVALUATION OF LONG SOAKING TIMES FOR REHYDRATION OF RECYCLED FIBERS

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ABSTRACT

The objective of this research is to investigate the effect of extended soaking times of recycled paper on the hydration of the fibers. Mass transfer limitations and morphological changes in the fibers prevent rapid rehydration, and thus the fibers do not return to a completely rehydrated state. Consequently, the fibers become less flexible and their bonding capability is decreased. This study investigated the effect of extended soaking times of up to 8 h to determine if longer contact with water will improve the hydration of the fiber before disintegration. Chemical addition was also investigated. The fibers were tested for water retention value, which correlates well with the strength properties of the sheet according to the literature. As expected, sodium hydroxide promoted fiber swelling, whereas the effect of calcium chloride was not as definite. Extended soaking apparently decreased the water retention value, probably as a result of the production of fines. The presence of fillers also had an effect on fiber rehydration.

INTRODUCTION

The drying of fibers in the papermaking process causes morphological changes in the fiber. These changes, while not completely understood, are thought to include the closing of pores and the reattachment of fibrils to the fiber surface through hydrogen bonding [1,2]. Upon recycling, these changes retard the rehydration of the fiber; the fibers become stiffer and less conformable. A higher degree of internal bonding within the cell wall is also thought to result in a less conformable fiber [2]. In many cases, most swelling introduced through the refining operation is lost during the subsequent drying of the paper [1]. The relationship between the amount of lignin in the pulp and the effect of drying has also been investigated [3]. Internal bond formation was greater in pulps containing less lignin (bleached pulps) upon drying, leading to greater hornification. Subsequent restoration of the fibers was more difficult with these more hornified fibers.

When recycled fiber is to be used for papermaking, it is necessary to reswell the fibers to recover some of their bonding potential. This is typically done through the mechanical action of beating and refining, as was done with the virgin fiber in its original use. However, this mechanical treatment also increases the drainage resistance of the pulp and produces fines, which affect how well the pulp is run on the paper machine (runnability) and limits the amount of beating that can be done. With most recycled fibers, this runnability limit is reached before the fiber properties are completely restored. Also, the process of restoring fibers with mechanical action tends to be very energy intensive, and thus expensive.

Increasingly, papermakers are looking towards traditionally lower quality recycled fiber sources for their fiber needs. Furthermore, recycled fibers are being included in better quality paper. Consequently, processes are needed to improve the strength of the resulting sheet. The objective of this study was to determine the effect of presoaking the paper furnish prior to disintegration to improve the papermaking properties of the resultant pulp. The change was measured by the water retention value (WRV) of the pulp, which, as discussed in a following section, is related to the strength properties of the pulp. The WRV is measured by centrifuging a sample of the pulp for a selected amount of time and measuring the amount of water retained in the pulp: the greater the degree of swelling, the greater amount of water that will be retained [4].

WATER RETENTION VALUE

The WRV is influenced by alkalinity of the pulp slurry, pulp fiber size, drying process, and other variables. There is a correlation between WRV and strength properties.

Variation in WRV

Many factors can have an effect on pulp WRV. The alkalinity of the slurry has a significant effect on the WRV of kraft pulp; the highest WRV occurs at a pH of approximately 9. In addition, a high cation concentration of the pulp has an adverse effect on the WRV of the pulp [5]. The fiber size characteristics of the pulp also tend to have an effect on the WRV. Fines tend to have higher WRV than the fibrous portion of the pulp [2,6]. The drying process has a significant effect on lowering the WRV of the pulp. The WRV of fibers decreases significantly when dried, especially when dried at high temperature [7,8]. Prolonged contact with water tends to increase the WRV of a pulp. However, some
pulps may take weeks to reach their ultimate swelling as water slowly enters the cell wall [8].

Multiple recycles, with the fiber being dried at each cycle, tend to decrease the WRV of the pulp and of the fibrous fraction [6]. Refining, which is the most common method of improving the papermaking properties of the fiber, is only partially successful in swelling the fiber [2]. Because the WRV value is affected by refining, it can be used as a measure of beating efficiency [7]. Swelling of fibers by means other than beating has some of the same effects as does refining for the improvement of strength properties of recycled fibers [9].

WRV and Strength Properties

The literature attests that the degree of fiber swelling as measured by the WRV is well correlated to the strength of the paper. Many researchers have found that for unbleached kraft and sulfite pulps, the WRV is linearly correlated with the tensile index of the paper [2,5,6]. This has also been shown for recycled fiber [7]. The raw material used in this case was a commercial carton board composed of 46% bleached birch sulfate, 52% stone groundwood, and 2% clay. For the purposes of our study, this relationship will be assumed to be valid, at least qualitatively, for the recycled fibers studied. Hence, measurements of the WRV of pulp will be used as indications of the improvement of the papermaking properties of the pulp.

EXPERIMENTAL PROCEDURE

We investigated two secondary fiber sources: office waste paper (OW) and old corrugated containers (OCC). The OWP was modeled by unprinted xerographic paper with a 10% recycled content taken from a single ream to maintain a consistent furnish. In a similar manner, the samples of OCC were cut from a single corrugated box to maintain a consistent furnish. The two furnishes differed in the amount of fillers and bleached fibers. The OCC had a minimal amount of fillers and was mainly unbleached. The OW consisted of mostly bleached fibers.

