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The Relation between Separate Refining and Mixed Refining on the Strength Properties of Paper

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THE RELATION BETWEEN SEPARATE REFINING AND MIXED REFINING ON THE STRENGTH PROPERTIES OF PAPER

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Object:

The purpose of this work is to determine whether or not a significant difference in the strength characteristics of paper made from two pulps is obtained if the pulps are refined separately as compared to pulps refined together. The direction and magnitude of any difference is also desired.

Literature Survey:

Literature on this topic is severely limited in several ways. First, very little has been written. Secondly, of the studies written, the procedure of sampling was so limited that any generalities drawn were almost unfounded. And, thirdly, the conclusions drawn from these few articles contradict one another.

I found only four small articles (starred in bibliography) which I felt had any pertinence to this topic at all. Of these four, only the article by Peckham and May falls within the scope of this paper.

Peckham and May used only one combination and limited the study further to the middle freeness ranges. They studied the effect of mixing before and after refining on the strength characteristics of a sixty percent pine kraft - forty percent gum kraft furnish. The sampling was taken such that a high freeness was mixed with a low freeness so that the mixture had a medium freeness value. Also, since the study included only one mixture of two kraft pulps, the study was not truely representative.

A similar study was made on a fifty percent straw -

fifty percent sulfite mixture with mixing after refining done so that low freenesses were mixed together and high freenesses were mixed together, etc.. Once again, this is not a truely representative sample.

In another study, the various freeness levels were obtained by mixing refined pulp with unrefined pulp which, to me, has no basis for comparison with a pulp mixed before refining.

These studies gave no consideration to varying the furnish components or to varying the degree of refining of the mixture in more than one way.

As to the strength characteristics of the paper made from these pulps, the conclusions drawn are listed below.

Peckham and May found a very slight increase in the strength characteristics by refining before mixing as compared to refining after mixing.

The results of another study indicated that the static strength values (tensile, stretch, burst) were greater if the pulps were mixed before refining whereas the dynamic strength values (tear, fold) were greater if the mixing was done after refining.

Still another report states that the strength characteristics of paper made from pulps mixed after refining was that calculated from the two components.

Thus, one can see that the literature reveals very little about this topic.

To overcome the shortcomings of the literature survey, I plan to examine, for strength properties, three different

pulp mixtures. I plan to vary the composition of these mixtures in three ways and take samples over the bulk of the freeness range.

Procedure:

Since a multitude of samples were desired but time was limited, three combinations of three different pulp mixtures were made and tested according to the procedure described below. Each mixture had one short fiber pulp and one long fiber pulp and they were combined in these three ways: 25% short fiber-75% long fiber; 50% short fiber-50% long fiber; 75% short fiber-25% long fiber. The three combinations used were, 1) Albacel Sulfite (long fiber)-Seagull Soda (short fiber), 2) Raymill Hardwood Sulfite (short fiber)-Rayonierred Semi-bleached Kraft (long fiber), and 3) Weyerhauser Bleached Sulfite (long fiber)-Penobscot Soda (short fiber).

In the interest of uniformity, everything was run on the same instruments or apparatus. That is, everything was refined on the same Valley Beater, everything was tested on the same instruments, everything was weighed on the same scales, etc..

For each mixture, the following weights of air dry pulp were weighed out:

300 g. short fiber - 100 g. long fiber.
200 g. short fiber - 200 g. long fiber.
100 g. short fiber - 300 g. long fiber.
400 g. short fiber.
400 g. long fiber.

Each system of 400 grams was then refined on the Valley Beater and samples were taken periodically. Four samples

were taken from the mixed furnishes at different degrees of refining and five handsheets were formed on the Nobel and Wood Sheet Mold for each sample. Four samples were taken from the long fiber and each sample was mixed with a sample of highly refined short fiber and a sample of slightly refined short fiber in the three combinations (25-75, 50-50, 75-25). These mixings were made in glass beakers and the mixing was done by hand with a glass rod. Four Nobel and Wood handsheets were made from each combination.

