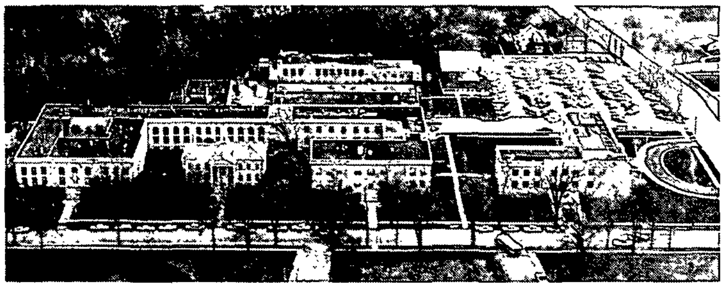

THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

IPC TECHNICAL PAPER SERIES

NUMBER 178

THE CONTRIBUTION OF DIFFERENT TYPES OF FINES TO THE PROPERTIES OF HANDSHEETS MADE FROM RECYCLED PAPER

JOHN M. HAWES AND MAHENDRA R. DOSHI

MAY, 1986

THE CONTRIBUTION OF DIFFERENT TYPES OF FINES TO THE PROPERTIES OF HANDSHEETS MADE FROM RECYCLED PAPER

John M. Hawes
Scott Paper Company
Chester, PA 19013

Mahendra R. Doshi
The Institute of
Paper Chemistry
Appleton, WI 54912

ABSTRACT

Primary and secondary fines (obtained from unrefined and refined pulps, respectively) from three different sources - TMP, kraft, and recycled paper - were added to unrefined and refined decrilled recycled paper stock. Results show that fines from kraft and recycled paper are quite effective, while those from TMP are ineffective in increasing handsheet density, breaking length, and burst index. In general, secondary fines are more effective than primary fines. Characteristics of different types of fines will be discussed in light of these results.

INTRODUCTION

Papermaking pulps consist of a distribution of particle sizes and shapes. The relative population of particles (fibers or fibrils) having a particular size and shape depends on species, pulping method, and later, the refining conditions. In sheet formation and consolidation, the various size fractions exhibit very different behavior. An arbitrary division exists today between the long fiber or fibrous fraction and the "fines" fraction of a pulp. There is general agreement that the properly beaten or refined long fiber fraction provides the majority of sheet strength and is considered a desirable pulp component. The fines fraction, however, has no comparable reputation. Although considered to be detrimental to drainage, the fines fraction is regarded as beneficial to sheet strength in certain situations, detrimental in others.

Several investigators (for example, 1, 2) have shown that the more rigid the fibers, the more essential the fines are in enhancing sheet strength properties. Thus, for mechanical pulps or unrefined chemical pulps, fines play an important role. However, for flexible fibers such as well refined chemical pulps the difference in tensile strength of handsheets made with or without fines is not significant. One can therefore conclude that the importance of fines will depend on the stiffness of the long fibers in the sheet.

In addition to the importance of fibrous environment, the nature of fines also plays an important role. Many investigators have studied the effect of "primary" fines - those present in the pulp before beating, and "secondary" fines - those formed during beating. There is general agreement in the literature that primary fines contribute negligibly to sheet bonding (3-5). Reasons mentioned for their undesirability include their low specific surface compared to secondary fines, and the presence of mineral particles in the fraction. However, different opinions exist as to what properties are responsible for the beneficial nature of secondary fines.

According to Lobben (6), improved bonding is brought about by the increased specific surface of the secondary fines, which increase the relative bonded area in the sheet. According to Szwarcsztajn and Przybysz (7), primary fines from unbleached pine kraft had a specific surface of approximately 25 m^2/g, while secondary fines (obtained after 25 minutes of beating) had a specific surface of 140 m^2/g. In this sense, secondary fines act as a filler material within the bond and provide a more uniform stress distribution over a larger bonded area.

The other possible role that secondary fines play in sheet bonding is described by Giertz (8) and later Molina-Mancebo and Krkoska (5). They claim that these fines increase the amount of "bound water" between surfaces so that wet web strength and eventually sheet bonding are enhanced via the Campbell effect. This increase in bound water is thought to be due to the exposed hemicelluloses on the fines surfaces.

