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MECHANICAL PULPING BY FRACTIONATION AFTER LOW ENERGY REFINING

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ABSTRACT

Recent research has indicated that in the initial stages of refining, energy is selectively absorbed by the earlywood portion of the annual growth increment. To evaluate the implications of this result, loblolly pine wood chips have been refined at very low energies and fractionated on a 10 mesh screen. The retained 10 mesh fraction should be enriched in latewood fibers, and the pass 10 mesh fraction enriched in earlywood fibers. Each fraction was then further refined to usable freeness levels and the resulting pulps compared to samples prepared using normal refining procedures that is without interstage fractionation. Juvenile whole chips require 15 to 20% more energy to obtain the same Tensile Index as mature whole chips. Mature pulp retained on the 10 mesh screen has the same specific energy requirements to constant Tensile Index as the mature whole chips, but the pass 10 mesh fraction requires about 12% more energy to obtain the same strength. Both the Juvenile wood pass 10 and retained 10 mesh samples require less energy to obtain a constant tensile index than the Juvenile whole wood chips, and have about the same specific energy requirements as the mature wood sample.

INTRODUCTION:

Shortleaf pine has nearly twice the latewood content of Norway spruce (on a volume basis) and the latewood in Shortleaf pine has 5 times the modulus of elasticity of the earlywood.[1] For comparison, in spruce, the latewood is just 3.5 times stiffer than the earlywood.[2] Similarly, the shortleaf pine latewood has 4.9 times the tensile strength of earlywood. In Norway spruce the latewood is just 3.1 times stronger than the earlywood. The high latewood content of the southern pines, and the difference between earlywood and latewood in parallel-to-grain tensile strength and parallel-to-grain elastic modulus, creates a condition where the two growth zones are likely to behave differently in refining.

To determine if the large differences observed in the parallel-to-grain modulus of elasticity are also true of cross-grain compression, a series of compression experiments was carried out. This work shows a near total absorption of compressive stress by the earlywood portion of the annual growth increment.[3] Temperature measurements taken during the cyclic compression experiments shows a rapid temperature rise in the earlywood portion of the test piece, confirming preferential energy absorption by the earlywood portion of the growth ring.

A logical consequence of the preferential stress and energy absorption by earlywood is that it will disintegrate faster in the refining process than latewood. If this is the case, an analysis of the earlywood and latewood fiber content of different particle size fractions produced after low energy refining should show an enrichment of earlywood fibers in the smaller particles.

A second logical consequence of preferential energy absorption by the earlywood portion of the annual growth ring, and the large amounts of latewood present in the southern pines, is that the earlywood fibers will absorb too much energy and be over refined while the latewood fibers will receive too little energy, leaving them stiff and poorly fibrillated. If earlywood fibers are indeed concentrated in the small particle size fractions after low energy refining, separating the small and large particles and refining them separately should improve pulp strength relative to conventional refining. Because of the larger earlywood content of juvenile trees, this would be expected to improve the performance of pulp made from juvenile wood more than the pulp made from mature wood.

Results of interstage fractionation have been reported several times in the literature. It was also hoped that this investigation would help to sort out the conflicting results.[4,5]

RESULTS and DISCUSSION:

Several disks were cut from the base section and top section of a large loblolly pine. Samples of latewood and earlywood were cut from the disks to obtain 25 OD gram each of mature earlywood and latewood, and top (juvenile) earlywood and latewood. Each of these samples was delignified using a combination of a chlorite holopulping procedure[6] followed by a peracetic acid holopulping procedure.[7] Fiber coarseness was then determined for each sample using the Kajaani FS100® optical fiber length analyzer. These results are summarized in Table 1. The coarseness values reported are based on the number average fiber length.

Table I. Fiber Coarseness

Wood	Coarseness mg/M		Fiber Length mm	
	EW	LW	EW	LW
Top	0.13	0.37	3.36	3.37
Base	0.16	0.38	2.80	3.26

As expected, the earlywood coarseness decreases slightly from the base (0.16 mg/M) to the top (0.13 mg/M) of the tree. For practical purposes, the latewood coarseness at 0.37 mg/M is unchanged.

