Synergistic Effects Between Chemical Mechanical Pulps And Chemical Pulps From Hardwoods

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ABSTRACT

Chemical pulps and chemical mechanical pulps from different hardwoods were compared for their intrinsic and other pulp properties. The comparison was made both separately and in combination of the pulps from these two types of pulping processes. The results showed that hardwood chemical mechanical pulps, like P-RC APMP, can be developed as strong as their chemical pulps, and have higher tensile at the same density, or higher bulk at the same tensile, compared to their chemical pulps. When combining pulps from the two different processes, addition of certain percentage of hardwood chemical mechanical pulps to its chemical pulp improved pulp intrinsic property, and the resultant pulp blends had a higher fiber bonding strength (tensile and tensile energy absorption) than the sum of weighted contributions from its individual components. This synergistic effect between the chemical and the chemical mechanical pulps may be used to improve papermaking processes and their paper and/or paper board products.

INTRODUCTION

Hardwoods have gained a growing interest in pulp and paper industry over the last two decades. Some of the reasons for this interest are their abundance in many parts of the world, fast growth (high wood yield per unit of land per year), and its fiber characteristics, which have been found suitable for many different papermaking applications. Hardwoods are particularly important for countries where the land for industrial forests is limited. Many different hardwoods, such as eucalyptus, aspen, birch, maple and acacia, have now been used widely in pulp and paper industry. On the other hand, pulping technologies for these hardwoods have also advanced in many different directions over the years. Generally speaking, these technologies may be divided into three groups: mechanical pulping, chemical mechanical pulping and chemical pulping. Mechanical pulping uses mostly mechanical energy to separate fibers and develop pulp properties. Chemical pulping uses mostly chemical energy, (from chemical reactions), to separate the fibers and to develop basic pulp properties. Chemical mechanical pulping, (CMP), is a combination of chemical and mechanical (refiner) pulping, and uses both chemical and mechanical energies to develop pulp properties. Because of this, chemical mechanical pulping is more flexible than the other two, and its pulp properties and process consumptions can be controlled to either similar to the mechanical pulping or the chemical pulping, or anywhere between the two.

As far as pulp properties are concerned, in chemical mechanical pulping, chemicals were used mainly to develop pulp inter-fiber bonding properties and optical properties. There are two types of chemical treatments are now commonly used in commercial CMP technology: 1) alkaline sulfite pretreatment; and 2) alkaline peroxide pretreatment. The former has traditionally been referred to as CTMP, and the latter as APMP. While the former has some advantages in applications where no or only a small amount of brightness gain is required, and is often in combination with a post bleaching system to have a significant improvement in brightness, (which then is often called as BCTMP). The latter can provide a high brightness pulp immediately after the refining process is completed. Although these two processes use different chemicals and strategies to develop pulp properties, the differences between their pulps are, in general, much less than their differences compared to chemical pulp. As for APMP, a new process concept, P-RC (*P*reconditioning followed by *R*efiner *C*hemical treatment), had been developed recently to improve its chemical efficiency [1,2]. This latest version of APMP is, therefore, called P-RC APMP.

In the first part of this study, fundamental pulp property characteristics, namely intrinsic property [3,4], from chemical pulping and chemical mechanical pulping processes were compared, using different hardwoods (HWD). In the second part of this study, attempts were made to compare mixture of HWD chemical pulp (bleached hardwood kraft pup, BHKP) and its CMP pulps (mainly from P-RC APMP process).

RESULTS AND DISCUSSION

Pulp Intrinsic Properties From Different Pulping Processes

In this part of the study, chemical mechanical and chemical pulps were compared in terms of their tensile/density relationship, which is intrinsic to, and dependent on, the nature of the wood and to how the fibers are separated and developed (pulping processes), but is independent of other variables, (e.g. the amounts of energy and chemicals), for a given pulping process.

