Chemical Mechanical Pulps From *Eucalyptus* and Their Comparison with *Eucalyptus* Chemical Pulps

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ABSTRACT

This paper presents some recent developments in chemical mechanical pulping technologies and introduces the latest and the most advanced chemical mechanical pulping technology, P-RC APMP. Results from applications of P-RC APMP technology on various *Eucalyptus* woods from South America are presented. The P-RC APMP pulps from the *Eucalyptus* woods were then compared with both *Eucalyptus* chemical pulps and other hardwood chemical mechanical pulps currently available in the market and widely used in the industry. The results showed that *Eucalyptus* P-RC APMP pulps have papermaking properties comparable or better than hardwood market BCTMP pulps used currently in the industry. When compared with the *Eucalyptus* chemical pulps, the P-RC APMP pulps have a much higher bulk *at the some fiber bonding strength (*tensile index), and can have comparable tensile strength as the chemical pulps. The higher bulk property renders P-RC APMP technology an attractive alternative in utilization of *Eucalyptus* woods for many applications in paper and board industry.

Key Words: *Eucalyptus*, P-RC APMP, BCTMP, Pulp Properties, and Papermaking.

INTRODUCTION

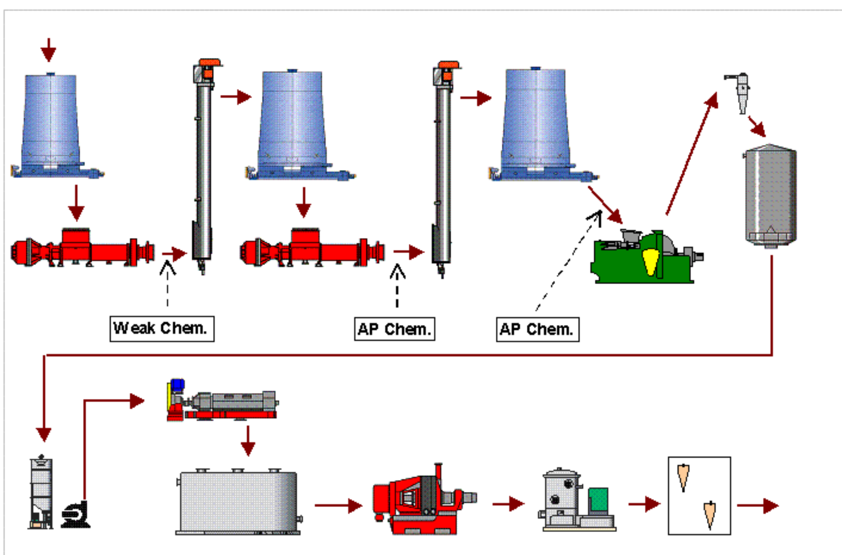
Recent years have seen a considerable growth in utilization of various high-density hardwoods in the pulp and paper industry, with various *Eucalyptus* woods being dominant among them. Traditionally, the utilization has been mostly from chemical pulping process, and its application is mainly complimentary to softwood chemical pulps. Chemical pulping of *Eucalyptus*, in general, gives a very low pulp yield, approximately 40-50%. And, the pulps produced from the chemical pulping processes typically have lower bulk and optical properties than other pulping technologies. As the industry starts to looking for higher yield and better bulk and optical properties for many applications, e.g. printing/writing and paperboard grades, there is a growing interest in high yield chemical mechanical pulping technologies, which gives much high pulp yield (>80%) and higher bulk and optical properties. From more recent studies, a synergy was observed between chemical pulps (kraft) and chemical mechanical pulps from hardwoods – a combination of these two types of pulps give not only higher bulk and optical properties, but high fiber bonding strength (tensile) as well.