After allowing the sheets to stand for several days at 50 percent relative humidity and 69° F., each sheet was weighed and then tested twice for burst on the Mullen tester and twice for tear on the Elmendorf Tear Tester according to Tappi Standards T 403 m-53 and T 414 m-49. An average weight, average burst, and average tear were determined for the four or five sheets of the same sample and these average values were then corrected to the same basis weight.

I used the technique for determining a relative strength index as discussed by Fanselow and Fanselow (see bibliography). That is, the product of the corrected burst and corrected tear gives the relative strength index for each sample which can be compared to the relative strength index of each of the other samples of the same composition.

Errors:

In this project, there are many places for errors to crop up. The largest possible error could be formed when the pulps were mixed after refining. Since they were mixed in small volume in a glass beaker with a glass rod, it is

possible that thorough mixing might not occur. If more effective agitation were supplied here, the results might be more uniform.

Working at the consistence of the Valley Beater (about 1.7 g. / 100 cc), it is difficult to accurately reproduce the combinations, especially in small volume, So, it might be better, for more precise results, to dilute the stock considerably so that it would be possible to reproduce the compositions desired.

It can be seen that many of the wild values appear when the stock has been only slightly refined.

It should be noted that none of these situations would necessarily cause erroneous conclusions but rather might cause wild values.

Results:

Data is presented in Tables I through IX and each table is discussed below. The freenesses are uncorrected. Although each table includes the average tear and average burst for the sheets of the same composition, these values are not important except that they show how the index is found and they show certain trends when compared with the other tables. This will be discussed in the conclusions.

Table I: 25% Seagull Soda - 75% Albacel Sulfite.

Separate refining gave an increase in the strength index of about 15% (2705 vs. 2348) and the sheets formed from sulfite and highly-refined soda exhibited slightly higher strength properties than those formed from sulfite and slightly refined soda (about 3.5% difference; 2750 vs. 2660).

Table I: 25% Seagull Soda - 75% Albacel Sulfite

freeness	burst	tear	index	freeness soda	freeness sulfite
mixed refining					
150	44.7	52.4	2342		
320	42.0	56.7	2422		
460	36.1	67.2	2426		
560	30.1	73.2	2203		
separate refining					
560	32.6	82.9	2700	195	625
575	25.6	97.6	2596	600	625
480	32.9	77.6	2550	600	485
370	40.8	78.0	3120	195	485
250	40.6	67.2	2725	195	285
370	34.7	70.0	2429	600	285
275	41.0	74.0	3033	600	180
180	42.0	59.2	2485	195	180

	mixed refining	separate refining		
		total soda	soda 195	soda 600
average tear	62.3	75.7	71.8	79.8
average burst	38.4	36.3	39.0	33.8
average index	2340	2705	2750	2660

Table II: 50% Seagull Soda - 50% Albacel Sulfite

freeness	burst	tear	index	freeness soda	freeness sulfite
mixed refining					
170	43.7	50.8	2220		
305	41.2	57.6	2370		
395	35.8	61.6	2200		
515	23.1	68.8	1585		
separate refining					
410	35.3	65.2	2298	195	625
565	21.5	82.0	1768	600	625
485	26.4	72.4	1910	600	485
345	38.6	63.2	2418	195	485
230	38.7	55.2	2140	195	285
415	27.9	71.0	1980	600	285
360	31.9	73.6	2345	600	180
190	39.1	60.4	2360	195	180

	mixed refining	separate refining		
		total soda	soda 195	soda 600
average tear	59.7	68.3	61.1	75.1
average burst	35.9	32.4	37.9	26.9
average index	2095	2153	2300	2000

Table II: 50% Seagull Soda - 50% Albacel Sulfite.

Refining before mixing gave only the slight increase in strength characteristics of about 3% (2153 vs. 2095) but the strength index for the paper from sulfite and highly-refined soda was about 15% greater than that for sulfite and slightly-refined soda (2300 vs. 2000).

