Effect of increased jack pine content on kraft pulp properties

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ABSTRACT: Over the next five years, UPM-Kymmene Miramichi is planning to increase the amount of jack pine in its chip furnish from 5–10% to 8–14%. The effects of this change on the properties of pulps are compared at two target ranges of delignification, kappa no. 23–26 and kappa no. 31–32. In both cases, the increase in jack pine increased the freeness and pulp strength (particularly the tear index). The refining energy required to reach the same target freeness increased as well. These results are consistent with results reported in related literature and can be explained by the long length and the coarseness of the jack pine fibers.

Application: As stands of jack pine are thinned, an anticipated increase of jack pine fiber in the furnish should increase the strength and freeness of the mill's kraft pulp.

At UPM-Kymmene Miramichi Inc., jack pine usage is approximately 5–10% of the total chip furnish. The mill is currently managing large forest stands of jack pine that need to be thinned because many of the trees are at the right age to be cut. Through the years of 2004–2008, the percentage of jack pine in the fiber furnish is expected to increase, along with a decline in the percentage of balsam fir. At the time this project was undertaken, the chip furnish was 58% spruce, 33% balsam fir, and 9% jack pine. In 2008, the chip furnish is expected to be 58% spruce, 28% balsam fir, and 14% jack pine.

In earlier studies comparing five different species, mature jack pine fibers were shown to be the longest and coarsest fibers of those studied [1–3]. These two parameters together resulted in the highest observed tearing strength and lowest peak tensile strength in all the sheets made from the various pulps. With such high fiber coarseness, mature jack pine required the greatest beating intensity to reach a target freeness of 500 mL CSF [3].

The woodyard at the mill can control the quantity of jack pine chips produced on site from whole logs, but it cannot control the quantity of jack pine in purchased sawmill residuals. Mill personnel predict an increase in the percentage of jack pine in purchased sawmill residuals, which will also increase the jack pine in the furnish and affect the pulp.

How will an increase in the percentage of jack pine in the fiber furnish affect the properties of the kraft pulp? Our objective in this project was to determine these effects.

BACKGROUND

Our earlier study on fiber characteristics showed that mature jack pine has a length-weighted fiber length of 2.54 mm. The average length of its fibers is 24% longer than the average length of the juvenile wood fibers and 16% longer than the average length of mature wood fibers of fir and spruce [3]. Mature jack pine also leads these other species in coarseness at 0.175 mg/m, which is 22% higher than the coarseness of juvenile jack pine and 21% higher than that of both mature balsam fir and mature black spruce.

Other researchers have shown that increasing the content of one species in a pulp mixture may have a positive effect on strength. Wang and McKimmy, for example investigated the effect of blending Douglas fir with lodgepole pine and observed an increase in tear factor when the content of Douglas fir was increased [4]. Douglas fir fibers have greater coarseness and higher individual tear strengths than lodgepole pine fibers have [5].

In this study, we anticipated that the increases in jack pine fibers in the furnish would have a significant impact on the strength properties of pulps, especially with the increase in fibers from mature wood.

EXPERIMENTAL

For the spruces, an equal portion of red and black spruce chips were used with a 50:50 split of mature and juvenile wood. Similarly for the balsam fir, a 50:50 mix of mature and juvenile chips was used for the furnish. On the other hand, the split for jack pine was 25% mature wood and 75% juvenile wood. The trees to be cut when the stands are thinned are roughly 25–35 years old, at which age the trees will be composed mainly of juvenile wood. (The first 20 growth rings consist of entirely juvenile wood for Canadian softwood species [5].) Some mature jack pine fiber will be derived from sawmill residuals.

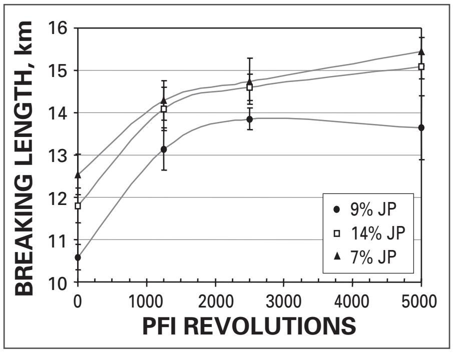
The experimental procedures for collecting chips and for beating, pulping, bleaching, and testing have been presented in detail for an earlier study [3] and were kept the same in this study except that we used fresh chips in this study. Also, the beating intensities in the PFI mill were set to 0, 1250, 2500, and 5000 revolutions; this change was made to approximate more closely the refiner currently in use at the paper mill.