For mechanical pulps, some researchers have identified two types of fines as "flour stuff" (having poor bonding potential) and "slime stuff" (having good bonding potential) (9). Flour type fines were described as lignin rich, slime type fines as cellulose rich. These two types of fines were reportedly distinguishable by size and settling rate: flour stuff was larger and settled faster. It was unknown whether lignin content or larger size of the flour type fines or both make them detrimental to bonding.

Finally, substantial data are available on cellulose swelling characteristics after various degrees of drying (10), but surprisingly, changes in the swelling characteristics of fines due to drying have not been studied extensively. The use of recycled pulps involves fines that have been dried. and a common opinion today is that the entire fines fraction of recycled pulp is an undesirable filler (5). This is in direct contrast with the results of Bliss (11) and Przybysz (12) who state that the contribution of secondary fines to handsheet strength properties is significant while that of primary fines is negligible.

Thus, the role of primary and secondary fines in the strength development of handsheets made from unrefined and refined recycled fiber stock was not clear. Furthermore, one would like to know how these fines compare with those obtained from, for example, chemical pulps and mechanical pulps. The purpose of our project is to provide answers to these questions.

OBJECTIVES

One of the objectives of this project was to evaluate the importance of primary and secondary fines (obtained from unrefined and refined pulps, respectively) in recycled paper stock. The performance of fines obtained from recycled paper was compared with that of fines obtained from TMP and unbleached softwood kraft pulp. Also, attempts were made to determine fines characteristics which

1

enhance sheet strength properties.

RESULTS AND DISCUSSION

Recycled pulp from unbleached kraft bag paper (approximately 80% softwood, 20% hardwood) was found to contain about 20% fines. These fines (called primary fines) were removed as described under Isolation of Fines and Long Fiber Fractions. Properties of handsheets made from unrefined decrilled pulp are reported in the top row of Table 1. The types of fines considered were:

	Recycled	Kraft	TMP
Primary fines:	1	2	3
Secondary fines:	4	5	6

The decrilled recycled pulp was refined in the Valley beater, and the secondary fines (about 8.7% by weight of the refined pulp) were removed. The handsheet properties of decrilled refined pulp, with and without addition of different fines, are displayed in Table 2.

First we will discuss the handsheet properties shown in Tables 1 and 2. Subsequently, some of the characteristics of the fines will be discussed so as to better understand the observed role of fines.

Effect of Fines on Handsheet Properties

Results of Table 1 show that both recycled and kraft primary and secondary fines (rows 1, 2, 4, 5) have considerable effect on the handsheet properties of unrefined recycled pulp. These fines

Table 1 The effect of adding different fines on handsheet properties of <u>unrefined</u> decrilled recycled pulp

(About 20% fines in handsheets)

Pulp	Handsheet Properties	Density, g/cm^3	Breaking Length, km	Burst Index	Elmendorf Tear	Bendtsen Air Permeability, mL/min	MIT Fold	Light Scattering Coefficient
	Decrilled	0.549	2.68	1.39	8.70	>3400	10	186
Primary Fines	Rec 1	0.656	3.67	2.37	11.4	254	82	200
	Kraft 2	0.670	3.84	2.15	9.38	355	42	194
	TMP 3	0.549	2.70	1.20	8.78	903	9	256
Secondary Fines	Rec 4	0.629	5.77	3.86	9.95	0	392	205
	Kraft 5	0.631	5.82	3.88	9.28	0	437	149
	TMP 6	0.594	3.96	2.64	8.64	152	70	280

Table 2 The effect of adding different fines on handsheet properties of <u>refined</u> decrilled recycled pulp

(About 8.7% fines in handsheets)

Pulp	Handsheet Properties	Density, g/cm^3	Breaking Length, km	Burst Index	Elmendorf Tear	Bendtsen Air Permeability, mL/min	MIT Fold	Light Scattering Coefficient
	Decrilled	0.713	5.35	3.16	9.00	1200	187	158
Primary Fines	Rec 1	0.659	5.61	3.58	9.35	190	227	194
	Kraft 2	0.640	5.47	3.41	9.25	310	186	197
	TMP 3	0.632	5.12	3.12	9.06	270	158	220
Secondary Fines	Rec 4	0.662	6.67	4.29	9.23	50	539	180
	Kraft 5	0.677	6.67	4.36	8.83	40	580	150
	TMP 6	0.620	5.44	3.27	9.23	410	200	230

significantly increase handsheet density, tensile strength (reported as breaking length), burst index, tear and folding endurance. Primary fines from recycled and kraft pulp are slightly better in improving density and tear, while secondary fines are better for tensile, burst, and fold.