The base log was chipped and a sample refined in an Asplund Defibrator D lab refiner using about 20 Wh/kg specific energy. The coarse pulp was fractionated on a Bauer McNett and each of the fractions was collected and holopulped. These results are reported in Table 2. The resulting pulps were also checked under a microscope to obtain a relative distribution of thick walled to thin walled fibers and fractions of whole and broken fibers. These results are also reported in Table 2.

The latewood content and fiber coarseness both change with particle size fraction. The 4 and 8 mesh samples have coarseness values close to that expected for whole wood but the R20 and R100 samples have low coarseness, suggesting an enrichment in earlywood fibers as expected. The pass 100 mesh, retained 200 mesh sample has also been analyzed. Since this fraction contains largely fiber fragments, coarseness measurements were not attempted, but the microscopic analysis shows that this fraction is enriched in fragments derived from latewood fibers.

Refining of Fractionated Wood:

The initial results provided some support for the premise that the smaller particles are enriched in earlywood fibers and that an 8 mesh screen provided a good fractionation for earlywood and latewood. Since most of the material in the initial Bauer-McNett fractionation was retained on the 4 mesh screen and the 4 mesh material did not appear to be heavily enriched in latewood, it was decided to pre-screen the sample,

Table II. Fiber Characterization of TMP Fractions

Mesh Size	Coarseness mg/M	Fiber Length mm	% EW	% Whole	
				EW	LW
4	0.22	3.21	46	37	59
8	0.21	2.41	49	18	35
20	0.17	2.62	53	1	23
100	0.18	1.21	43	0	3

collect the retained 4 mesh sample, and refine it a second time to improve the separation of the earlywood and latewood fibers. Large samples of coarse mature and juvenile wood TMP were prepared by combining multiple runs on the Defibrator D. The material was screened on a 4 mesh screen and the retained fraction refined again in the Defibrator D. The samples were combined and screened on a 10 mesh screen to collect the R10 and P10 fractions.

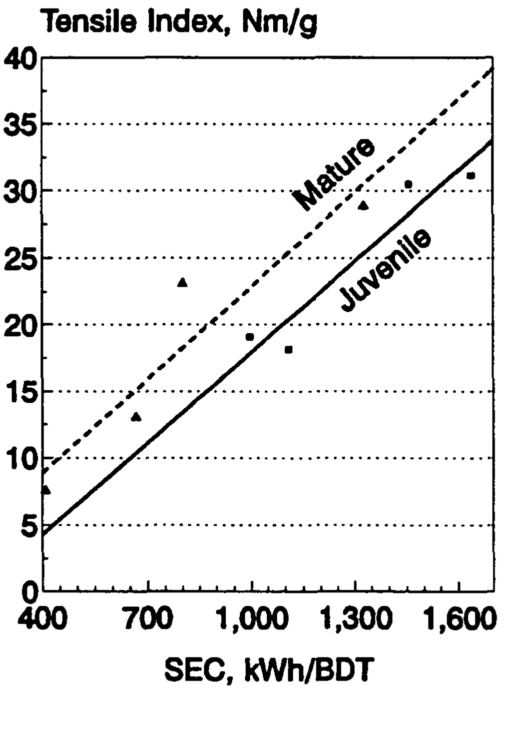

Figure 1. Tensile Index for the mature whole pulp and juvenile whole pulp samples.

Each sample was refined on a Sprout-Waldron 12" Atmospheric Refiner to provide four samples with freeness levels ranging from 250 to 50 ml.

In addition to the fractionated samples, a mature wood sample, and a juvenile wood sample were prepared from the same chips and refined as whole samples to provide controls. Results from the refining runs are summarized in table 3.

Tensile index is graphed against specific energy consumption for the conventional juvenile and mature samples in Figure 1. The lines are fit with a least squares regression and have an R^2 of 0.88 for mature wood and 0.91 for juvenile wood. This shows the expected relationship with the juvenile wood requiring about 15% additional energy to match the tensile index of the mature wood sample.[8,9] Although the correlations are good, the two lines in this graph are not statistically different at high confidence levels. The results are supported by the cited literature and are deemed valid. The differences in the fractionation experiments reported below are also not statistically significant. They do appear to confirm the original hypothesis and are reported in hopes they will generate enough interest for others to validate or disprove the results.