RESULTS AND DISCUSSION

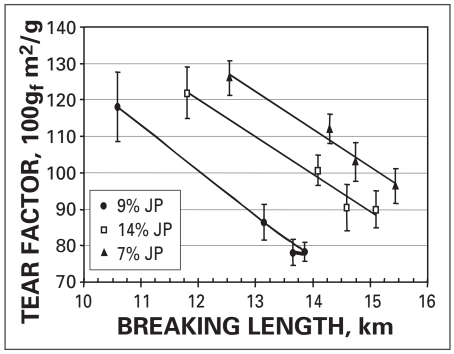
We have subdivided the pulping results into two sections on the basis of variations in delignification: one section of pulps with initial kappa numbers of 23–26 and one with initial kappa numbers of 31–32. The initial kappa number has an effect on the pulp strength in that pulps of higher kappa number will have strength properties with lower values [6].

Low-kappa pulps

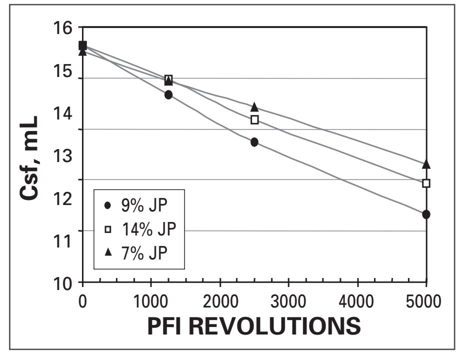
Table I summarizes the pulping results obtained from three furnishes with different percentages of jack pine. The first case represents the fiber furnish (9% jack pine) at the time this study was undertaken, and the second case is the fiber furnish expected in 2007 (14% jack pine). In both situations, the ratio of juvenile to mature jack pine was held constant at 75% juvenile wood.



1. An increase in jack pine content increases the beating requirements for the low-kappa pulps.



2. An increase in jack pine content increases the tear strength for the low-kappa pulps.



3. As beating intensity increases, the pulp sample with 14% jack pine has the highest freeness.

Jack pine %	Mature wood,* %	Kappa no.	H-factor	Yield, %	Residual effective alkali, lb Na_2O/ft^3
9	2.3	26.4	2250	48.7	0.39
14	3.5	23.7	2550	47.3	0.34
7	pure	22.8	2270	46.5	0.34

*Percentage of mature wood in the jack pine contribution.

I. Pulping results for low-kappa pulps with different percentages of jack pine.

In the third case, we carried out pulping to see if increased quantities of only mature fibers from jack pine would affect the pulp strength. This pulp contains mature jack pine only (no juvenile jack pine) at a quantity of 7% by mass.

Figure 1 shows the relationship between the beating intensity and tensile strength development for these three pulps. As shown, increasing the quantity of jack pine fibers in the chip furnish from 9% to 14% results in an increased breaking length. Both curves follow similar trends in the development of tensile strength as a result of increased beating. The 14% jack pine pulp shows increased breaking length even at 5000 PFI revolutions. Conversely the pulp sample with 9% jack pine drops off in breaking length at about 2500 revolutions, at which point the fibers start breaking up as a result of cell wall delamination, fibrillation, and node fractures.

Increasing the content of the longer mature jack pine fibers from 3.5% (in the 14% jack pine sample) to 7% has no significant effect on tensile strength development, because the juvenile jack pine contributes to the pulp strength. Juvenile jack pine was also found to have high fiber coarseness (0.135 mg/m) in comparison to that of the fir and spruce species (both 0.112 mg/m). **Figure 2** shows tear strength vs. breaking length for the three pulps. At the same breaking length, the tear strength increases with increasing quantities of mature jack pine, presumably as a result of its long fibers.

As shown in **Table II**, the increased tear strengths are confirmed at 500 mL CSF, which is the practical degree of beating at the mill. The results also show that more beating is required to reach a target of 500 mL CSF for pulps with a higher content of mature jack pine. This result is in agreement with the earlier results showing that the coarser jack pine fibers demand greater refining energy than the fir and spruce fibers [3].

Figure 3 shows the freeness levels for each pulp sample at 0, 1000, 2500, and 5000 revolutions. For the 14% jack pine sample, the freeness levels are substantially higher than those for the 9% jack pine. Consequently, increasing the percentage of jack pine in the fiber furnish will improve the drainage on the paper machine.

