

PEROXIDE BLEACHING OF EUCALYPTUS CTMP USING MAGNESIUM HYDROXIDE AS THE ALKALI SOURCE

Z. He and Y. Ni

Limerick Pulp and Paper Centre,
University of New Brunswick,
Fredericton, NB

ABSTRACT

Hydrogen peroxide bleaching of a eucalyptus CTMP by a $Mg(OH)_2$ -based process was investigated at both medium-consistency (MC) and high-consistency (HC) for three levels of brightness targets (75, 80 and 85% ISO), with an objective to explore the potential advantages and disadvantages of using magnesium hydroxide to replace sodium hydroxide as the alkali source. Process parameters studied include dosages of peroxide, alkali and silicate, reaction temperature and retention time. Results show that for the MC system, the $Mg(OH)_2$ -based process produced significantly lower pulp brightness than the conventional NaOH-based process at given peroxide dosages, although the difference can be narrowed markedly by increasing temperature and retention time. The brightening effect of the $Mg(OH)_2$ -based process improved substantially in the HC system combined with higher reaction temperature and longer retention time. Bleached pulp with brightness of 76.9, 80.8 and 83.2% could be produced by the $Mg(OH)_2$ -based process with 2.5, 4.0 and 6.2% H_2O_2 , respectively. It was demonstrated that under the optimized conditions, the $Mg(OH)_2$ -based process has a brightening effect close to that of the conventional NaOH-based process at the same peroxide dosages. Results also indicate that at similar brightness levels of bleached pulp, the $Mg(OH)_2$ -based process produced substantially less anionic trash and COD, with significantly higher pulp yield than the NaOH-based process.

INTRODUCTION

Eucalyptus is a fast-growing hardwood species which has proved to be suitable for both chemical and mechanical pulping. The eucalyptus plantations in South America are important sources of hardwood fibers for the global pulp and paper industry. As a major pulp product from eucalyptus, bleached chemi-thermo-mechanical pulp (BCTMP) can find applications in many paper grades that include fine papers, provided that its optical properties and physical strength properties develop sufficiently in the pulping and bleaching processes [1]. Caustic soda is commonly used together with sodium sulfite to impregnate wood chip in the CTMP pulping process to improve the strength properties of CTMP pulp, but the alkaline conditions and high temperature can also cause darkening of the resultant pulp [2,3]. In addition, the colored extractives of eucalyptus can also contribute to the low brightness of unbleached eucalyptus CTMP. Currently, peroxide bleaching is the only process available commercially

for brightening eucalyptus CTMP to high brightness, e.g. above 80% ISO.

The conventional peroxide bleaching process uses sodium hydroxide (NaOH) as the alkali source. The strong alkalinity can cause excessive dissolution of lignin and hemicellulose, resulting in increased COD load of the effluent and decreased pulp yield [4]. In addition, the high alkalinity of the process leads to the formation of a significant amount of anionic trash which is carried over to the wet-end of the paper machine and interferes with the chemicals used in the papermaking process, leading to increased polymer/additive cost, reduced drainage and decreased product quality [4,5]. Using weak alkalis, such as magnesium hydroxide, may be a solution to this problem.

Recent studies have shown that the substitution of magnesium hydroxide ($Mg(OH)_2$) for caustic soda (NaOH) in peroxide bleaching of mechanical pulp can result in many beneficial effects, such as less anionic trash formation, lower COD load of the effluent, higher bleaching yield and better optical properties of the bleached pulp [6-13], as well as decreased oxalate-related scaling problems in the bleach plant [14]. A number of mills in North America have implemented the technology. In the literature, different brightness responses to the $Mg(OH)_2$ -based peroxide bleaching process have been reported. Results by Nyström et al [8] showed that using $Mg(OH)_2$ instead of NaOH as the alkali source in peroxide bleaching of a spruce SGW increased pulp brightness. Zhang et al. [9] observed that the $Mg(OH)_2$ -based peroxide bleaching process gave lower brightness of a maple CTMP than the NaOH-based process. On the other hand, no significant changes in brightness and strength properties of bleached pulp have been observed when a TMP mill switched its bleaching operation from the conventional NaOH-based process to the $Mg(OH)_2$ -based process [10]. However, little information is available in the literature about the $Mg(OH)_2$ -based peroxide bleaching of eucalyptus CTMP. A more recent study [11] shows that the comparison of the bleaching response of the two bleaching processes depends on the properties of unbleached pulp and the bleaching conditions.

The objective of this study was to investigate the bleaching response of a eucalyptus CTMP to the $Mg(OH)_2$ -based peroxide process, in comparison to the conventional NaOH-based process. Two bleaching systems, namely, the medium-consistency (MC) and the high-consistency (HC) were studied with three levels of brightness targets. Process parameters included the peroxide and alkali charges, peroxide stabilizers, and reaction temperature and retention time. The bleaching performance was determined in terms of brightness, peroxide consumption, pulp yield, anionic trash formation, chemical oxygen demand (COD), conductivity and dissolved solid content in the bleach filtrate.