Traditionally, there are three different chemical pretreatment processes applicable in mechanical pulping of *Eucalyptus*. They are cold caustic soda (CCS), alkaline sulfite (CTMP, alkaline sulfite thermomechanical pulp), and more recently peroxide (APMP, **a**lkaline **p**eroxide **m**echanical **p**ulping). Over the past years, a systematic investigation and development was carried out at Andritz Pilot Plant and R&D Laboratory in Springfield, Ohio USA, to evaluate and compare these different treatments and their applications in various *Eucalyptus* from South America. Some of the results were published in various conferences and meetings [XU – (1998)(1996) (1997)]. Based on those investigations, a more advanced technology, P-RC APMP, was developed. This technology uses a mild Preconditioning, (**P**), with chemicals and then use Refiner Chemical treatment, (**RC**), for the main chemical treatment (for brightness and other pulp property development). The word "P-RC" is to emphasize the importance of the preconditioning, the refiner chemical treatment and proper distribution of chemical reactions between the two. It is different from the conventional APMP process, which aims at doing all the chemical treatment work on chips before refining; and from the refiner bleaching, which has no preconditioning and does all the bleaching in the refiner. There are papers available for more detailed discussions about P-RC APMP technology, its latest developments and its differences from other chemical mechanical pulping processes [XU (1999) (2004) (2002) (2003), (2001) (2003)].

For industrial operations, a typical simplified process flowsheet for P-RC APMP process is showed in **Figure 1**. The raw materials, or chips, are first impregnated with chemicals. The total impregnation system may have one to three stages, but a two-stage, as shown in the figure, in general, is sufficient for many applications. In a multi-stage impregnation, the first stage generally receives less chemicals than the later stages, and most of bleaching chemicals are applied at the last stage. At each stage of the impregnation, chips are thermally treated for 10 to 30 minutes first, and then pressed by a high compression chip press. Chemical liquor is applied at the discharge end of the press. The pressure release at the chip press discharge helps the chemicals to penetrate into the chips.

After the last stage of impregnation, the chips are allowed to have some retention time before being refined using conventional refiners, either atmospheric or pressurized. After being refined, the pulp may be either dropped directly, or blown, into a high consistency retention tower to allow enough time for the chemical reactions to complete. After the chemical reactions are completed, the pulp can either be washed using an inter-stage press or directly go into a latency chest, as shown in the figure, or a secondary refiner. At this point, the pulp has already received all the chemical treatment, and the rest of the process is for refining, screening, washing and some other stock preparation works like any other normal mechanical pulping system.

Figure 1. Example of Simplified P-RC APMP Process Flowsheet



EXPERIMENTAL

Wood: The process materials were received in log form with bark from different countries in South America, and from trees of 6-9 years old. They were debarked and chipped at the Andritz Pilot Plant before processing.

P-RC APMP Process: Two or three stage impregnations were applied for alkaline peroxide pretreatment, using an Andritz Model 560GS Impressafiner for compression and maceration of the chips. A detailed description of the chemical treatment in the P-RC APMP process may be found elsewhere [XU et.al

(2003) (1996)]. Total chemicals used in the pretreatment varied: sodium hydroxide being 4.0% to 9.0%; hydrogen peroxide 2.0% to 7.0% (all based on oven dry chip), plus peroxide stabilizers (DTPA, sodium silicate and magnesium sulfate).

Refining: The impregnated wood chips were refined using an Andritz 914 mm diameter atmospheric double disc refiner (Model 401).

Pulp Testing: Tappi standard test methods were used for all handsheet tests.

RESULTS AND DISCUSSIONS

Pulp Properties from P-RC APMP Process

To understand how pulp properties can be developed under certain process conditions, it is important to understand how the properties can be affected by the process conditions, and, more importantly, to find and use intrinsic characteristics of pulp property relationships, which are independent of, or less sensitive, to process conditions. These characteristics are more useful in that they can be used to compare different processes using the same process material, or to compare different wood materials using the same process. As discussed above, P-RC APMP is a very flexible process. Pulp properties at a given freeness can be changed easily by varying chemical charges and refining energy. Previous investigations of chemical treatment in mechanical pulping of South American *Eucalyptus* [XU (1997)] and North American aspen [XU (1998)] have demonstrated that for a given chemical mechanical pulping process, there were close correlation among pulp mechanical properties, and the correlation were independent of the process chemical charges and energy consumption. Handsheet strength properties, such as tensile, tear, burst can all be related to handsheet density. For this reason, a similar approach was adopted in the present investigation.