Table III: 75% Seagull Soda - 25% Albacel Sulfite.

Refining before mixing gave the decided increase in strength properties of about 23% (1757 vs. 1427) and the highly-refined soda increased the strength index by about 31% over the slightly-refined soda (1955 vs. 1495).

Seagull Soda - Albacel Sulfite (general):

In all three cases, separate refining gave the higher strength index. Also, the papers formed from sulfite and highly-refined soda exhibited greater strength properties than those formed from sulfite and slightly-refined soda. This difference increased as the amount of soda in the sheet decreased. The strength index increased as the proportion of long fiber in the sheet increased.

Table IV: 25% Raymill Sulfite- 75% Rayonierred Kraft.

The strength properties of this sheet seemed to be unaffected by the refining-mixing schedule as the strength index for refining before mixing (5200) was about the same as the index for refining after mixing (5240). The negligible increase in the strength index of 1% was exhibited by refining the hardwood portion more severely (5220 vs. 5170).

Table III: 75% Seagull Soda - 25% Albacel Sulfite

freeness	burst	tear	index	freeness soda	freeness sulfite
mixed refining					
135	42.7	46.4	1985		
275	30.6	40.2	1230		
420	30.0	56.2	1685		
525	15.4	52.4	807		
separate refining					
330	34.2	57.2	1955	195	600
625	18.6	70.9	1320	600	600
505	20.8	66.4	1380	600	485
220	37.0	52.7	1952	195	485
200	37.8	53.1	1950	195	285
465	23.1	63.8	1470	600	285
430	23.4	66.3	1814	600	180
180	37.6	53.7	2015	195	180

	mixed refining	separate refining		
		total soda	soda 195	soda 600
average tear	47.8	60.5	54.3	66.8
average burst	29.6	29.6	36.6	22.5
average index	1427	1757	1955	1495

Table IV: 25% Raymill Sulfite - 75% Rayonierred Kraft

freeness	burst	tear	index	freeness kraft	freeness sulfite
mixed refining					
592	42.5	122.8	5220		
325	51.3	104.4	5360		
160	52.4	98.4	5150		
separate refining					
600	39.6	136.8	5390	670	200
660	35.5	152.8	5400	670	550
500	42.5	123.2	5280	490	550
370	48.7	118.8	5790	490	200
300	46.6	103.2	4800	290	200
375	46.1	112.0	5160	290	550
290	44.3	108.4	4810	180	550
200	48.8	100.4	4910	180	200

	mixed refining	separate refining		
		total sul.	sul. 200	sul. 550
average tear	108.5	119.4	112.3	124.1
average burst	48.8	44.0	45.9	42.1
average index	5240	5200	5220	5170

Table V: 50% Raymill Sulfite - 50% Rayonierred Kraft.

In this case, refining separately apparently weakened the sheet as the strength index was about 7% lower (4630 vs. 4920). However, the sheets made from kraft and highly-refined short-fiber sulfite were about 16% stronger than those from kraft and slightly-refined short-fiber sulfite (4980 vs. 4280).

Table VI: 75% Raymill Sulfite - 25% Rayonierred Kraft.

Refining before mixing increased the strength characteristics of the sheet by about 28% (4360 vs. 3410) but the degree of refining of the short fiber had a negligible effect on the strength index of the sheets formed since the highly-refined short-fiber sulfite caused only a 1% increase over the slightly-refined short-fiber sulfite. (4380 vs. 4340).

Raymill Sulfite - Rayonierred Kraft (general):

In one case, separate refining increased the strength index, in one case it decreased the strength index, and in one case it did not affect the strength index. In one instance, the highly-refined short-fiber sulfite increased the strength over the slightly-refined short-fiber sulfite and in two instances, it negligibly increased the strength properties. The strength index increased as the percent short fiber decreased.

Table VII: 25% Penobscot Soda - 75% Weyerhauser Sulfite.

Refining before mixing caused a decrease in strength index of about 13% (2330 vs. 2690) or, if one unlikely value was omitted, the decrease was about 9% (2450 vs. 2690).