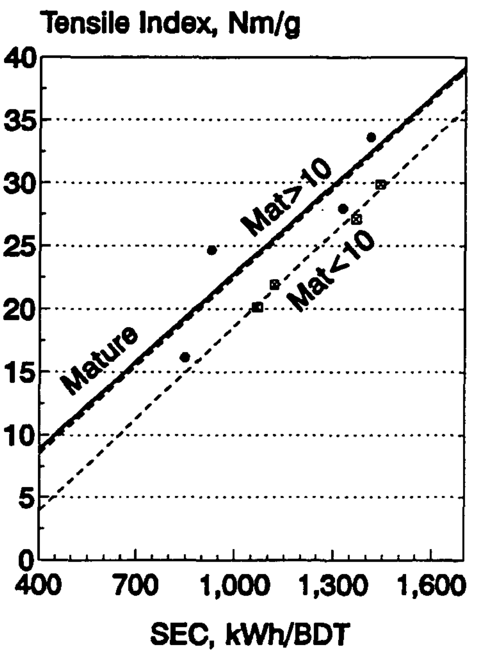

Figure 2. The tensile index response of the mature wood samples. Retained 10 mesh has the same response as the whole pulp.

Tensile Index vs. SEC is graphed in Figure 2 for the three mature samples. The mature R10 sample has the same energy requirements as the whole wood sample, but the pass 10 mesh sample required about 10% additional energy to match the strength of the whole wood sample. Since this (pass 10 mesh) sample should be enriched in earlywood fibers, it should behave much like a juvenile wood source and the lower strength should be expected.

The tensile index for the juvenile pass 10 and retained 10 mesh samples are graphed against the mature whole sample in Figure 3. A line is not provided for the juvenile retained 10 mesh sample because the refiner plugged during one series of refining runs and these two data points have unreliable energy integrations. The two samples with tensile index near the pass 10 mesh samples were obtained without significant problems during refining and are considered accurate.

Notice that for the fractionated juvenile wood cases, the tensile index of both samples is improved relative to the juvenile whole wood sample. The tensile index and specific energy relationship for these samples is now very close to the refining results of mature wood.

CONCLUSIONS:

Earlier results indicated that energy from cyclic compression was preferentially absorbed in the earlywood portion of the annual growth increment. The logical consequence of this is an enrichment in earlywood fibers in the smaller particle size fractions from very low energy refining. Evidence for this enrichment is presented.

It was also postulated that fractionation of earlywood and latewood fibers early in the refining process and refining the two fractions separately would improve the tensile index, specific energy relationship. This has been observed in the juvenile wood sample but not in the mature wood sample.

Experimental:

Three 6 foot logs were obtained from one loblolly pine tree. The base log was used as the mature tree sample. This section was nominally 12" in diameter and

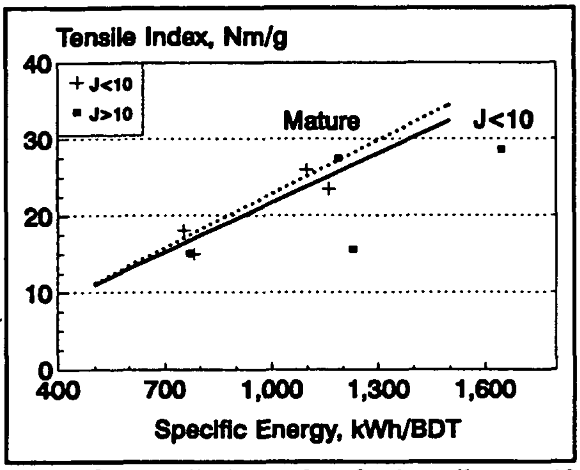

Figure 3. Tensile index data for juvenile pass 10 and juvenile retained 10 samples plotted against the mature whole wood.

contained about 25 growth rings. The top section provided a juvenile type wood source. It was about 5" in diameter and consisted of 11 annual rings. Several slices were taken from each end of both logs to provide the samples for determining earlywood and latewood coarseness.

The two log sections were chipped and the chips screened on a Williams Classifier. The pass 3/4" retained 1/2 inch and pass 1/2" retained 1/4" samples were collected and used in the refining experiments. Large samples of coarse TMP were prepared by multiple 50 OD gram refining runs in the Defibrator D laboratory refiner. Samples were steamed for 5 minutes at 15 psig before blowing the chips into the refiner using 60 psig steam. Specific energy consumption was controlled to very low levels by leaving the blow valve of the refiner open, preventing extensive refining.