Figure 1 illustrates pulp intrinsic property from different pulping processes, namely kraft and two different chemical mechanical processes: P-RC APMP and BCTMP using North American aspen. As can be seen, the chemical mechanical pulps tend to have a higher tensile (inter-fiber bonding strength) than the kraft at a given density, (apparent handsheet density), in the range of 30-60 N.m/g tensile index, or 0.5-0.65 g/cm^3 density. In other words, the chemical mechanical pulps had tendency to have a higher bulk than the chemical pulp at a given tensile. It is well known in the paper industry that a higher bulk at a given tensile is often preferred in many paper/board applications, as had been discussed elsewhere [5-7]. Between the two chemical mechanical pulps investigated, the P-RC APMP pulp showed an increasingly higher tensile than the BCTMP as the density increased from 0.3 g/m^3 to higher.

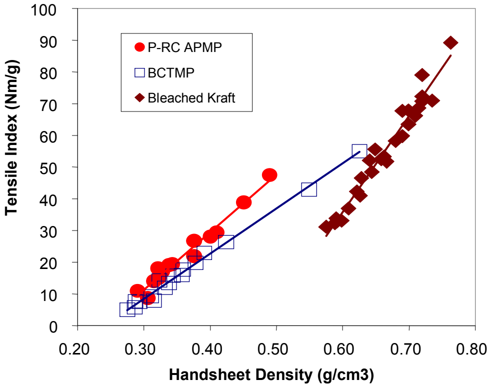


Figure 1. Process Comparison (Aspen from North America)

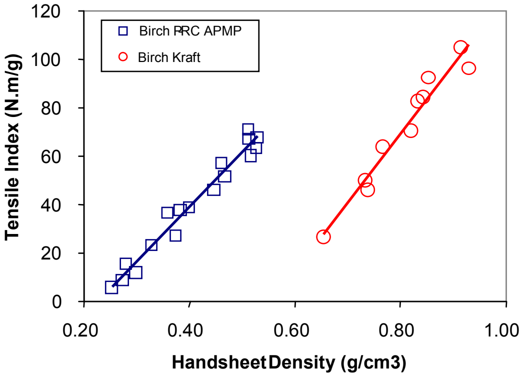


Figure 2. Process Comparison (Birch From North America)

Figure 2 compares P-RC APMP and BHKP from birch, which again shows that the chemical mechanical pulps had higher tensile than the BHKP at a given density, or bulk. As has been discussed elsewhere, this difference observed between pulps from chemical mechanical (P-RC APMP or BCTMP) and chemical pulping (kraft) processes was likely due to their different fiber development mechanism that resulted in different fiber surface bonding ability (or specific bonding strength) [6]. Chemical mechanical pulping is relatively mild in chemical treatment in comparison to chemical pulping. Pulps from the former tend, therefore, to have more hemicellulose on the fiber surface than that from the latter, and hemicellulose is known to improve fiber bonding [8]. The difference between P-RC APMP and BCTMP may also be understood similarly in terms of their differences in pulp development mechanism, as had been discussed elsewhere [6,9,10].

It is worth pointing out that the highest tensile points from the CMP (or P-RC APMP) pulps shown in Figures 1 and 2 do not mean the top limit for the pulping process. For a given hardwood, by simply adding more caustic, chemical mechanical puling can develop pulps of comparable strength to chemical pulps. Because the purpose of those figures is to show the intrinsic property, or tensile/density relationship, absolute values of the tensile and the density shown in the figures are of less significance for this particular study. In commercial practice, CMP process is often better used for taking its advantage of combination of mechanical and chemical pulp characteristics, and not to make it too close to either pure chemical or mechanical pulps. In most of its papermaking applications, 50 N.m/g tensile index is the top end for its fiber bonding strength.

Combination of Bleached Kraft and Chemical Mechanical Pulps

While it is interesting to know the differences between chemical and chemical mechanical pulps from hardwoods, it is also important to understand how pulp properties change when chemical pulp is mixed with the chemical mechanical pulps, especially in light of the fact that there are many paper and board mills that are now using a combination of chemical and chemical mechanical pulps from hardwoods.