In all cases, TMP fines were found to be inferior to recycled and kraft fines. TMP secondary fines outperformed TMP primary fines in improving handsheet density, tensile, burst and fold. TMP primary or secondary fines had virtually no effect on the handsheet tear strengths.

It is not surprising to note that the addition of fines reduces the air permeability of handsheets. Air flow rate through the decrilled pulp sheet is so high that it is outside the range of Bendtsen instruments. At the other extreme, recycled and kraft secondary fines render the handsheets virtually impermeable to air. The effect of other fines is somewhat less severe.

The light scattering coefficient, which is an approximate measure of the unbonded area, is expected to increase due to the addition of 20% fines. The fact that the coefficient is not significantly affected by the addition of primary or secondary fines from recycled and kraft pulp (it even decreased for secondary kraft fines) is indicative of the bonding potential of these fines. In other words, these fines are participating in fiber bonding and are therefore not available for light scattering. Both primary and secondary TMP fines increase the light scattering coefficient by 40 to 50%. Thus, it is clear that recycled and kraft fines are desirable for unrefined recycled pulp, while TMP fines do not improve sheet strength properties.

Let us turn our attention now to the effect of fines on refined recycled pulp, Table 2. Note that only 8.7% fines are added here compared to 20% fines added to the unrefined pulp (Table 1). These percentages of fines by weight may be termed the "natural" fines content of the pulp in question, either before or after beating. We see that the effect of fines on refined pulp is much less pronounced compared to the effect on unrefined pulp. This is not due to the difference in the amounts of fines used but because refined decrilled pulp fiber possess greater bonding potential. Thus, in the words of Cardwell and Alexander (13) there is not much "headroom" for improvement for refined pulp compared to that for unrefined pulp. Results in Tables 1 and 2 are in agreement with the literature (1,2) that stiffer and unrefined fibers are more responsive to fines addition compared to more flexible refined fibers.

The addition of fines to refined recycled pulp lowered the handsheet density and air permeability. In general, secondary fines were more effective in improving tensile, burst and fold, compared to primary fines. Handsheet tear strength was not significantly affected by fines. Light scattering coefficient displayed trends similar to that for unrefined pulp.

In summary, one can say that fines from recycled pulp and kraft pulp are quite valuable in improving handsheet strength properties. Thus, the common belief that fines from recycled pulp are not useful in improving handsheet properties is not necessarily correct. However, one must note that the laboratory recycled pulp considered here did not contain any debonders like ink, fillers or stickies. It is possible that excessive concentration of such debonders could make fines much less valuable than shown here. Some of the fines and contaminants will be removed from the system during washing and thickening and via screen and cleaner rejects. It would be interesting to separate primary fines (after washing, thickening, screening and cleaning but prior to refining) and secondary fines from a mill stock and study their effect on the paper properties.

CHARACTERISTICS OF FINES

An important question is, What makes these fines behave the way they do? In an attempt to answer this question we measured size and shape, lignin and hemicellulose content and compressibility of these fines.

Size and Shape of Fines

SEM photographs of all six fines are presented in Fig. 1-6. All fines have been examined at 300X magnification. A white horizontal line at the bottom of each photograph provides a reference scale of low microns. Note that all primary fines (Fig. 1-3) consist of considerable amounts of flakelike, lamellar, or chunky particles. On the other hand secondary fines from recycled and kraft pulps (Fig. 4 and 5) show a very fibrillar appearance. TMP secondary fines contain a mixture of flakes and fibrillar materials. Thus, domination of chunky material in TMP fines compared with the higher amounts of fibrillar fines in kraft and recycled pulps (particularly in secondary fines) can be correlated with the effectiveness of these fines in enhancing sheet strength properties. One can hypothesize that fibrillar fines, by virtue of their relatively higher specific surface area, have greater bonding potential compared to chunky or flaky fines.