Eucalyptus Grandis from South America

E. grandis from Argentina, Brazil, Paraguay and Venezuela were investigated. **Figure 2** shows pulp handsheet tensile strength development from these species. As expected from the previous study [XU, (1998)], a linear tensile/density correlation existed for all the species, and they all more or less fell in line with a common relationship parameters. The correlation was independent of the chemical charges and refining energy applied. At a high chemical, or energy application, a good tensile strength (> 50 N.m/g) was developed, which is high enough for many paper-making requirements.

FIGURE 2. TENSILE/DENSITY PROPERTIES
- *E. Grandis*

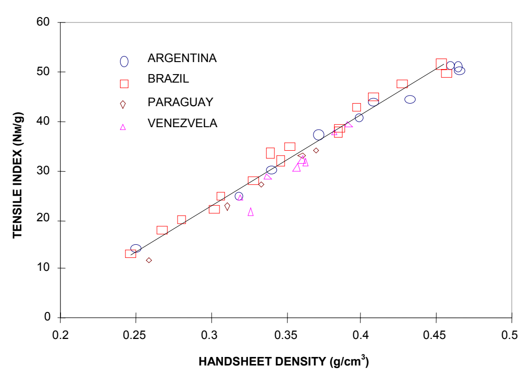
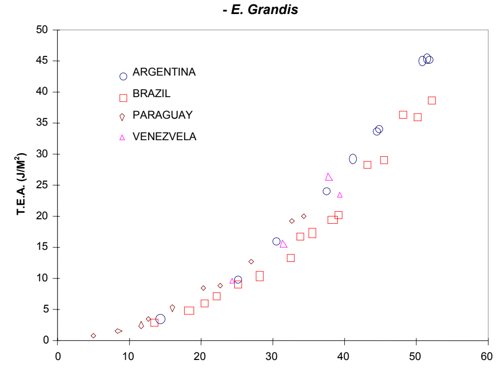


FIGURE 3 T.E.A./TENSILE PROPERTIES
- *E. Grandis*



Results from tensile energy absorption (T.E.A.), which is also an important papermaking property, are presented in **Figure 3**. While the *E. grandis* from Argentina, Paraguay and Venezuela had a similar T.E.A. development that from Brazil had slightly lower T.E.A., especially at a higher tensile strength. At 50 N.m/g tensile index, T.E.A. of the Brazilian *E.grandis* reached approximately 38 J/m^2, and that of others about 42 J/m^2. These numbers again are also good for many papermaking processes.

Different Eucalyptus Species

Four different *Eucalyptus* species (*E. grandis, E. pilularis, E. dunny* and *E. urophylla*) from Brazil and *E. saligna* from Paraguay were compared in this study. *E. Saligna* was used to compare the *Eucalyptus* species from Brazil investigated earlier and reported previously [XU, 1998].

Figure 4 depicts results from tensile/density analysis. While *E. saligna* from Paraguay was the same as *E. grandis* from Brazil, the other *Eucalyptus* species all had a lower tensile index (by approximately 8 N.m/g) at a given density. Correlation between tensile and density were linear for the species studied.

The T.E.A./tensile relationship was similar among the *Eucalyptus* studied, as shown in **Figure 5**. Only a slight drop in T.E.A. was observed from *E. grandis* at tensile levels of higher than 30 N.m/g. A high level of T.E.A., >50 J/m^2, could be achieved at a tensile index of > 55 N.m/g.