Figure 3 presents pulp intrinsic property results from a study involving aspen bleached kraft and aspen P-RC APMP pulps from high tensile grade, “P-RC HT”, and high bulk grade, “P-RC HB”. In this study, different pulp furnishes were each refined at low consistency to different tensile or density. As expected, the P-RC APMP pulps had a higher tensile at a given density or higher bulk at a given tensile than the kraft, and pulp blends from the P-RC APMP and the kraft had tensile/density intrinsic properties that were between those of the chemical mechanical and chemical pulps.

This study was repeated using birch P-RC APMP pulp to replace the aspen, and the results are shown in Figure 4. The similar trends were again observed.

Figure 3. Comparison of Intrinsic Property - Aspen P-RC APMP & Aspen BKP

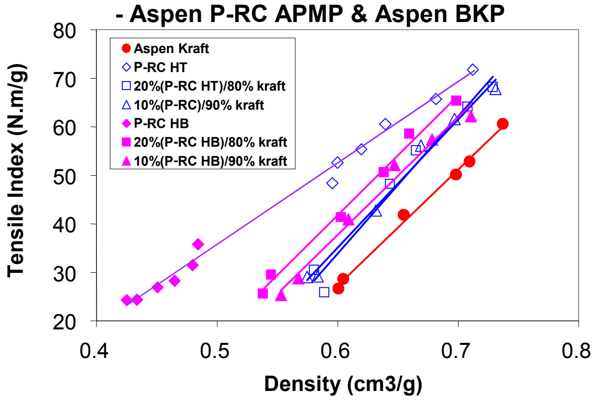
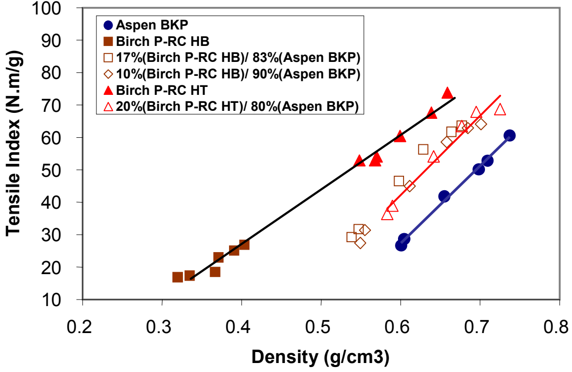


Figure 4. Comparison of Intrinsic Property - Birch P-RC APMP & Aspen BKP



A closer examination of Figure 3 shows that when a high bulk grade of the P-RC APMP pulp was used, intrinsic property of the pulp blend continued to increase as the percentage of the P-RC APMP pulp increased from 10% to 20%. In the case of the high tensile P-RC APMP, the blends of 10% and 20% of the chemical mechanical pulp had approximately the same intrinsic tensile/density property. This observation suggests that a different type (or grade) of chemical mechanical pulp has different effects on its mixture with a chemical pulp.

In order to gain more detailed information about interactions between the CMP and chemical pulps, the aspen BKP and different grades of the aspen and birch P-RC APMP pulps were refined both separately and in combination. For the P-RC APMP pulps, typical grades from both high tensile (HT) and high bulk (HB) were selected from the aspen and birch P-RC APMP pulps. Some of the results are shown in Figures 5-10.