Fig. 1 Recycled Primary Fines. Some fibrillar material present but primarily flakelike.

3

Fig. 2 Kraft Primary Fines. Many flakes 40-70 μm, very little fibrillar material.

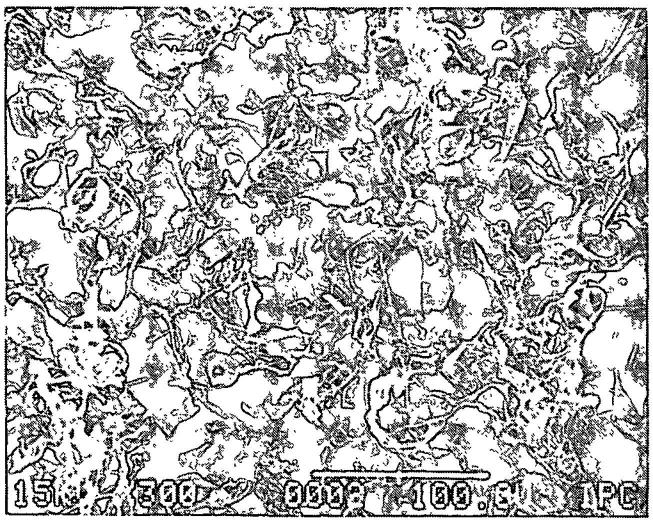

Fig. 3 TMP Primary Fines. More flaky material than Kraft Primary Fines.

To shed more light on the effect of fines shape, an investigation of the "equivalent spherical diameter" - ESD of the six fines types was performed. ESD data were obtained from the Coulter Counter by assigning higher channel numbers to increasing ESD of particles passing through an aperture tube.

To minimize the effect of size on ESD, and to maximize the impact of fines shape on ESD, the P200/R400 fraction was considered for this study. It was hoped that the primarily fibrillar nature of secondary kraft and recycled fines could be distinguished from the chunky nature of primary fines once particle size was controlled.

Fig. 4 Recycled Secondary Fines. Very similar in appearance to Kraft Secondary Fines (fibrillar).

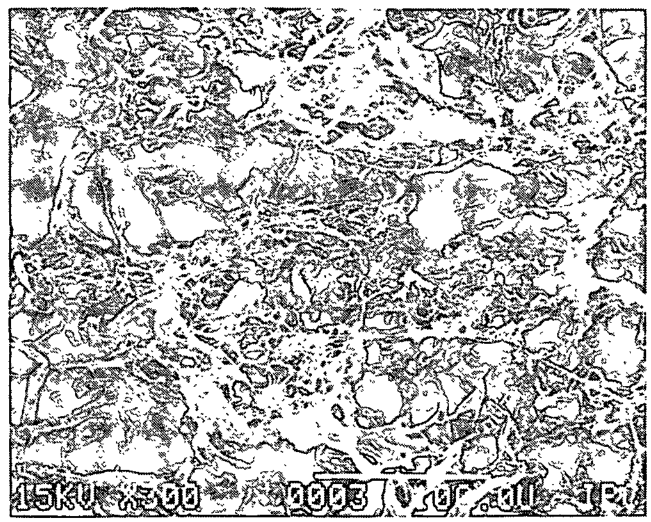

Fig. 5 Kraft Secondary Fines. Very fibrillar in appearance, few chunks present.

The critical size of the P200/R400 fraction in screening would be the fibril length for fibrillar fines and flake width for chunky or flaky fines: both between 38 and 76 microns. With these dimensions known, it can be shown that fibrillar particles occupy a smaller equivalent spherical diameter than flakelike particles (14).

Coulter Counter analysis of the six fines types showed (Table 3) noticeable increases in low channel populations for secondary kraft and recycled fines, with heavier high channel populations for all primary fines and TMP secondary fines. However, if a proportionately larger amount of chunky, flakelike material was in the 38-40 micron range, it could be responsible for the trends seen here. It is obvious that the narrower

4

the size distribution, the greater the utility of the Coulter Counter in quantifying fines shape.