Two chemicals, sodium hydroxide and calcium chloride, were added separately to study their effect on fiber swelling. Sodium hydroxide is commonly used with recycled fiber as an aid in repulping. Because the effect of calcium chloride is not well understood, we chose it as the second reagent to investigate. Calcium chloride is also sometimes used in the recycling process. Both chemicals were added at 1% and 3% (as weight of chemical per weight of dry fiber). The control sample had no chemical additives.

The paper samples were presoaked in water with the chemical for zero hours (that is, disintegrated immediately after addition) and 8 h. The presoaking was done at approximately 2% consistency (a 20-g sample in 1 L of water). Ten conditions were investigated for each fiber source.

After soaking, the paper was disintegrated in a standard British disintegrator for 50,000 revolutions at approximately 1.3% consistency. No washing was done between soaking and disintegration. After disintegration, a 1-g (ovendry) sample of pulp was centrifuged at 800 x g for 30 min by the WRV determination described in the literature [8]. The WRV is reported as the weight of water retained after centrifugation per ovendry weight of pulp. This can be expressed as a percentage or simply as grams of water per gram of pulp. For the cases involving chemical addition, two replicates were performed at each condition. For no chemical addition, four replicates were performed at each condition.

RESULTS AND DISCUSSION

Table I summarizes the experiments performed using the xerographic paper (OW). Only small changes in WRV were observed in this case. The addition of both sodium hydroxide and calcium chloride increased the WRV initially. An analysis of variance of the data shows that the most significant effect was the addition of sodium hydroxide (Table II). For calcium chloride addition, the soaking time as well as the interaction between the chemical addition and soaking time were significant at the 99% confidence level.

Table III summarizes the results of the experiments involving OCC. As the table shows, the changes in WRV with the various treatments for OCC were much more pronounced than in the case for OW. This may have been due to fewer additives and fillers present in the paper or to the lignin in the OCC. Bleached fibers contain less lignin and thus are more prone to hornification, which is a carbohydrate phenomenon [3]. Since the presence of lignin in the fiber should interfere with the hornification process, the recovery of the WRV is greater in the unbleached fiber. Statistical analysis (Table IV) showed that the addition of swelling agents had the most significant effect on the WRV of the pulp. In the case of the sodium hydroxide treatment, time was also an important parameter that had a negative impact on the WRV. The interaction between time and swelling agent addition was not significant.

Consistent for both furnishes, but much more noticeable for the OCC, was the decrease of WRV with an increase in presoaking time. This is contrary to what we expected, since
The increased contact time with water should promote the absorption of water by the cell wall. One possible explanation for this phenomenon involves the dependence of the WRV on the fiber length distribution. Extended soaking does indeed allow time for the fiber to swell and become more flexible. Hence, when it is disintegrated, less damage is done to the fiber. On the other hand, immediate disintegration does not allow time for the fibers to “soften;” thus, more fines are produced that swell quickly. Therefore, the production of fines with no presoaking results in an increase in WRV at zero soaking time.

The results of the sodium hydroxide treatment were as expected: increased chemical addition improved the swelling of the fiber. This was especially evident in the case of the OCC. In the case of the OW, the effect was not as great. For calcium chloride, the chemical addition resulted in a lowering of the WRV in the case of the OCC. This is consistent with the results from the literature, in which increasing the concentration of Ca\(^{2+}\) ions decreased the WRV for virgin unbleached kraft pulp [5]. Again, the OW results were not as significant. The effect of the swelling agents on the OW may have been affected by the presence of fillers.

**CONCLUSIONS**

The two furnish—office waste paper (OWP) and old corrugated containers (OCC)—differed in their response to chemical treatment and soaking time. This difference may have been due to the differences in the amount of additives and fillers in the two furnishes (the OCC was a more “pure” fiber system) or to the chemical composition of the fibers. As expected, sodium hydroxide swelled the fiber, especially in the case of the OCC. Calcium chloride seemed to cause a decrease in the swelling of the OCC, but slightly increased
the swelling in the case of the OWP. Again, this may be due to the greater presence of fillers in the OWP or possibly due to bleaching.

It has been postulated that the production of fines during disintegration has a significant effect on the measured water retention value (WRV), which masks the increase in the WRV caused by prolonged soaking. This effect needs to be verified through analysis of fiber length distribution. Optimum increases in WRV with minimum production of fines may involve extended soaking before and after repulping. The effect of the presence of fines in the sheet needs to be investigated more thoroughly.

This work has just touched the surface of possible treatments for improving the papermaking properties of recycled fibers through swelling. Only soaking times up to 8 h were investigated, longer times of 24 to 48 h need to be tested. Additionally, the effect of temperature (especially due to the effect of process water) is an important parameter to consider. Soaking after initial disintegration would bring the fibers into more intimate contact with the water, perhaps promoting swelling. Soaking consistencies of 10% to 20% also need to be investigated since most recyclers are tending towards processing at higher consistencies. The effects of other “swelling” agents—including the use of enzymes—should be considered in the future plans for this study. As mentioned, the effect of the production of fines needs to be considered. Experiments that separate the effects of fillers and the effects of bleaching on WRV restoration need to be performed; the experiments described here using OCC and OWP cannot make this distinction. Finally, the relationship between the WRV and the strength properties of the paper needs to be verified for these recycled fiber furnishes.

LITERATURE CITED