FIGURE 4 TENSILE/DENSITY PROPERTIES

- Different *Eucalyptus*

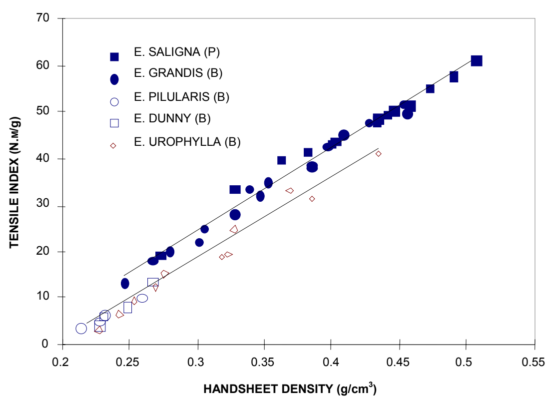


FIGURE 5 T.E.A./TENSILE PROPERTIES

- Different *Eucalyptus*

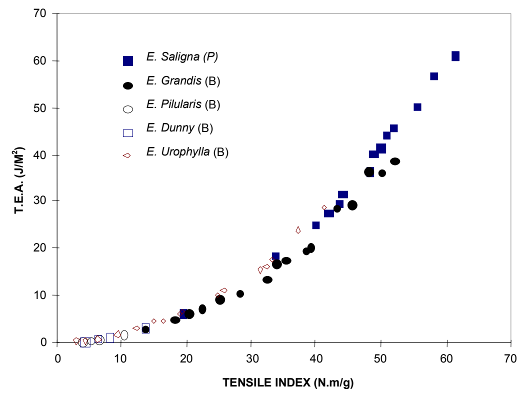


Figure 6. Different Eucalyptus Pulps - Pulp Intrinsic Properties

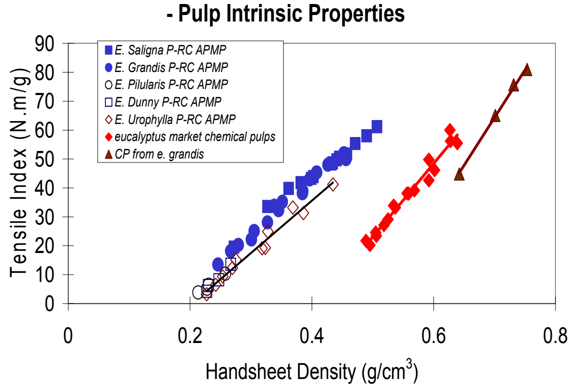
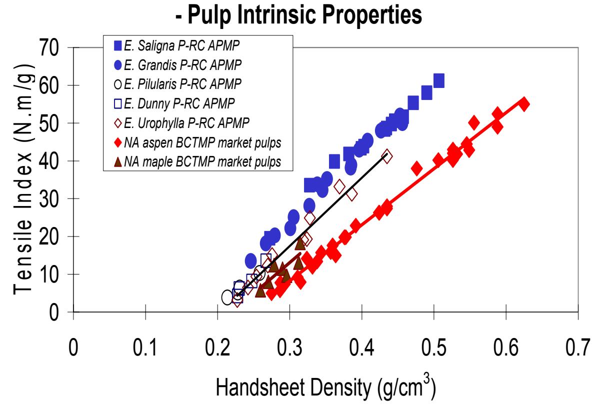