EXPERIMENTAL

Materials

A eucalyptus (*saligna* and/or *grandis*) CTMP pulp sample with an initial brightness of 36.5%, which was sampled after the secondary refiner but before the chelation stage, was received from a Brazilian mill as its air-dry form. It was stored in a cold room until use. Chemicals were reagent

grades purchased from Scientific Fisher except sodium silicate (40%, National Silicate), magnesium hydroxide (61% slurry, Martin Marietta Magnesia Specialties).

Methods

Chelation of pulp was performed at 3% pulp consistency, pH 6.0 and 70°C for 30 minutes with 0.2% DTPA (as 100%). Then the pulp suspension was thickened to about 25% consistency in a Büchner funnel with a 200-mesh Teflon screen. The filtrate was recycled once to go through the fiber mat to collect the fines. The pulp cake was pressed between blotting papers to thicken further to about 35% consistency.

Peroxide bleaching experiments were conducted in plastic bags using the following conditions: 2.5-8.0% H₂O₂, 1.5-6.0% NaOH or/and 0.5-3.0% Mg(OH)₂, 0-2.6% silicate (water glass), 0-0.13% Epsom salt (MgSO₄·7H₂O), 16% (MC) or 30% (HC) pulp consistency, 70-90°C, and 2-6 hours, or otherwise as specified. The chemicals were mixed in a beaker by the following order: water, sodium silicate, sodium hydroxide or magnesium hydroxide, Epsom salt and then hydrogen peroxide. The prepared bleach liquor was then added to the pulp which was pre-heated to the reaction temperature, and good mixing was provided by kneading. The plastic bag was sealed and placed into a water bath for the desired retention time at the set temperature.

At the completion of the bleaching time, the pulp sample was cooled down with cold running water to room temperature and diluted to 1-2% suspension with deionized water. The well-mixed pulp suspension was then filtered in a Büchner funnel with a 200-mesh Teflon screen. The filtrate was recycled once to go through the fiber mat to collect the fines. The resultant filtrate was further filtered with a Whatman medium-fast filter paper to remove the residual fines, and then used for determining the end pH, conductivity, residual peroxide and chemical oxygen demand (COD) according to the PAPTAC standard methods (J.16P and H.3), and cationic demand (anionic trash) by a Müttek PCD-03 titrator. The pulp cake (about 25% consistency) was then dispersed into a 2% pulp suspension with deionized water, and its pH adjusted to 5.0 with sulfurous acid, and then handsheets were prepared and measured for optical properties according to the TAPPI standard methods (T205 sp-95 and T220 sp-96).

RESULTS AND DISCUSSION

Medium-Consistency (MC) Bleaching System

Table 1 shows the results of NaOH-based and Mg(OH)₂-based peroxide bleaching of the eucalyptus CTMP at various peroxide and alkali charges. For each level of peroxide dosage, the pulp brightness increased with the alkali charge first and then leveled off or started to decrease. With optimal alkali charges, the maximum brightness obtained was 75.6, 81.1 and 83.8% ISO for peroxide dosages of 2.5, 4.0 and 6.2%, respectively. However, significantly lower brightness gain was observed for the same pulp in the Mg(OH)₂-based process. As shown in Table 1, Mg(OH)₂ charges had little effect on the brightness under the conditions, and the corresponding maximum brightness was only 67.4, 72.3 and 75.4% ISO, respectively, for the three levels of peroxide

charges. Such a big difference of brightness gain was unexpected between the NaOH-based and Mg(OH)₂-based process. A number of studies have shown that for the peroxide bleaching of mechanical pulps (TMP, CTMP, PGW, and SW), the Mg(OH)-based process gives similar or slightly lower (about 1-2 units) brightness when compared with the NaOH-based process [6-13]. The discrepancy is probably due to the difference of pulp properties, such as the chromophore structures of lignin and their reactivity towards peroxide bleaching.

