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The High Consistency Refining of Reclaimed Paper Stock

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THE HIGH CONSISTENCY REFINING OF RECLAIMED PAPER STOCK

by

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ABSTRACT

By subjecting reclaimed paper stock to high consistency refining (HCR) the strength of the paper was developed, without having an adverse effect on the drainage. HCR was performed on the stock at (29% ± 1%) consistency in a Bauer single disc refiner. The HCR stock was compared to conventional refining at 4.5% consistency, which was also refined in the disc refiner.

It was shown that the conventional refining of the paper stock had an adverse effect on drainage because it developed a large percentage of fines and shives. It is believed that these were developed because the reclaimed paper stock fiber is less flexible and that the conventional refining is a more severe process than HCR. When refining the paper stock under high consistency conditions the mullen and tensile were developed without producing the fines and shives, and therefore the drainage was not effected.

TABLE OF CONTENTS

HISTORICAL BACKGROUND

It is the purpose of every industry to use all of its resources in the most economical way. For this reason inferior pulps, such as sawdust, hardwoods, and reclaimed paper stock will continue to be used in the paper industry. However, there are two significant problems encountered with inferior pulps, in particular reclaimed paper stock, and these problems are low strength, and slow drainage.

It has been shown, for many different pulps, that the strength of a sheet of paper, and also its drainage can be increased by using a new process of refining called high consistency refining. By using reclaimed paper stock and subjecting it to this new method of refining it is hoped that an increase in strength and drainage can be shown.

The process of high consistency refining, (HCR) can be described in the following manner. The stock, originally at 2-5% consistency, is dewatered to 20-30% consistency, passed through a refiner and then diluted down again to 2-5%.

Different types of refining processes have been tried using the high consistency pulp; curulator, kneader, disc refiner, and hand curulating between two flat plates. With these different types of refiners it was found that the disc refiner worked best. One major reason for the use of the disc refiner was because it could easily be adapted to large scale production and therefore the experimental data obtained would corelate very well.

High consistency refining was introduced to the industry in 1955 by E. H. Cumpston(1). In his experimental work he used the Idar (Integral dewatering and refining) process, and found that this process did not work well with wood pulp, because one pass through the refining zone was more than enough to develop the fibers. Encountering this difficulty, Cumpston then turned to cotton fibers, and his work did show that the HCR process would increase their strength. Because of his difficulty in refining wood pulps the further development of HCR was held back until around 1960.

However, with the use of different refiners, research in HCR increased. With this increase in experimentation many unique properties were discovered, and as a result it became necessary to develop a new theory called, axial compression, to explain these properties(2). A literal interpretation of this theory would be that the fiber is being compressed in its axial or longest dimension. This can be visualized by noting that in the high consistency form when the fiber experiences a force in the refining zone, it will do so in the axial direction, because the neighboring fibers will stop the fiber from bending. Along with this axial compression theory, it has been said that because of the positive clearance between the two refining surfaces, the resulting action is fiber against fiber, and therefore less cutting and more fiberizing results (3). Keeping these two theories in mind the reason for the following results from HCR will become more evident.

The first interesting property of HCR was that the fiber was developed with very little decrease in fiber length. This refining action fibrilates the fibers; they become thinner, and twisted, but they are not shortened (3,4). As a result of the long fibers the tear value was maintained during refining (5,6). It was also found that the mullen was increased, while the tensile remained constant or decreased only slightly (7). In general it can be said that the HCR gave higher strength properties in comparison to conventional refining. This can be explained by noting that the HCR maintained the fiber length while refining the fibers. Whereas conventional refining decreased fiber length while refining.

The second interesting property of HCR was the high flexibility and increased stretch (3). This property can be explained by examining the theory of the axial compression of the fibers. The fiber was compressed in its long dimension, and if this compression can be released then this would explain the high stretch (2).