Table V: 50% Raymill Sulfite - 50% Rayonierred Kraft

freeness	burst	tear	index	freeness kraft	freeness sulfite
mixed refining					
610	30.4	129.6	3940		
455	45.0	107.6	4850		
325	48.1	102.0	4900		
290	59.8	101.2	6050		
separate refining					
460	41.3	118.0	4870	670	200
670	29.6	140.0	4150	670	550
520	36.0	122.8	4430	490	550
310	44.5	108.0	4820	490	200
290	49.3	104.0	5130	290	200
440	38.0	110.8	4100	290	550
360	40.7	109.6	4450	180	550
?	43.3	94.8	4100	180	200

	mixed refining	separate refining		
		total sul.	sul. 200	sul. 550
average tear	110.1	113.5	106.2	120.8
average burst	42.8	40.3	44.6	36.6
average index	4920	4630	4980	4280

Table VI: 75% Raymill Sulfite - 25% Rayonierred Kraft

freeness	burst	tear	index	freeness kraft	freeness sulfite
mixed refining					
630	26.2	96.8	2539		
330	42.7	93.6	4000		
150	44.0	84.0	3690		
separate refining					
340	41.5	96.4	4000	670	200
610	25.8	124.0	3200	670	550
540	39.1	159.2	6220	490	550
240	42.5	100.4	4420	490	200
290	45.0	103.2	4650	290	200
500	29.6	106.0	3140	290	550
290	44.3	108.4	4800	180	550
200	44.5	100.4	4480	180	200

	mixed refining	separate refining		
		total sul.	sul. 200	sul. 550
average tear	92.2	99.7	75.1	124.3
average burst	37.2	39.0	43.3	34.7
average index	3410	4360	4380	4340

The sheets formed from sulfite and highly-refined soda were about 16% stronger than those from sulfite and slightly-refined soda (2500 vs. 2150), but if the unlikely value was omitted, the strength difference was reduced to about 6% (2500 vs. 2360).

Table VIII: 50% Penobscot Soda - 50% Weyerhauser Sulfite.

Refining before mixing increased the strength index by about 4% (2085 vs. 2005) even when unlikely figures were omitted (2186 vs. 2100). The sheets formed with highly-refined soda were about 8.5% stronger than those formed with slightly-refined soda (2160 vs. 1990) unless an unlikely figure was omitted. Then the reverse is true (2160 vs. 2295).

Table IX: 75% Penobscot Soda - 25% Weyerhauser Sulfite.

Using all values obtained, refining before mixing increased the strength index by about 15% (1980 vs. 1720) but omitting wild values reversed the situation. Then the separate refining caused a decrease in the strength properties of about 4.7% (1830 vs. 1920). Sheets formed with highly-refined soda exhibited lower strength indexes (8%) than those formed with slightly-refined soda (1900 vs. 2060). If an unlikely value was omitted, however, the highly-refined soda caused the strength to be about 10% higher than the slightly-refined soda (1900 vs. 1720).

Penobscott Soda - Weyerhauser Sulfite (general):

In two cases, the strength index was higher when separate refining was employed and in one case the strength index was lower. In two cases, the sheets formed with highly-refined soda had higher strength indexes than those

Table VII: 25% Penobscot Soda - 75% Weyerhauser Sulfite

freeness	burst	tear	index	freeness soda	freeness sulfite
mixed refining					
625	22.3	123.2	2750		
465	32.3	88.0	2840		
265	37.4	73.2	2740		
160	37.0	66.0	2440		
separate refining					
690	12.2	119.6	1460	620	660
560	20.0	107.2	2144	160	660
400	31.1	83.2	2580	160	500
560	25.3	99.6	2520	620	500
375	29.9	82.8	2440	620	250
250	35.2	80.0	2840	160	250
110	36.6	67.0	2450	160	110
190	31.4	69.6	2180	620	110

	mixed refining	separate refining		
		total soda	soda 160	soda 620
average tear	87.6	88.6	84.3	92.9
average burst	32.2	26.4	30.7	24.7
average index	2690	2330	2500	2150