Table 1. Comparison of the NaOH-based and Mg(OH)₂-based peroxide bleaching of the eucalyptus CTMP at medium-consistency (MC)						
H ₂ O ₂ charge %	Alkali charge (NaOH or Mg(OH) ₂), %	End pH*	Residual H ₂ O ₂ , %	Brightness % ISO	Anionic trash µeq/g	Filtrate conductivity* ms/cm
NaOH-based process						
2.5	1.50	8.35	0.83	72.3	32.3	0.71
2.5	1.75	8.53	0.71	75.1	35.7	0.78
2.5	2.00	8.79	0.55	75.6	39.9	0.89
2.5	2.25	8.99	0.44	75.6	45.4	0.99
4.0	2.00	8.39	1.62	79.2	38.9	1.08
4.0	2.50	8.88	1.24	80.2	49.7	1.27
4.0	3.00	9.33	0.90	81.0	59.9	1.48
4.0	3.50	9.57	0.60	81.1	64.1	1.49
6.2	3.00	9.02	2.17	82.9	58.0	1.26
6.2	4.00	9.55	1.10	83.8	73.4	1.64
6.2	5.00	9.91	0.40	83.4	78.6	2.16
6.2	6.00	10.4	0.02	81.2	87.1	2.63
Mg(OH)₂-based process						
2.5	0.50	7.65	1.48	67.2	18.6	0.34
2.5	0.75	7.87	1.45	67.4	17.2	0.36
2.5	1.00	7.90	1.42	67.1	17.5	0.36
2.5	1.25	8.06	1.37	67.0	17.9	0.37
4.0	1.00	8.04	2.49	71.9	18.5	0.41
4.0	1.30	8.14	2.45	72.0	18.3	0.42
4.0	1.70	8.18	2.29	72.3	17.8	0.43
4.0	2.10	8.23	2.32	72.1	17.8	0.44
6.2	1.50	8.22	3.79	75.4	17.6	0.48
6.2	2.00	8.27	3.68	75.3	16.8	0.50
6.2	2.50	8.25	3.65	75.1	17.9	0.49

Other bleaching conditions: 2.6% silicate, 0.13% Epsom salt (for the NaOH-based process), 16% pulp consistency, 80°C, 3 hours. *The end pH and conductivity was measured as of 2% pulp suspension.

Figure 1 compares the brightness response of the eucalyptus CTMP and a maple CTMP to the Mg(OH)-based process. Evidently, the bleachability of the eucalyptus CTMP is lower than that of the maple CTMP in the Mg(OH)-based peroxide process, in particular at lower chemical charges. In Figure 2, the comparison of the brightness development in the NaOH-based process between the eucalyptus CTMP and the maple CTMP indicates that the eucalyptus pulp reached its maximum brightness at a lower alkali charge. The difference might be caused by the chemical treatment conditions in the CTMP pulping process, wherein various amount of NaOH is used to impregnate woodchips, and the acetyl groups of hemicellulose are hydrolyzed to different degrees. The eucalyptus CTMP might have had a stronger alkaline treatment in the pulping process and lost most of its acetyl

groups, which may explain its lower alkali demand in peroxide bleaching. In the meanwhile, alkali darkening can also have taken place, leading to formation of less reactive chromophores towards peroxide bleaching in lignin [2,3,15]. This is supported by the fact that the unbleached eucalyptus CTMP had a lower original brightness than the maple CTMP (36.5 vs. 45.8% ISO). To verify this hypothesis, a softwood TMP was subjected to an alkali pretreatment to simulate the alkaline conditions of CTMP pulping process, and then bleached by the NaOH-based and Mg(OH)₂-based peroxide bleaching processes respectively. As shown in Table 2, without the alkali pre-treatment, the bleaching response in terms of brightness gain was similar for the two bleaching processes. However, with the alkali pretreatment, the brightness of the bleached pulp from the Mg(OH)₂-based process was about 5-7 units lower than that from the NaOH-based process. Therefore the chromophores generated during the alkali pre-treatment are less reactive toward the Mg(OH)₂-based peroxide bleaching although the residual peroxide was very high.

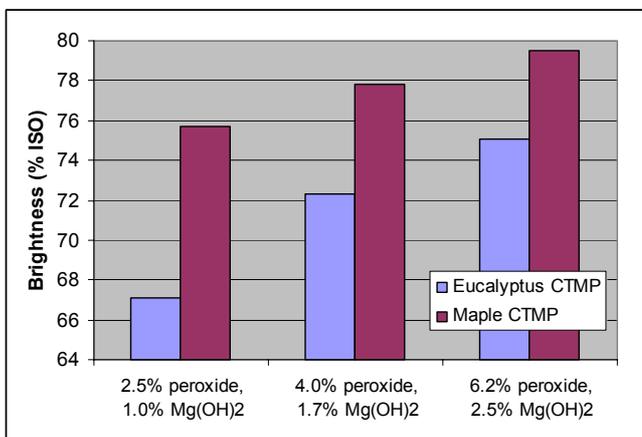


Figure 1. Comparison of the brightness response of the eucalyptus CTMP and a maple CTMP in the Mg(OH)₂-based peroxide bleaching (Other bleaching conditions: 2.6% silicate, 16% pulp consistency, 80°C, 3 hours. Data for the maple CTMP was from references [14, 15]).

The data of residual peroxide in Table 1 shows a sharp increase of peroxide consumption with the increase of alkali charges in the NaOH-based process. In contrast, the peroxide consumption in the Mg(OH)₂-based process was not significantly affected by the increase of Mg(OH)₂ charge, and at the end of bleaching more than 50% of the peroxide added was present as residual. Therefore, the lower bleaching response of the eucalyptus CTMP to the Mg(OH)₂-based process was not due to peroxide decomposition. The lower reactivity of the lignin chromophores produced during the pulping process might be the reason. Stronger conditions such as higher chemical concentration, higher temperature and/or longer time may be needed to increase the brightening reactions.