Figure 7. Different Hardwood Pulps - Pulp Intrinsic Properties



P-RC APMP and Chemical Pulps from *Eucalyptus*

Chemical pulping has been a popular process in South America for converting *Eucalyptus* into papermaking material. It is, therefore, of interest to compare P-RC APMP pulping with chemical pulping process. **Figure 6** shows pulp intrinsic properties from different *Eucalyptus* and from different pulping methods. The *E. grandis* chemical pulps were from reference [MACRAE et.al (1998), and the *Eucalyptus* market chemical pulps were from purchased market *Eucalyptus* BHKP from Brazil and refined to different tensile/density with low consistency refiner at the pilot plant. As can be seen, the P-RC APMP pulps from all the *Eucalyptus* woods studied, even the ones from inferior *Eucalyptus* woods like *E. dunny, E. pilularis* and *E. urophylla*, had better intrinsic property than both the *E. grandis* chemical pulp and the common *Eucalyptus* market BHKP and they had a higher tensile at the bulk, or high bulk at the same tensile than the chemical pulps. This is consistent with results reported elsewhere from other hardwood species [XU (2004)]. As will be discussed later, handsheet bulk properties are important in many paper and board applications. The high bulk properties observed here from P-RC APMP process suggest that for some applications where bulk is important, the P-RC APMP pulps are expected to perform better than the chemical pulps. In other words, the P-RC APMP process may be a better process choice for pulping *Eucalyptus* wood in those applications.

Papermaking Potentials

Eucalyptus mechanical pulp has long been used in the paper industry. The earlier applications were mostly in newsprint grades [SOMERVILLE et.al (1958); BANHAM et.al (1991)]. In recent years, its application has been extended into value-added grades such as tissue and printing/writing grades. Advanced pulping/bleaching technology like P-RC APMP developed in recent years has made it possible to produce a high quality *Eucalyptus* chemical mechanical pulps with a high brightness of > 85% ISO, and has generated an increased interest global wide in expanding its application in the paper industry, especially high brightness paper and board grades. One way to better understand the potential of P-RC APMP pulps from the eucalyptus woods studied in this investigation is to compare these P-RC APMP pulps against other hardwood market chemical mechanical pulps, such as market BCTMP pulps, that are already in the market and widely used in the industry. **Figure 7** shows the pulp intrinsic properties from the eucalyptus P-RC APMP pulps and their comparisons with two mostly popular hardwood BCTMP market pulps from aspen and maple in North America. As can been seen, the eucalyptus P-RC APMP pulps have much better intrinsic properties than both the aspen and the maple BCTMP market pulps, and they give a higher tensile at the same density (or bulk), or lower density (higher bulk) at the same tensile.

High Brightness Paper Grades

Aspen BCTMP market pulps have seen a significant growth since the late 1980's and have been used widely in various paper grades such as printing/writing and tissue/towel [BARBE et. al (1990)]. The role of aspen BCTMP in these applications is mainly for functional properties such as sheet formation, surface smoothness, sheet bulk and good brightness. **Table 2** compares overall pulp properties between typical aspen BCTMP market pulps [BARBE et.al (1990)] and the *Eucalyptus* P-RC APMP pulps. As can be seen, at the same tensile strength, the *Eucalyptus* species have a much higher bulk (by about 0.5 cm^3/g at 50 Nm/g tensile index), opacity and light scattering coefficient (LSC). These give the *Eucalyptus* APMP some advantages relative to aspen BCTMP in high brightness grade applications. The higher bulk would give tissue/towel grades an improved surface softness, and provide printing/writing paper grades a better sheet stiffness. The higher opacity and LSC would improve printing/writing paper resistance to "print-through" or ink "show through" problems.

Table 2. *Eucalyptus* P-RC APMP versus Aspen BCTMP Market Pulps

Wood	Aspen	South American *Eucalyptus*	
Process	BCTMP	P-RC APMP	
Freeness (CSF) (ml)	110-350	110-350	
Bulk (cm^3/g)	1.6-1.8	2.1-2.3	1.7
Density (g/cm^3)	0.63-0.56	0.48-0.44	0.59
Tensile Index (N.m/g)	48-52	50	70-80 [a]
Tear Index ($mN.m^2/g$)	5.0-5.3	5-6.5	>7 [a]
Burst Index ($kPa.m^2/g$)	2.4-2.7	2.4	> 3.5 [a]
Brightness (% ISO)	85	85	85 [a]
Opacity (%)	76-77	80-85	75-80 [b]
LSC (m^2/kg)	< 40 [B]	>45	>40 [b]