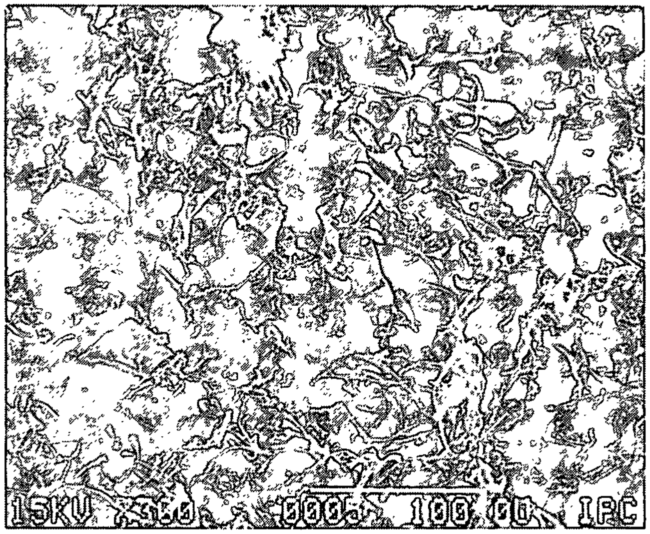

Fig. 6 TMP Secondary Fines. Still primarily flakelike, but smaller overall than TMP Primary Fines (20-30 μm).

Table 3 Equivalent spherical diameters and relative populations of fines within Coulter Counter channels

Channel Number	ESD[a], μm	TMP		Recycled		Kraft	
		Pri.	Sec.	Pri.	Sec.	Pri.	Sec.
1	1.59	0.0	0.0	0.0	0.0	0.0	0.0
2	2.00	3.0	3.2	2.0	4.1	2.1	4.0
3	2.52	3.0	3.4	2.5	5.0	3.0	6.0
4	3.17	3.8	4.3	3.0	6.5	4.0	8.8
5	4.00	4.2	5.0	4.0	7.5	4.1	10.8
6	5.04	6.0	6.5	5.2	9.0	5.0	12.0
7	6.35	7.0	7.7	6.0	9.6	4.0	9.8
8	8.00	7.4	8.5	6.7	9.8	3.3	7.7
9	10.08	9.2	9.8	7.5	9.8	4.2	7.5
10	12.70	13.0	12.0	9.0	10.4	11.0	8.6
11	16.00	15.4	12.9	10.8	10.5	26.0	9.1
12	20.20	15.8	12.8	17.2	10.7	25.0	8.7
13	25.40	10.8	10.0	16.5	5.7	7.0	7.1
14	32.00	5.2	6.0	8.0	3.1	3.5	5.2
15	40.30	1.2	2.5	3.5	2.1	2.0	0.4
16	50.8	0.0	0.0	0.0	0.0	0.0	0.0
Av. ESD, μm:		14.2	14.0	16.5	11.6	15.5	10.9
Median ESD, μm:		11.9	10.9	14.7	8.1	14.2	6.6

[a]Calculated equivalent spherical diameter based upon calibration of instrument using monosized spheres and a 100-micron aperture tube. Note channels 1 and 16 are outside the nominal particle diameter range for this aperture tube. All values of relative volumes are averages of two separate samplings.

Chemical Analysis

Table 4 gives the chemical distributions of the six fines types plus the three original whole pulps:

Table 4 Lignin and carbohydrate analysis of pulps and fines

Sample	Weight Percentages					
	Arab.	Xyl.	Mann.	Galac.	Glucan	Kl. Lig.
TMP whole pulp	1.4	6.2	9.5	3.1	38.4	32.0
TMP pri. fines	1.6	5.6	7.7	3.1	32.9	38.9
TMP sec. fines	1.4	6.3	10.8	3.1	40.9	32.3
Rec. whole pulp	0.9	10.1	6.0	1.7	67.0	13.4
Rec. pri. fines	0.9	9.3	3.8	2.3	41.3	28.7
Rec. sec. fines	0.6	7.5	5.0	1.5	57.8	18.5
Kraft whole pulp	0.8	8.0	6.4	0.4	74.8	4.3
Kraft pri. fines	0.7	6.7	5.2	1.5	64.6	14.2
Kraft sec. fines	0.5	7.6	5.2	0.5	64.6	11.5

Several interesting trends are apparent from Table 4. To no surprise, the lignin content of the samples reflects the stiffness of the particles. According to Tam Doo and Kerekes (15), mechanical pulps can be up to 30 times stiffer than kraft pulps. Although their work involved individual fibers, it is felt that the same analogy can be drawn for fines, especially if the fines are fibrillar in shape. Thus, higher lignin content does indicate a stiffer particle.