As shown in Table 3, higher reaction temperature and longer retention time improved the brightening effect of the Mg(OH)-based process markedly, although the remaining

difference in pulp brightness between the two bleaching processes is still quite significant.

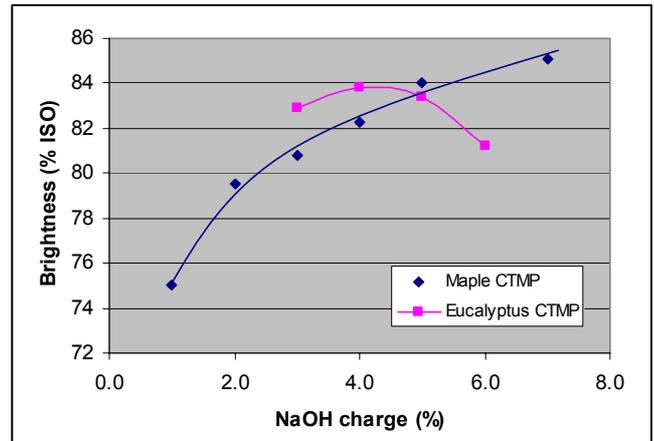


Figure 2. Comparison of the brightness response of the eucalyptus CTMP and a maple CTMP in the NaOH-based peroxide bleaching with 6.2% H₂O₂ and various NaOH charges. (Other bleaching conditions were the same as in Figure 1. Data for the maple CTMP was from references [14,15].)

NaOH %	Mg(OH) ₂ %	Silicate %	DTPA (40%) %	End pH	Residual H ₂ O ₂ , %	Brightness % ISO
Without alkali pre-treatment						
1.0	0	2.0	0	7.97	1.24	71.5
1.0	0	0	0.4	7.65	1.24	71.6
0	1.0	0	0.4	7.81	1.70	71.2
With alkali pre-treatment						
1.0	0	2.0	0	9.20	1.43	67.6
1.0	0	0	0.4	9.39	1.22	67.3
0	1.0	0	0.4	8.90	1.83	62.7

Other bleaching conditions: 2.7% H₂O₂, 0.07% Epsom salt (for the NaOH-based process), 11% pulp consistency, 70°C for 2 hours. Alkali pre-treatment: 2% NaOH, 5% pulp consistency, 95 °C and 60 minutes.

H ₂ O ₂ charge, %	Mg(OH) ₂ charge, %	Temp., °C	Time Hrs.	End pH	Residual H ₂ O ₂ , %	Brightness % ISO
4.0	1.3	80	3	8.28	2.29	72.0
4.0	1.3	80	6	8.26	1.86	76.2
6.2	1.5	80	3	8.22	3.79	75.4
6.2	1.5	80	6	8.17	3.08	79.3
6.2	1.5	90	6	8.13	2.73	80.0

Other bleaching conditions: 2.6% silicate, 16% pulp consistency, 80°C.

On the other hand, the advantages claimed for the Mg(OH)-based process in the literature are well supported by the results of the present study. As shown in Table 1, the conductivity of the bleaching filtrate from the Mg(OH)₂-based

process was substantially lower than that from the NaOH-based process. In the NaOH-based process, the filtrate conductivity was mainly affected by the alkali charge, while it was mainly affected by the peroxide charge in the Mg(OH)₂-based process. A substantial reduction of anionic trash formation was realized when Mg(OH)₂ instead of NaOH was used as the alkali source for the peroxide bleaching of the eucalyptus CTMP. It is noted that for the NaOH-based process, the anionic trash formation appeared to be independent of the peroxide charge, and it increased linearly with the alkali charge in the range of 1.5-4.0% NaOH, although it leveled off at higher alkali charges. On the other hand, the anionic trash formation in the Mg(OH)₂-based process remained constantly low, independent of the increase of peroxide and alkali charges.

High-Consistency (HC) Peroxide Bleaching System

The optimized bleaching conditions such as alkali charge and retention time for the MC system may not be optimal in a HC system. For example, for the NaOH-based process, a three-hour retention time was too long in the HC system under the conditions studied (Figure 3). Alkaline darkening may take place after peroxide is exhausted [3,15]. However, for the Mg(OH)₂-based process, higher temperature and longer retention time led to further brightness increase in the HC system, as shown in Figure 4. Table 4 shows the effect of peroxide stabilizers (silicate and DTPA) on the brightening efficiency of the two bleaching process. The silicate dosage can be reduced from 2.6% to about 1.5% in both bleaching processes without affecting the brightness significantly, but it could not be completely replaced by DTPA.