Figure 5. Tensile Development From Refining - Aspen P-RC APMP and Aspen BKP

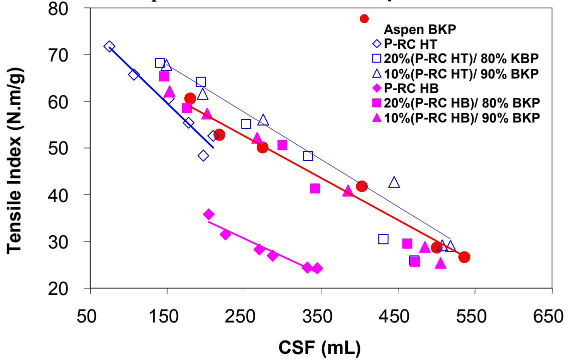


Figure 6. Tensile Development From Refining - Birch P-RC APMP and Aspen BKP

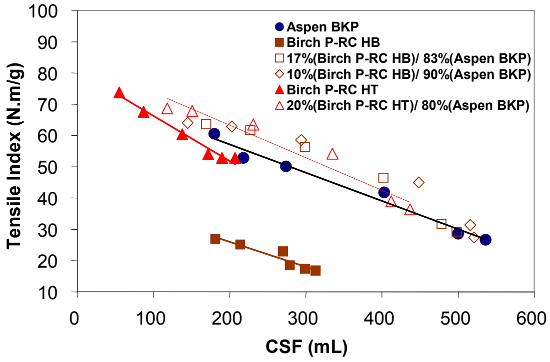


Figure 5 shows pulp tensile development from the pulp blends from the aspen. Although the aspen P-RC APMP pulps both had a lower tensile at a given freeness than the kraft pulp, the blends, after being refined to 350 ml CSF or lower, had the same, (from the high bulk, low tensile P-RC APMP HB), or even higher, (from the high tensile P-

RC APMP HT), tensile compared to the kraft. These results suggest that there is a synergistic effect between the P-RC APMP and the kraft pulps: the combined pulp has a high inter-fiber bonding strength than the weighted contributions from each of the components. The blend from the P-RC APMP HT had, on average, approximately 5 points higher tensile index than the kraft, even though the former had a comparable or lower tensile than the latter at a given freeness.

Figure 6 shows the repeat of the same study from the birch P-RC APMP. The same trends were also observed. In this case, even the BH grade, which had much lower tensile, gave a higher tensile than the aspen BKP when combined with the latter, suggesting their synergistic effects were even stronger than that from the aspen P-RC APMP.

In both the studies, as expected, pulp bulk property was improved when the aspen BKP was blended the P-RC APMP pulps, as shown in Figures 7 and 8 from the aspen and the birch respectively.

Figure 7. Bulk Development From Refining - Aspen P-RC APMP and BKP

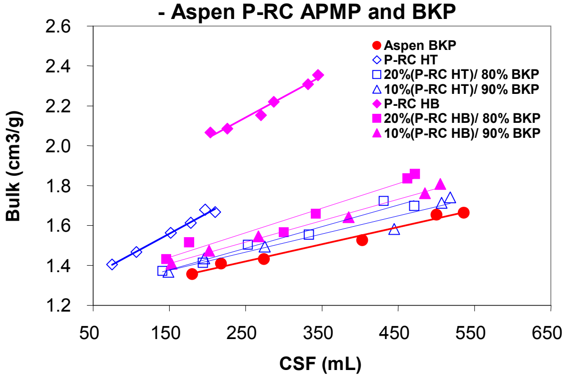
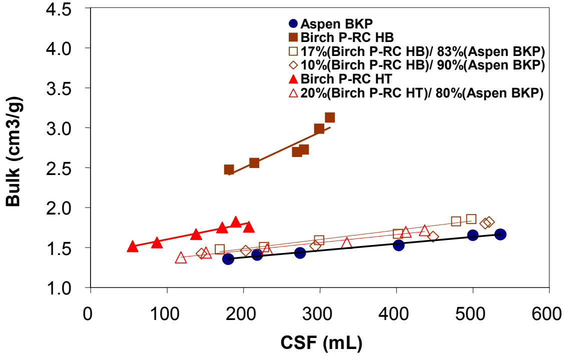


Figure 8. Bulk Development From Refining - Birch P-RC APMP and Aspen BKP



Consistent with the bulk property development shown above, similar trends were also observed in light scattering property development from the aspen BKP and its blends with both the aspen and birch P-RC APMP pulps, as shown in Figures 9 and 10 respectively.