However, the descending ranking of fines according to lignin content does not absolutely correspond to the descending order of fines bonding potential. If it did, kraft primary fines would be better than recycled secondary fines. So, although the overall trend of increased lignin content giving decreased bonding capacity is evident, the results indicate other factors are involved.

Upon examination of the hemicellulose composition of the samples, it is evident that degradation during kraft pulping lowers the hemicellulose content compared to mechanical (TMP) pulping. Also, for both chemical pulp fines species, a higher hemicellulose content is found on the primary fines. For the TMP fines, the secondary fines have the higher hemicellulose content. This can best be explained by redeposition of dissolved hemicelluloses, particularly xylans, on the fiber surface during kraft cooking. This raises an interesting question: if hemicelluloses which are hydrophilic and generally considered to be beneficial to bonding are more prevalent in primary fines from chemical pulps, why are the secondary fines from these pulps more beneficial to bonding? Thus, bonding potential of fines as attributed to hemicelluloses by Giertz (8) and Molina-Mancebo (5) appears questionable from the data presented here.

Compression - Filtration Resistance Tests

The filtration resistance of a mat formed from fines was calculated by measuring filtration velocity at constant pressure:

$$U = \frac{Q}{A} = \frac{A.\Delta P}{\mu.W.R}$$

where U = filtration velocity, cm/s
Q = volumetric flow rate, cm^3/s
A = pad area, cm^2
ΔP = pressure drop across the pad, $g/cm\ s^2$
μ = viscosity of filtrate, g/cm s
W = mass of fines, g

5

and R = specific filtration resistance of fines, cm/g

The variation of filtration resistance with pressure was considered to be an indirect measure of the compressibility of fines. This variation is generally expressed as (16):

$$R = a\ \Delta P^b$$

where a is the filtration resistance of the uncompressed mat and b is called the compressibility constant. If the fines pad is incompressible, changing the pressure will have no effect on the specific filtration resistance, i.e., b = 0, for incompressible mat. Thus, the higher the value of b, the more compressible the fines are.

The results of the filtration resistance measurements are given in Table 5. The fibrillar secondary recycled and kraft fines are clearly much more compressible compared to much stiffer TMP fines. Also, the values of b for recycled and kraft primary fines are higher than those for TMP fines. Thus, the compressibility constant, b, appears to be a good indicator of fines effectiveness. One can conclude that the higher the value of b, the more effective fines would be in enhancing sheet strength properties. An interesting application of this result is in mechanical pulping. The performance of various equipment can be compared by measuring the amount and the nature (compressibility) of fines produced. More work in this area could be rewarding.

Table 5 Compressibility testing of fines

	Filtration Resistances @ listed ΔP (psi) ($\times 10^{-11}$ cm/g)							
Type	20	40	60	80	100	0[a]	Slope b	r^2
TMP pri.	4.58	5.08	5.83	6.74	7.45	1.74	0.306	0.932
TMP sec.	4.72	5.88	6.37	7.04	7.33	2.10	0.274	0.993
Rec. pri.	5.11	6.18	7.25	8.02	9.04	1.75	0.349	0.987
Rec. sec.	8.34	10.70	13.60	19.33	23.83	1.05	0.649	0.934
Kraft pri.	5.43	7.55	8.34	8.68	9.69	2.00	0.342	0.967
Kraft sec.	9.68	17.12	21.71	26.8	32.7	1.07	0.739	0.935

[a]Also called specific filtration resistance of the uncompressed mat.