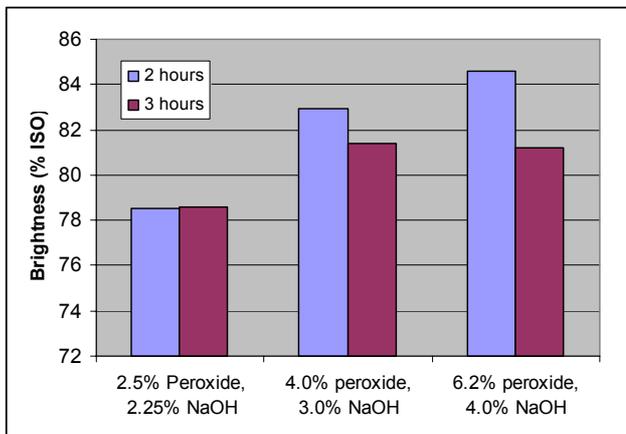


Figure 3. The effect of retention time on pulp brightness for the NaOH-based process in the HC system (30% pulp 2.6% silicate, 0.13% Epsom salt, 80°C).

The comparison of the two bleaching processes in the HC system under the newly optimized bleaching conditions is summarized in Table 5. Less alkali is needed in the HC system than in the MC system. As shown in Table 5, higher concentrations of bleaching chemicals markedly improve the brightening efficiency of the Mg(OH)₂-based HC system. The brightness of the bleached pulp from the Mg(OH)₂-based process was only about 2-unit lower than that from the NaOH-

based process at the same peroxide charge, although the peroxide consumption was still lower in the former process.

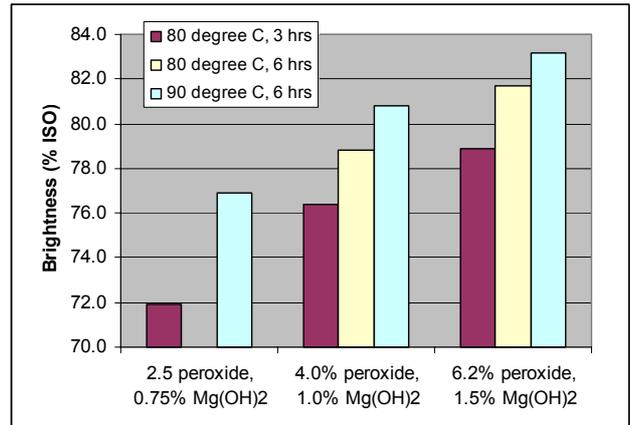


Figure 4. The effect of retention time on the pulp brightness from the Mg(OH)₂-based process in the HC system (30% pulp consistency, and other bleaching conditions were the same as in Figure 1).

Table 4. The effect of silicate and DTPA on the Mg(OH) ₂ -based and NaOH-based peroxide bleaching of the eucalyptus CTMP in a HC system						
NaOH-based process (80°C, 2 hours)						
H ₂ O ₂ dosage (%)	4.0	4.0	4.0	4.0	4.0	4.0
NaOH dosage (%)	2.5	2.5	2.5	2.5	2.5	2.0
Silicate dosage (%)	2.6	1.5	1.0	0	0	0
DTPA dosage (%)	0	0	0	0	0.2	0.2
Epsom salt dosage (%)	0.05	0.05	0.05	0.05	0.05	0.05
End pH	8.87	8.98	8.94	9.34	9.38	8.90
Residual H ₂ O ₂ (% on pulp)	1.08	0.88	0.63	0	0	0.02
Brightness (% ISO)	82.9	82.4	81.5	74.9	74.4	75.9
Mg(OH) ₂ -based process (90°C, 6 hours)						
H ₂ O ₂ dosage (%)	4.0	4.0	4.0	4.0	4.0	
Mg(OH) ₂ dosage (%)	1.0	1.0	1.0	1.0	1.0	
Silicate dosage (%)	2.6	1.5	1.0	0	0	
DTPA dosage (%)	0	0	0	0	0.2	
End pH	7.10	7.19	7.25	6.88	6.97	
Residual H ₂ O ₂ (% on pulp)	1.53	1.40	1.22	0.02	0.02	
Brightness (% ISO)	80.8	80.3	80.0	70.8	71.2	

The results in Table 5 also show that the Mg(OH)₂-based process produced about 40-50% less COD and gave significantly higher yield of bleached pulp at each brightness level. Figure 5 plots the pulp-yield loss during bleaching against the pulp brightness, using the data in Table 5, clearly showing more clearly that the Mg(OH)₂-based process has lower loss of pulp yield at a given brightness than the NaOH-based process. Figure 6 shows the comparison of the COD load of the bleaching effluent from the two bleaching processes. The Mg(OH)₂-based process produced markedly lower COD than the NaOH-based process at the same brightness. COD is a measurement of the amount of dissolved

organic in the filtrate, and the loss of pulp yield is due to the dissolution of organic materials from pulp fibers during bleaching. Therefore, the two parameters should correlate with each other. Figure 7 shows a single linear relationship between the loss of pulp yield and the COD of the bleaching filtrate for both processes, indicating that the higher pulp yield of the Mg(OH)₂-based process is due to less dissolution of organic substances from fibers, not due to the retention of Mg(OH)₂ and/or magnesium salts.