The third property of HCR was the increase in drainage which was primarily a result of maintaining the fiber length, and not creating fines and shives(8). Globig(9) noted that increasing the refining in the high consistency state would show only a small freeness change. For this reason the freeness test was not a good basis for comparing sheet properties.

Along with these many advantages there were also some shortcomings. The most significant of these were in the optical properties. The heat generated in the refining zone was presumed to lower the brightness 1-2 points(7). Because HCR maintained the fiber length it was found that it was particularly applicable to shorter fibered inferior pulps such as sawdust and hardwood (7,9). It was also noted that for reclaimed paper stock the strength was lower and the drainage was slower(10). From the literature it was stated that HCR would increase strength without effecting drainage. Therefore it was felt that by subjecting reclaimed paper stock to HCR the benefits of strength and drainage can be realized.

EXPERIMENTAL DESIGN

In the experimental work a roll of paper was obtained from the pilot plant. This was colored paper and therefore optical tests were not run. This paper was chosen to meet the following requirments; (i) not a high degree of refining when first made into paper, (ii) slack sized so that it could be repulped easily, (iii) no filler, because this would have been another variable which would have been difficult, if not impossible, to explain. This paper stock was then repulped in the morden slusher, making sure that the agitating discs were not doing any refining on the stock. The stock was then placed in a Bock centrifuge where the consistency was raised to 29% $\pm$ 1%. The high consistency paper stock was then broken up by hand to enable it to be refined. The low consistency stock was taken directly from the morden slusher. Both the low consistency and high consistency stock was refined in the Bauer single disc refiner.

For the low consistency refining (LCR) the discs were brought together and the power was maintained in the range of 4-6 amps. For the HCR the discs were at a positive clearance of four to ten thousandths of an inch. This clearance gave a power of 3-4 amps. The reason less power was used was because the refiner and screw feeder attachment would plug up. Therefore the power was decreased for the HCR and it was passed through more times to try and obtain the same degree of refining.

Softwood bleached kraft pulp was also prepared and refined in the same manner as the above paper stock. Handsheets were made on the British Sheet mold according to Tappi 220, and various tests were run according to their respective Tappi Standard. The drainage time was used as a measure of the degree of refining, and this test was used as a comparison for other tests on the sheets. Drainage time was just a measure of the time it takes for the handsheet to form in the sheet mold. It was also run according to Tappi Standard T-202.

DISCUSSION OF RESULTS

The drainage time is the most important advantage of the HCR of paper stock. The fibers from the paper stock are not as flexible because they have already absorbed water and have been dried, therefore in the second time through they cannot absorb as much water. This is explained in the irreversable hornification theory. It is this loss in flexibility which accounts for the difference in drainage between the HCR and LCR. (see Table I).

When the fiber is refined in the low consistency state is comes in contact with the two metal surfaces. The paper stock does not have its original flexibility and for this reason many fines and shives develop, thus decreasing drainage. However in the HCR the action is more delicate, because the action is fiber on fiber, therefore less shives and fines result and the drainage is increased. In the case of the pulp the drainage is not affected in as marked a fashion, because the fibers are much longer initially and more importantly the fibers are more flexible.

The effect of HCR on fiber length as displayed in Table I has nearly been explained already. In the LCR the action is metal against fiber which causes cutting. In the HCR the action is fiber against fiber because of the positive clearance between the refining plates and therefore one would expect less cutting.

The paper stock showed a decrease in density in the HCR over the

LCR, as shown in Table I. This would seem logical from the previous discussion. In the LCR there are more fines and shives developed which would fill in the voids in a sheet more easily, and therefore the density would increase. In the pulp samples there was no positive trend in density possible because no shives or fines developed. And in this case it is the developement of shives and fines which would be the primary factor.

Table II displays the optical tests on the virgin pulp samples. The LCR decreased the brightness 2-5 points. Whereas the HCR decreased it only 1-2 points . This data seems contrary to literature in that HCR usually decreases Brightness more than LCR. However, in this study the LCR decreased Brightness more than the HCR.