Figure 9. Light Scattering Development From Refining - Aspen P-RC APMP and BKP

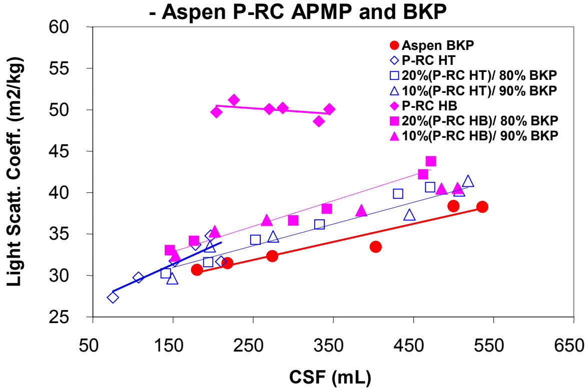
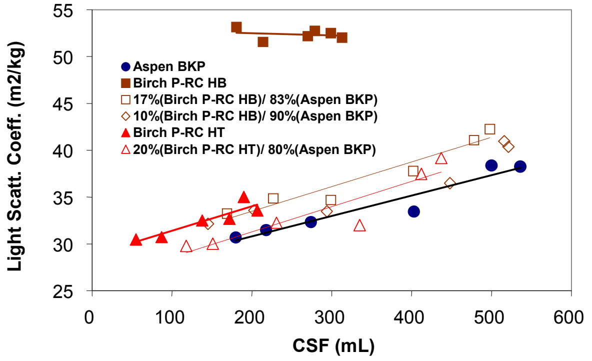


Figure 10. Light Scattering Development From Refining - Birch P-RC APMP and BKP



To further investigation interactions and the synergistic effects between aspen BKP and the P-RC APMP pulps from aspen and birch, pulp properties were investigated and compared by refining the pulps separately to targeted freeness levels first and then combining them together. Table 1 presents some of the results from the blends of aspen kraft (80%) and different aspen P-RC APMP pulps (20%): one from high bulk and another from high tensile grade. It was very interesting to notice that when the high bulk P-RC APMP was used, which had a higher freeness (345 ml versus 274 ml) and much lower tensile index (24.3 versus 50.1 N.m/g) than the kraft, 20% P-RC APMP/80% kraft blend gave a comparable tensile and tensile energy absorption (T.E.A.) as the 100% kraft at a similar freeness, but higher bulk (1.62 versus 1.47 cm^3/g), opacity (76.3 versus 73%), light scattering (35.8 versus 33 m^2/kg), and stretch (2.4 versus 2.1%).

In the case of the high tensile P-RC APMP, which had a lower freeness (210 versus 274 ml) and similar tensile compared to the kraft, the 20% blend of this chemical mechanical pulp gave a similar freeness (280 versus 274 ml), but much higher tensile index (59.3 versus 50.1 N.m/g), T.E.A. (80.1 versus 48.6 J/m^2) and stretch (3.2 versus 2.2%) than the kraft. The largest synergy was found in T.E.A. property, which was a result of combined effects from tensile and stretch. Opacity and light scattering, however, remained approximately the same.

In both cases, as expected, the blends had a slightly lower tear (7-7.2 versus 8 mN.m^2/g) than the chemical pulp. Tear, however, is often not an important parameter for hardwood pulps in papermaking because they often are used in combination with softwood pulps that provide most of tear strength required in papermaking. And also, there have been a number of studies [11,12] that demonstrated that paper sheet in-plane fracture, which is often related to machine runability, depends very much more on inter-fiber bonding ability like tensile and T.E.A than on tear, which measures out-of-plane fracture.