Table 5. Comparison of the NaOH-based and Mg(OH) ₂ -based processes in a HC system under the optimized bleaching conditions								
Process	NaOH-based process				Mg(OH) ₂ -based process			
H ₂ O ₂ , %	2.5	4.0	6.2	8.0	2.5	4.0	6.2	8.0
NaOH, %	2.0	2.5	4.0	4.0	0	0	0	0
Mg(OH) ₂ , %	0	0	0	0	0.75	1.0	1.5	2.0
Na ₂ SiO ₃ , %	2.6	2.6	2.6	5.2	2.6	2.6	2.6	5.2
MgSO ₄ , %	0.05	0.05	0.05	0.1	0	0	0	0
Temp., °C	80	80	80	80	90	90	90	90
Time, hrs	2	2	2	2	6	6	6	6
End pH	8.76	8.87	9.48	9.33	7.20	7.10	7.88	7.94
Residual H ₂ O ₂ , %	0.60	1.08	1.53	2.30	0.67	1.53	2.05	2.97
Brightness, % ISO	78.5	82.9	85.8	86.9	76.9	80.8	83.2	85.0
CIE Whiteness, %	45.6	57.5	66.4	69.3	40.1	49.5	59.0	63.7
b*	9.98	7.84	5.91	5.35	11.0	9.32	7.41	6.55
Anionic trash pH 7.0, µeq/g	45.7	63.4	91.2	-	20.4	20.7	21.2	-
Anionic trash pH 4.5, µeq/g	22.5	33.0	50.3	-	12.5	12.7	13.9	-
COD, kg/t	40.8	52.6	72.1	-	24.7	27.5	32.7	-
Pulp yield, %	96.99	96.41	95.76	-	97.64	97.57	97.31	-

Note: The end pH and conductivity was measured as of 1% pulp suspension.

Figure 8 shows that the Mg(OH)₂-based process had about 40-60% less dissolved solid in the bleaching filtrate. This is due to lower alkali charge and less dissolution of organic materials. A lower concentration of dissolved solid often leads to lower filtrate conductivity. As shown in Figure 9, the conductivity of the bleaching filtrate is significantly lower from the Mg(OH)₂-based process than from the NaOH-based process.

It is well known that anionic trash is formed during peroxide bleaching of mechanical pulps and it has detrimental effects to the papermaking process. The formation of less anionic trash helps reduce its carryover to the paper machine. Table 5 shows that a substantial reduction (60-80%) of anionic trash formation was observed for the Mg(OH)₂-based process when compared with the NaOH-based process at the same brightness. Unlike in the NaOH-based process, the increase of

anionic trash formation with brightness levels was small in the Mg(OH)₂-based process. This is due to the relatively low alkalinity in the system even at higher Mg(OH)₂ charges. As reported earlier [4], anionic hemicellulose (mainly pectic acids), and oxidized lignin and extractives are the major components of anionic trash produced from peroxide bleaching of mechanical pulps. The total anionic trash is defined as the cationic demand of the filtrate measured at pH 7.0. The cationic demand of filtrate measured at pH 4.5 is mainly due to hemicellulose type of anionic trash, while the difference of cationic demand measured between 7.0 and pH 4.5 is mainly due to lignin and extractives type of anionic trash [4]. Results in Table 5 show that much less anionic hemicellulose (anionic trash at pH 4.5) was dissolved in the Mg(OH)₂-based process, and it did not increase with the pulp-yield loss. Similarly, Table 5 also shows a constantly lower formation of lignin and extractive type of anionic trash from the Mg(OH)₂-based process.

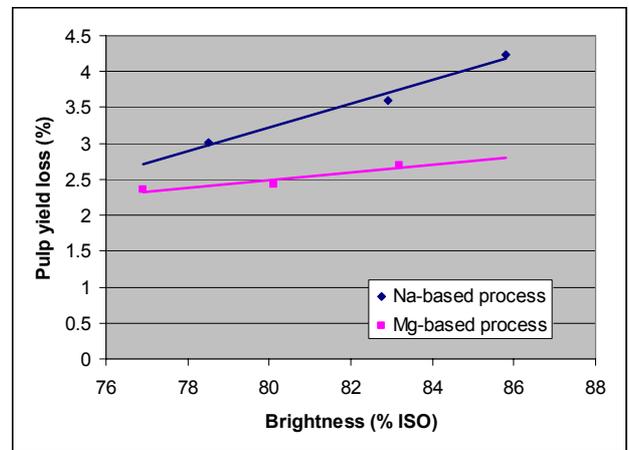


Figure 5. Comparison of pulp yield loss at various brightness levels between the NaOH-based and Mg(OH)₂-based peroxide bleaching process in the HC system (Data from Table 5).