NOTE: [a] From extrapolation
[b] Estimated numbers

High Quality Paperboard

Hardwood chemical mechanical pulp has also been used in paperboard grades for many years [UDY, 1994; UDY, 1996]. Both aspen and maple have been reported for this application. For multi-ply paperboard, addition of the hardwood was found to improve the furnish formation, surface smoothness, scoring and folding, especially when it was applied at the middle ply of a three-ply board [BARBE et.al (1990)]. In this application, maple was reported to perform better than aspen. The improved performance from maple was mainly attributed to a higher bulk of the maple BCTMP compared to aspen [UDY, (1996)]. A higher bulk improves not only bending stiffness, but also the folding characteristics such as creasing/scoring and folding, which are important to the paperboard.

Table 3 compares the *Eucalyptus* P-RC APMP pulps with Canadian maple BCTMP [UDY (1996)], which has been used in multi-ply paperboard. As can be seen, at a given tensile strength, the *Eucalyptus* APMP pulps have a higher bulk, suggesting the *Eucalyptus* P-RC APMP is expected to perform better than maple BCTMP in paperboard applications. The higher bulk would improve the sheet stiffness and folding characteristics.

Table 3. *Eucalyptus* P-RC APMP versus Maple BCTMP

Wood	Maple[a]	South American *Eucalyptus*
Process	BCTMP	P-RC APMP
Freeness CSF (ml)	380-400	380-400
Bulk (cm^3/g)	3.0-3.2	3.4-4.1
Density (g/cm^3)	0.31-0.33	0.245-0.295
Tensile Index (N.m/g)	15-18	15-18
Tear Index ($mN.m^2/g$)	3.0	2.5-3.0
Burst Index ($kPa.m^2/g$)	0.8-1.0	0.4-0.6
Brightness (% ISO)	78-80	78-80
% Opacity	80-83.5	84-90
LSC (m^2/kg)	-	> 50

Note: [a] from Reference [UDY, (1996)]

Among the Eucalyptus species investigated

In terms of papermaking potential, the *Eucalyptus* species studied in this investigation may be divided into two groups based on their bulk properties: Group A: *E. grandis, E. saligna* and Group B: *E. pilularis, E. dunny, E. urophylla.* Group A has a higher bulk at a given tensile strength than Group B, and is expected to perform better in both value-added paper and paperboard grades.

CONCLUSIONS

In this paper, the latest chemical mechanical pulping technology, P-RC APMP, is introduced. Using this latest technology, the *Eucalyptus* species investigated can all be converted to pulps with good strength properties, (e.g. tensile index of > 50 N.m/g). The pulps also have good optical properties (brightness of > 80% ISO, LSC of > 40 m^2/kg). These *Eucalyptus* P-RC APMP pulps have, in general, similar T.E.A. strength properties. At a given tensile strength, however, *E. grandis* and *E. saligna* species had higher bulk than *E.pilularis, E. dunny* and *E. urophylla* from Brazil. The *E. grandis* woods from the different countries were, however, similar in their pulp intrinsic properties.

When compared with eucalyptus chemical pulps, all of the *Eucalyptus* P-RC APMP pulps gave better pulp intrinsic properties (- higher tensile at the same bulk, or higher bulk at the same tensile). It was possible also for the P-RC APMP pulps to reach comparable tensile strength as the chemical pulps.

Based on their pulp handsheet property analysis, the *Eucalyptus* P-RC APMP pulps showed a very good potential for applications in value-added paper and paperboard grades. They in general have much better pulp intrinsic properties (tensile/density relationship) than, and compare favorably against both *Eucalyptus* chemical pulp and some of other HWD BCTMP market pulps currently used in the industry.

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