The coarse TMP samples were diluted and screened on a 4 mesh wire screen, and the retained fraction was refined a second time in the Asplund Defibrator D. Energy levels in these second refining runs were all well below 20 Wh/kg. The coarse pulps were then recombined and screened on a 10 mesh wire screen. Both fractions were dewatered to 20% consistency for refining in the Sprout Waldron disk refiner. Pulps were dewatered back to 20% consistency between runs and the filtrates recovered and used as dilution for the following runs. The atmospheric refining was carried out in parallel sequences with the first series using plate gaps of 0.43, 0.30 and 0.20 mm, respecively, and the second series at plate gaps of 0.35, 0.25 and 0.20 mm, respecively. The third atmospheric stage was only performed when the first two stages failed to produce two samples with freeness between 50 and 250 ml. Filtrates were common to both series.

Refining energies were obtained using a Load Controls, Hall Effect power transducer, and a Hewlet Packard 3390 reporting integrator. Specific energy input in the Defibrator D refining runs was quite variable, but averaged 20 Wh/kg for all samples.

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REFERENCES:

1. Ifju, G., "Within-Growth-Ring Variation in Some Physical Properties of Southern Pine Wood," *Wood Science* 2(1): 11-19(1969).

2. Kennedy, R.W., "Intra-Increment Variation and Heritability of Specific Gravity, Parallel to Grain Tensile Strength, Stiffness and Tracheid Length in Clonal Norway Spruce," *TAPPI J.*, 49(7): 292-296(1966).

3. Hickey, K.L. and Rudie, A.W., "Preferential Energy Absorption by Earlywood in Cyclic Compression of Loblolly Pine," Poster Presentations, 1993 International Mechanical Pulping Conference, p. 81-86.

4. Yan, J.F. and Sinkey, J.D., "Selective Screening and Refining: A Negative Answer to Energy Reduction and Pulp Strength Improvement," Preprints, International Symposium on Fundamental Concept of Refining, Appleton, WI, September, 1980.

5. Garceau, J.J. and Goel, K.N., "Stone Groundwood - An Approach to Save Energy," *Pulp and Paper Magazine of Canada*, 86(6): T181-185(1985).

6. Thompson, N.S. and Kaustinen, O.A., "Modifications of the Physical Properties of Tracheids and Pulps Prepared from Coniferous Chlorite Holocellulose," *TAPPI J.*, 53(8): 1502-1506(1970).

7. Leopold, B., "Chemical Composition and Physical Properties of Wood Fibers," *TAPPI J.*, 44(3): 230-232(1961).

8. McMillin, C.W., "Gross Wood Characteristics Affecting Properties of Handsheets Made From Loblolly Pine Refiner Groundwood," *TAPPI J.*, 51(1): 51-56(1968).

9. Corson, S.R., "Influence of Wood Quality Characteristics on TMP and RMP From New Zealand Grown Radiata Pine," *APPITA* 37(5): 400-408(1992).

Table III. Results of Refining Runs

Sample	Run	SEC Wh/kg	CSF ml	Tensile Index (Nm/g)
MatR10	1-2	384	435	
	1-3	928	94	24.7
	1-4	1412	43	33.6
	2-2	848	173	16.1
	2-3	1327	86	27.9
MatP10	1-2	477	300	
	1-3	1118	121	21.9
	1-4	1441	43	29.9
	2-2	360	382	
	2-3	1067	145	20.1
	2-4	1367	52	27.7
JuvR10	1-2	771	205	15.1
	1-3	1187	83	27.5
	2-2	1229	192	15.6
	2-3	1647	70	28.7
JuvP10	1-2	784	167	15.0
	1-3	1161	79	23.5
	2-2	754	120	18.1
	2-3	1099	59	26.0
Mat	1-2	408	483	7.6
	1-3	802	98	23.2
	1-4	1197	27	
	2-2	668	314	13.1
	2-3	1329	80	29.0
Juv	1-2	997	116	19.1
	1-3	1458	53	30.5
	2-2	1112	111	18.1
	2-3	1637	42	31.2