What is believed to have happened was that in the LCR the discs were touching and small amounts of iron fell into the pulp slurry. Because of a time lapse of 1-2 days between refining and making the handsheets the iron was allowed to discolor the pulp. Literature states that iron in the pulp slurry can decrease the brightness by as much as five points.[1] The opacity of the pulp samples follows the same course as the density, in that as the sheet becomes more dense the opacity will decrease.

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1. Britt K. W., " Handbook of Pulp and Paper Technology," New York, Reinhold, 1964, p. 470.

Table III consists of the strength tests. These are the most important tests, because here it is shown that the strength can be developed, without having an adverse effect on drainage. What the mullen and Tensile tests have shown is that the strength of the reclaimed paper stock was increased without effecting the drainage. In the case of the virgin pulp the advantage cannot be seen. In the LCR of the pulp the strength can be developed without a marked decrease in drainage. Therefore the benefites of HCR are of no value.

The effect of HCR on elongation is what would be expected. This is easily explained by remembering the refining action of the high consistency process. The fiber is kinked like an accordian in the high consistency state, and therefore when a stress is applied to the sheet it will have more stretch because of this kinking action.

TABLE I

Sample	Draingae time (sec)	Ave. Fiber Length (mm)	Appearant Density[1]
A. Unrefined Paper Stock	10.2	1.4	11.75
B. LCR Paper Stock (2 passes)	48.2	1.2	12.2
C. LCR Paper Stock (4 passes)	infinite time	1.0	----
D. HCR Paper Stock (3 passes)	10.1	1.6	11.57
E. HCR Paper Stock (6 passes)	11.7	1.5	11.52
F. Unrefined SWK Pulp	5.1	2.8	10.14
G. LCR Pulp (2 passes)	5.1	2.6	10.85
H. LCR Pulp (4 passes)	6.2	2.6	11.84
I. HCR Pulp (3 passes)	5.0	2.9	11.35
J. HCR Pulp (6 passes)	4.8	3.0	11.26

1. Appearant Density = $\frac{\text{Basis wt. (25x38-500}}{\text{Caliper (mills)}}$

TABLE II

Sample	Appearant Density	I.P.C. Brightness %	B&L Opacity %
F. Unrefined SWK Pulp	10.14	83.2	75.5
G. LCR Pulp (2 passes)	10.85	80.7	75.6
H. LCR Pulp (4 passes)	11.84	76.8	73.2
I. HCR Pulp (3 passes)	11.35	82.3	73.1
J. HCR Pulp (2 passes)	11.26	81.6	73.5

TABLE III

Sample	Drainage time (sec)	Mullen, lb./in^2	Tensile[1] kg.	Elongation %
A. Unrefined Paper Stock	10.2	16.5	5.5	2.5
B. LCR Paper Stock (2 passes)	48.2	21.6	6.3	2.4
C. LCR Paper Stock (4 passes)	infinite time	——	——	——
D. HCR Paper Stock (3 passes)	10.1	17.4	5.6	3.0
E. HCR Paper Stock (6 passes)	11.7	20.0	6.1	3.6
F. Unrefined SWK Pulp	5.1	25.9	5.7	3.2
G. LCR Pulp (2 passes)	5.1	36.4	7.7	3.9
H. LCR Pulp (4 passes)	6.2	44.2	9.6	4.6
I. HCR Pulp (3 passes)	5.0	40.2	8.5	4.9
J. HCR Pulp (6 passes)	4.8	36.2	7.7	4.5

1. Measured on Instron, Sample length = 10.0cm , width = 1 inch
Rate of Elongation; 1cm on chart = 1% elongation

CONCLUSION

From the data obtained it can be concluded that the high consistency refining of the paper stock is much more benificial in that the strength is developed without decreasing the drainage. With respect to the virgin pulp the benefits are not that striking. In the experimental work the actual power input was not determined. Perhaps a further study in this field would show the high consistency refining process to be economical.

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