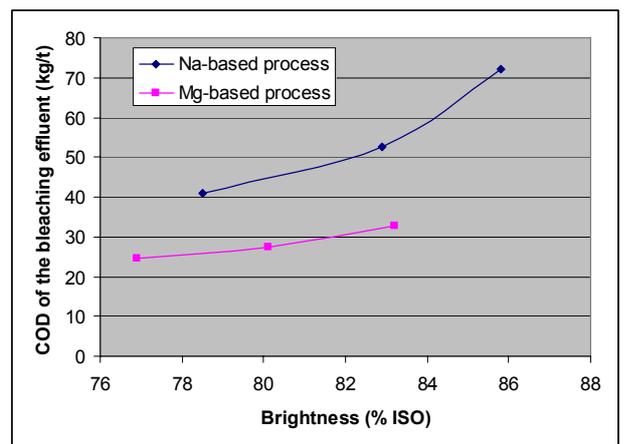


Figure 6. Comparison of COD at various brightness levels between the NaOH-based and Mg(OH)₂-based peroxide bleaching process in the HC system (Data from Table 5).

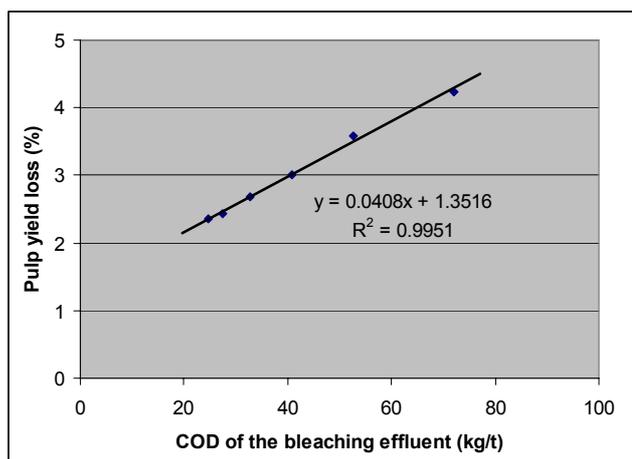


Figure 7. The relationship of pulp yield loss and the COD load of the bleaching effluent in the HC system for both the NaOH-based and Mg(OH)₂-based processes (data from Table 5).

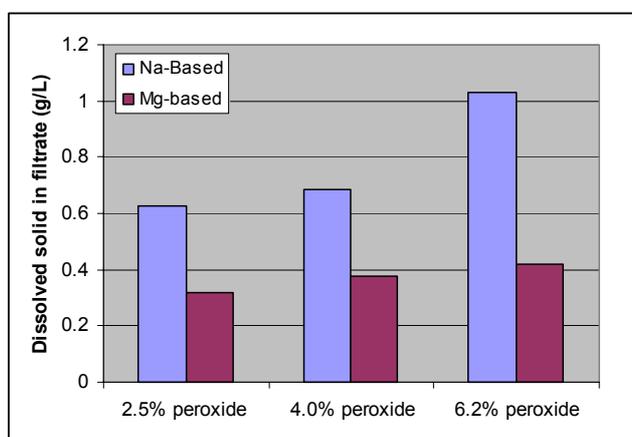


Figure 8. Comparison of the dissolved solid in the bleaching filtrate from the NaOH-based and Mg(OH)₂-based processes in the HC system (Other bleaching conditions were the same as in Table 5).

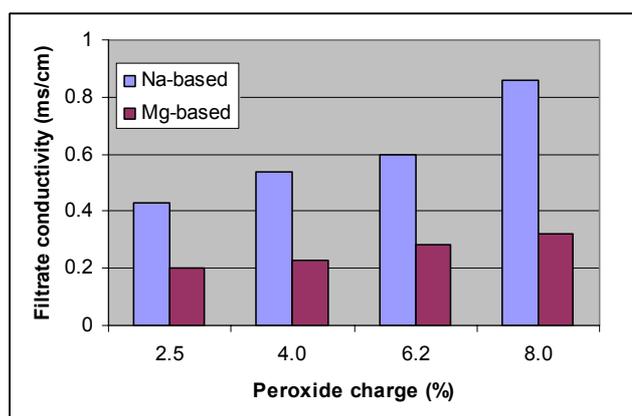


Figure 9. Comparison of the conductivity of the bleaching filtrate from the NaOH-based and Mg(OH)₂-based processes in the HC system (Other bleaching conditions were the same as in Table 5).

Although in the HC system the brightness response of the eucalyptus CTMP to the Mg(OH)₂-based process is close to the NaOH-based process, to reach a 85% ISO brightness target, the peroxide dosage needs to increase from 6.2% in the NaOH-based process to 8.0% in the Mg(OH)₂-based process. An alternative is the addition of fluorescent whitening agent (FWA) or optical brightening agent (OBA) during or after peroxide bleaching to offset the yellowish color of the bleached pulp from the Mg(OH)₂-based process. As shown in Table 6, the FWA addition was very effective in improving the optical properties of the bleached pulp. With 0.4% FWA, the brightness increased from 83.2 to 87.2%, and CIE whiteness from 59.0 to 71.5%.