CONCLUSIONS

Results show that recycled pulp fines - both primary and secondary - are almost as effective as the corresponding virgin kraft fines in improving handsheet strength properties. Fines from recycled pulp, provided it does not contain excessive amounts of debonders like ink, stickies, and fillers, could contribute significantly in increasing the strength properties of the paper or board. TMP fines, on the other hand, are not as effective.

Fines characterizations show that valuable fines are fibrillar in shape with relatively higher compressibility constants. Lignin and carbohydrate analysis or Coulter Counter measurements provide clues to, but are not very definitive in assessing, the usefulness of fines. Filtration resistance or compressibility measurements are good indicators of fines characteristics.

EXPERIMENTAL

Three pulp types were chosen as sources of fines because they represent the broadest range of both fines content, and perceived effectiveness that have been described in the literature. The three pulp types were: southern pine/Virginia pine TMP, 50% yield northern softwood kraft, and 80% softwood-20% hardwood recycled kraft.

Isolation of Fines and Long Fiber Fractions

The first experimental step was to isolate the fines and fiber fractions of the pulp. The most common definition of fines (and that which has been used in this work) has been the material passing through a 200 mesh (76 micron) screen in a Bauer-McNett classifier. Earlier work done at IPC indicated that good agreement with the Bauer-McNett could be obtained by washing the pulp on a Sweco Dynoscreen Separator equipped with a 200 mesh synthetic screen after disintegrating the pulp for 4 minutes in a British disintegrator (17). With this method, a 5 to 10 g (OD) charge of pulp was placed on the vibrating screen and washed with tap water from a hose until 15-20 liters of filtrate was collected below. The amount of wash water varied, but it was found that 2 liters per OD gram of pulp gave good agreement with the Bauer-McNett.

By operating the Sweco unit with the 200 mesh screen right side up, the long fiber fraction of the pulp (rejects) are forced out a side trough due to centrifugal motion and because the screen is flush with the side trough. In this configuration, it was impossible to prevent rejects from exiting through the side trough before being thoroughly washed. To ensure maximum washing and fines removal, the screen was installed upside down so that a 1-inch lip prevented the fibers from exiting. In fact, with this arrangement the pulp tended to aggregate near the center of the screen and could be forced outward with the water jet for more washing.

To generate secondary fines and decrilled refined pulps, the decrilled unrefined pulps were refined in the Valley beater according to TAPPI Standard T 200 os-70. A total of 50 minutes was required to generate enough fines from beating for collection. Removal of these secondary fines was also accomplished through the Sweco unit.

Extended settling (48 hours) of the fines rich filtrate yielded either the primary or the secondary fines as well as a nonsettling "colloidal" portion. After decanting the nonsettling portion, the more concentrated settled fines were stored in Mason jars with 2-3 drops of formaldehyde to retard microbial action, and stored in a cold room. The nonsettling portion was eventually discarded for this study.

Handsheet Formation

Handsheets were formed on the British handsheet

6

mold in the Pulp Lab according to TAPPI Standard T 205 om-81 with the following modifications. First, it was determined that there was no loss of the long fiber fractions through the handsheet septum. Second, to get a desired fines weight percentage in the handsheet, an excess of fines was added to the mold to compensate for fines loss through the screen. Target handsheet weights were usually obtained within four tries, and in all cases the OD weight was determined by drying after pressing. Once target weights with desired fines content were achieved, five handsheets for each pulp were made in strict accordance with T 205 om-81.

Physical Testing of Handsheets

Handsheet testing was performed according to TAPPI Standard T 220 om-83 with the exception that only one burst measurement per handsheet was made. Tests included density, tensile strength, burst index, tear index, Bendtsen porosity, MIT fold, and light scattering coefficient. All samples were conditioned and tested at 50% relative humidity and 73°F unless otherwise noted.

SEM Photography

Samples of all six fines types were submitted to the SEM laboratory for centrifugation, critical point drying, and photography using the JEOL scanning electron microscope. The main purpose of the SEM photography was to illustrate differences in appearance between the fines types, i.e., between predominantly fibrillar and predominantly flakelike fines.