Table VIII: 50% Penobscot Soda - 50% Weyerhauser Sulfite

freeness	burst	tear	index	freeness soda	freeness sulfite
mixed refining					
640	14.4	112.4	1620		
450	25.3	82.4	2085		
315	29.2	52.0	2175		
190	32.1	63.6	2040		
separate refining					
680	11.1	109.2	1215	620	660
400	23.8	91.6	2180	160	660
290	29.6	74.6	2210	160	500
600	18.5	117.0	2170	620	500
500	22.2	100.0	2220	620	250
220	32.4	66.8	2160	160	250
125	32.3	63.8	2060	160	110
370	25.1	91.6	2300	620	110

	mixed refining	separate refining		
		total soda	soda 160	soda 620
average tear	77.6	89.4	74.2	104.4
average burst	25.2	24.4	29.5	19.2
average index	2005	2085	2160	1990

Table IX: 75% Penobscot Soda - 25% Weyerhauser Sulfite

freeness	burst	tear	index	freeness soda	freeness sulfite
mixed refining					
640	11.0	102.4	1130		
510	19.8	95.2	1880		
365	24.3	80.0	1940		
210	28.6	68.0	1940		
separate refining					
670	11.0	118.0	2580	620	660
240	25.5	70.8	1810	160	660
210	30.1	64.4	1940	160	500
640	13.7	109.6	1505	620	500
575	15.5	111.2	1725	620	250
170	30.9	62.0	1920	160	250
110	31.0	62.4	1940	160	110
500	17.6	109.2	1920	620	110

	mixed refining	separate refining		
		total	soda 160	soda 620
average tear	86.4	88.4	64.9	112.0
average burst	20.9	21.8	29.4	14.4
average index	1720	1980	1900	2060

formed with slightly-refined soda but in one case the strength index was lower. The strength index decreased with a larger percentage short fiber.

Conclusions:

1. The strength characteristics of paper from two pulps refined separately tend to be greater if the short fiber is highly refined than if it is slightly refined. It can be seen that for the sheets formed with highly-refined short fiber, the burst value tends to be higher and the tear value tends to be lower than for the sheets formed with slightly-refined short fiber. The fact that the burst increase is proportionately larger than the tear decrease accounts for the fact that the strength indexes of sheets using highly-refined short fiber are higher than those of sheets using slightly-refined short fiber.

This is probably due to the fact that, being short fibers to start with, the increased beating didn't as appreciably alter the fiber length (fiber length partially determines tear properties) as it did alter the bonding qualities through fibrilation.

2. The strength properties as indicated by the product of burst and tear of paper from two pulps increase as the percentage of short fiber present decreases.

3. Because of the unlikely values obtained in several cases, it is difficult to draw conclusions as to the effect of separate refining vs. mixed refining on the strength properties of the final paper product. However, there is a trend toward stronger paper being formed if the pulps are

refined separately. If all values obtained are used, six cases follow this trend, two cases go opposite to the trend, and one case is unaffected. If the unlikely values are omitted, five cases follow the trend, three go opposite to the trend, and one is unaffected. An average increase of between six and nine percent in the strength properties of paper was obtained if the pulps were refined separately. This is in agreement with Peckham and May and Johnson and Olsson (see bibliography).

4. There is a tendency for the burst value of the sheets formed from pulps refined separately to be slightly less than if mixed refining is employed.

5. Separate refining tends to increase the tear value over mixed refining.

Conclusions 4. and 5. agree with the work of Vamos and Mero (see bibliography).

The fact that the tear increase is proportionately larger than the burst decrease explains the fact that the strength index is higher when separate refining is used. Averaging the burst values and the tear values gives an average tear increase of 11% and an average burst decrease of 6% for separate refining compared to mixed refining.

Thus, the seemingly contradictatory literature is now explained, substantiated, and enlarged.

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