Table 1, Pulp Mixture from Aspen Kraft and P-RC APMP

	Aspen Bleached Kraft		**Aspen P-RC APMP**		**Mixture**	
PULP SAMPLE ID	E1	A128	T7 (High Bulk)	T10 (High Tensile)	O5 20% T7 80% A128	O6 20% T10 80% A128
FREENESS (CSF)	320	274	345	210	312	280
BULK (cm3/g)	1.47	1.43	2.35	1.67	1.62	1.47
TENSILE INDEX (N.m/g)	47.0	50.1	24.3	52.6	45.8	59.3
TEAR INDEX (mN.m2/g)	8.0	8.0	2.6	4.5	7.0	7.2
%STRETCH	2.1	2.2	1.0	2.1	2.4	3.2
T.E.A.(J/m2)	44.0	48.6	9.1	41.8	45.1	80.1
% OPACITY	73.0	72.3	83.6	73.9	76.3	73.0
SCATT. COEFF. (m2/kg)	33.0	32.3	50.0	31.7	35.8	31.6

The increased fiber bonding strength (tensile and T.E.A.) of the blends from the chemical and chemical mechanical pulps observed in this investigation suggests that there is a synergistic effect between the two types of pulps (at least to a certain level of chemical mechanical/chemical pulp ratio). This effect makes the combined pulp better, or stronger, than the sum of weighted contributions from its individual components.

Table 2. Pulp Mixture of Aspen Kraft and Birch P-RC APMP

	Apsen Bleached Kraft		**Birch P-RC APMP**		**Mixture**	
PULP SAMPLE ID:	E2	A128	T16 (High Bulk)	T19 (High Tensile)	O7 20%-T16 80%-A128	O8 20%-T19 80%-A128
FREENESS (CSF)	350	274	313	207	340	272
BULK (cm3/g)	1.50	1.43	3.13	1.76	1.63	1.52
TENSILE INDEX (N.m/g)	44.0	50.1	16.8	52.9	48.2	54.9
TEAR INDEX (mN.m2/g)	8.0	8.0	1.4	4.6	6.6	6.9
%STRETCH	2.0	2.2	0.8	2.0	2.8	2.9
T.E.A.(J/m2)	42.0	48.6	5.3	43.4	58.0	68.7
% OPACITY	73.0	72.3	84.1	75.2	77.3	74.3
SCATT. COEFF. (m2/kg)	33.5	32.3	52.0	33.6	38.2	33.6

To confirm the above observation, the study was repeated using birch P-RC APMP pulps to replace the aspen CMP pulps. Results are summarized in Table 2. The similar trends were again observed: the 20% birch P-RC APMP blends had higher tensile and T.E.A. than either the kraft pulp or the combination of weighted contributions from the individual components. And again, the largest synergy was found for the T.E.A. property development.

EXPERIMENT

All the chemical and chemical mechanical pulps used in Part 1 of this investigation were from laboratory or pilot plant processes. The pulps used in the second part were from commercial market pulp mills.

All the pulp tests were performed using Tappi standard methods, except pulp freeness was based on Canadian Standard Freeness (CSF) method. Andritz Twin-Flo IIIB (20" diameter) was used for the pulp refining studies for both the kraft and the P-RC APMP pulps.

CONCLUSIONS

This investigation had demonstrated:

- Hardwood chemical mechanical pulps give a higher bulk at a given tensile, or higher tensile at a given bulk, than their chemical pulps.
- Both chemical and chemical mechanical pulping processes can produce very strong pulps from hardwoods.
- Mixing hardwood (aspen) chemical pulp with up to 20% HWD chemical mechanical pulp, helps to not only improve pulp bulk and light scattering properties, but also maintain or improve the inter fiber bonding strength (tensile and T.E.A.), in comparison to the chemical pulp alone.
- There are synergistic effects between hardwood the chemical and the chemical mechanical pulps investigated: a blend of the two, (at a certain ratio), has a higher tensile and T.E.A., (or higher in-plane fracture resistance), than the sum of weighted contributions from its individual components.

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