Coulter Counter Analysis

All six fines types were individually passed over a 400 mesh screen and the rejects portions were saved. The rejects then consisted of particles between 38 and 76 microns. Thus the "size" range was quite narrow. These P200/R400 samples were then tested on a model TA II Coulter Counter in the following manner:

A 2% NaCl (by weight) solution in distilled water was used as the electrolyte after being purified by two passes through a 0.22 micron filter membrane. A 100 micron aperture tube was used on the counter. After verifying electrolyte purity and calibrating the instrument, the fines samples were run with one repetition.

Chemical Analyses

All six fines types were placed in a vacuum oven at 30°C and 20-inch Hg vacuum for three days. Five hundred mg of these air-dry samples were analyzed for % lignin and % carbohydrate determinations. The lignin determination was done according to the method described by Effland (Tappi, Oct., 1977). Carbohydrate compositions were obtained by TAPPI method T 249 pm-75.

Compressibility and Filtration Resistance of Fines Types

The P200/R400 fractions described earlier for the Coulter Counter analysis were also used for this final experimental step. A pressure cell and reservoir was attached to a compressed air cylinder. Air from the cylinder went to the top of the cast iron, 1000 mL reservoir which sat above the Gelman pressure cell. The fines cake was formed at the base of the pressure cell, and filtrate through the cake was collected in a beaker below. The detailed procedure for this test is given by Hawes (14).

ACKNOWLEDGMENTS

Portions of this work were used by J. Hawes as partial fulfillment of the requirements for the Master of Science degree at The Institute of Paper Chemistry.

LITERATURE CITED

1. Przybysz, K., and Szwarcsztajn, E. Effect of crill on pulp freeness. Przeglad Papier., **29** (2):105-108 (April, 1973).

2. Thode, E. F., and Ingmanson, W. L. Factors contributing to the strength of a sheet of paper. I. External specific surface and swollen specific volume. Tappi, **42**(1):74-83 (Jan., 1959).

3. Yan, J. F., and Sinkey, J. D. Selective screening and refining: a negative answer to energy reduction and pulp strength improvement. Preprint: International Symposium on Fundamental Concepts of Refining, IPC, Appleton, WI, Sept., 1980.

4. Kibblewhite, R. P. Interrelations between pulp refining treatments, fiber and fines quality, and pulp freeness. Paperi Puu, **57** (8):519-522, 525-526 (Aug., 1975).

5. Molina-Mancebo, R., Krkoska, P., and Blazej, A. The concept, properties, and papermaking role of fines. Vyskum. Prace Odboru Papiera Celulozy **26**:V75-81 (1981).

6. Lobben, T. H. On the influence of pulp components on the shrinkage and elongation of paper. Norsk Skogind., **32**(4):80-84 (April, 1978).

7. Szwarcsztajn, E., and Przybysz, K. Some aspects of the fractionation of pulp and paper. Papier **29**(7):295-300 (July, 1975).

8. Giertz, H. W. The influence of beating and the causal effects on paper properties. Preprint: International Symposium on Fundamental Concepts of Refining, IPC, Appleton, WI, Sept., 1980.

9. Honkasalo, et al., Paperi Puu, (11):693-698 (1983).

10. Swanson, J. W. Lecture notes from Colloid Chemistry of Papermaking Materials, IPC, Appleton, WI.

11. Bliss, T. Secondary fiber fractionation using centrifugal cleaners. Proc. TAPPI 1984 Pulping Conference, Nov., 1984:217-225.

12. Przybysz, K. Model study of the effect of fines on the papermaking properties of secondary pulps. Przeglad Papier., **34**(11):397-401 (Nov., 1978).

13. Cardwell, R. D., and Alexander, S. D. Effects of recycling on softwood kraft pulp properties. Appita, **30**(4):327-333 (Jan., 1977).

14. Hawes, John M. Characterization of the fines fraction of papermaking pulps. A291 Report, The Institute of Paper Chemistry, Dec., 1984.

15. Tam Doo, P. A., and Kerekes, R. J. The flexibility of wet pulp fibers. Pulp Paper Can. **83**:2 (1982).

16. Tiller, F. M. Compressible cake filtration. The Scientific Basis of Filtration, Proceedings of the NATO Advanced Study Institute, Cambridge, U.K., July, 1983. p. 315-325.

17. Hoffman, G., Personal communication, Feb., 1984.

8