Mature wood is also seen in Fig. 3 to increase the pulp freeness. The 7% jack pine sample, having no juvenile wood, has a higher freeness than the 14% jack pine sample, which has only 3.5% mature wood. The higher freeness for the 7% sample is the result of the longer, coarser fibers in the mature wood.

By the same token, we might expect that the higher freeness for the 14% sample over the 9% sample is also caused by the difference in length and coarseness of the fibers. As **Table III** shows, the fiber length and coarseness values for the 14% jack pine sample are indeed higher than those for the 9% sample.

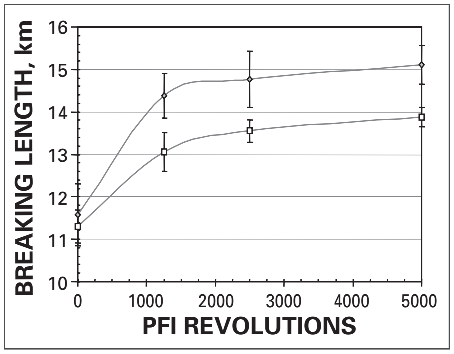
High-kappa pulps

For the pulps of high kappa number, the chip furnish used in one sample contained 20% mature jack pine chips with no juvenile jack pine added. The spruce and fir percentages were 55% and 25%, respectively. The other sample contained 14% jack pine with a 75:25 split between juvenile and mature wood.

We found that a significant increase in the quantity of mature jack pine fibers does not have an effect on pulp yield. The residual effective alkali in the case of the 20% mature jack pine sample is slightly lower than that of the sample with 3.5% mature jack pine.

As with the low-kappa pulps, an increase in mature jack pine results in increased tensile strength, as shown in **Fig. 4**. At the higher content of mature jack pine wood, the breaking length is higher by approximately 1 km.

Figure 5 demonstrates that a higher content of mature jack pine also leads to a higher tear strength, as a result of the beneficial effect of fiber length on tear strength [7, 8]. The relatively high fiber coarseness of mature jack pine contributes to the tear strength as well [8]. At a breaking length of 12 km, the 14% jack pine sample, with only 3.5% mature wood, has a tear factor of about 100, while the sample with 20% mature jack pine has a tear factor of 135.



4. For the high-kappa pulps, the sample with 20% jack pine has a higher breaking length at the same beating intensity.

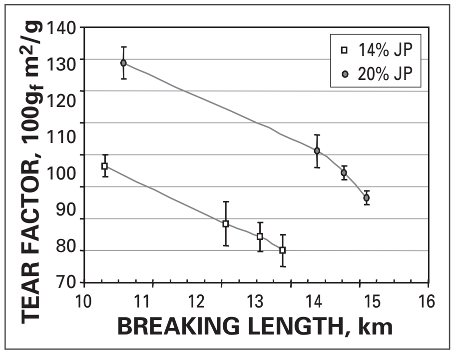
The tear strength at 500 mL CSF is shown in **Table IV**. Tear strengths are high when mature jack pine contents are high. Furthermore, more PFI revolutions are required to reach the target freeness of 500 mL CSF.

CONCLUSIONS

As UPM-Kymmene Miramichi thins its stands of jack pine, its fiber furnish is expected to have a higher percentage of jack pine. This change should increase the strength of the mill's kraft pulp.

The fiber coarseness of juvenile wood is lower than that of mature wood. As a result, its tensile strength can be developed to a greater extent.

The pulp freeness is higher when more jack pine is present in the fiber furnish. This finding is reasonable. Compared to balsam fir and black spruce, jack pine has longer fiber lengths and greater fiber coarseness in both its juvenile and mature wood [3]. **TJ**



5. For the high-kappa pulps, the sample with 20% jack pine has higher tear strength.

ACKNOWLEDGMENT

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Jack pine, %	Tear factor, kg•m^2/g	PFI revolutions
9	79±2.7	2590
14	90±4.9	3130
7	97±3.6	3500

II. Tear factors and PFI revolutions at 500 mL CSF.

	9%	14%
Fiber length		
Length weighted	1.87	1.95
Weight weighted	2.44	2.52
Coarseness, mg/m	0.128	0.123

III. Average fiber length and coarseness for the 9% and 14% jack pine samples.

	14%	20%
Kappa number	31.7	32.2
H-Factor	2440	2140
Yield, %	49.2	49.3
Residual EA, lb Na_2O/ft^3	0.4	0.3
Tear factor, kg•m^2/g	81±4.5	97±2.8
Beating, PFI revolutions	2610	3430

IV. Pulping results for high-kappa pulps with 14% and 20% jack pine.

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