Sample ID	FWA-0	FWA-0.2	FWA-0.4	FWA-0.8
FWA (Tinopal UP), %	0	0.2	0.4	0.8
End pH	8.05	8.01	8.02	8.00
Residual H ₂ O ₂ , %	2.05	2.12	2.15	2.14
Brightness, % ISO	83.2	85.5	87.2	87.8
Fluorescent comp., % ISO	0	2.76	4.00	5.17
CIE whiteness, %	59.0	66.9	71.5	72.9
L*	97.1	97.2	97.3	97.3
a*	-2.12	-1.51	-1.21	-1.04
b*	7.41	5.71	4.77	4.46

Other bleaching conditions: 6.2% H₂O₂, 1.5% Mg(OH)₂, 2.6% silicate, 30% pulp consistency, 90°C, 6 hours.

CONCLUSIONS

- In the medium consistency (MC) system, the Mg(OH)₂-based process produced significantly lower pulp brightness than the conventional NaOH-based process at a given peroxide dosage, although the difference can be narrowed markedly by increasing the temperature and retention time. The brightening effect of the Mg(OH)₂-based process improved substantially in the HC system combined with higher reaction temperature and longer retention time. Bleached pulp with brightness of 76.9, 80.8 and 83.2% could be produced by the Mg(OH)₂-based process with 2.5, 4.0 and 6.2% H₂O₂, respectively. An 85% ISO brightness or higher could be achieved by either increasing peroxide charge or addition of a fluorescent whitening agent (FWA). A small amount of FWA added during the Mg(OH)₂-based peroxide bleaching can boost the brightness from 83.2 to 87.2% ISO.
- Under the optimized conditions, the Mg(OH)₂-based process in the HC system has a brightening effect close to that of the conventional NaOH-based process at the same peroxide dosages. At similar brightness levels of bleached pulp, the Mg(OH)₂-based process produced substantially less anionic trash and COD, and gave significantly higher pulp yield than the NaOH-based process. Use of magnesium hydroxide instead of sodium hydroxide in bleaching also led to significant reduction of conductivity and dissolved solid content of the bleaching filtrate. However, the Mg(OH)₂-based process requires higher temperature and longer retention time to reach desired pulp brightness due to the mild alkalinity of the system.

REFERENCES

1. Jackson, M.; Falk, B.; Moldenius, S.; Edstrom, A. "Manufacture and end-use potential of high-yield pulp from eucalyptus", *Pulp & Paper Canada*, 89(10): 79-82, 84-86 (1988).
2. Heitner, C.; Bolker, H.I.; Jones, H.G. How Chromophores are Generated by Alkaline Treatment of Wood. *Pulp and Paper Canada* 1975, 76 (8), T243-T247.
3. He, Z., Ni, Y. and Zhang, E., "Alkaline darkening and its relationship to peroxide bleaching of spruce TMP", *J. Wood Chem. and Technology*, 24 (2): 153-168 (2004).
4. He, Zhibin, Ni, Yonghao and Zhang, Eric, "Further understanding on the cationic demand of dissolved substances during peroxide bleaching of a spruce TMP", *Journal of Wood Chemistry and Technology*, 24 (2):153-168 (2004).
5. Johan Gullichsen and Hannu Paulapuro (Series editors), Leo Neimo (book editor), *Papermaking Science and Technology, Book 4, Papermaking Chemistry*, Fapet Oy, Helsinki, Finland (1999).
6. He, Z B, Wekesa, M. and Ni, Y H. "A comparative study of the Mg(OH)₂-based and NaOH-based peroxide bleaching of TMP: Anionic trash formation and its impact on filler retention". *Pulp & Paper Canada*, 107(3):29 (2006).
7. He, ZB; Wekesa, M; Ni, YH. 2004. Pulp properties and effluent characteristics from the Mg(OH)₂-based peroxide bleaching process. *TAPPI JOURNAL* 3 (12): 27-31.
8. NYSTRÖM, M., PYKÄLÄINEN, J. and LEHTO, J., "Peroxide bleaching of mechanical pulp using different types of alkali", *Paperi Ja Puu – Paper and Timber*, 75(6): 419-425 (1993).
9. ZHANG, J.X., NI, Y., ZHOU, Y., and JOLIETTE, D., "Using magnesium hydroxide (Mg(OH)₂) as the alkali source during peroxide bleaching at Irving Paper", Proceedings of the 90th PAPTAC Annual Meeting, B133-B136, Jan. 26-29, Montreal (2004).
10. Li, Z.; Court, G.; Belliveau, R.; Crowell, M.; Murphy, R.; Gibson, A.; Wajer, M.; Branch, B.; Ni, Y. "Using magnesium hydroxide (Mg(OH)₂) as the alkali source in peroxide bleaching at Irving paper." *Pulp & Paper Canada* 106.6 (2005): 24-28.
11. He, Z., Qian, X. and Ni, Y. "The effect of Mg(OH)₂-based peroxide bleaching on the strength properties of mechanical pulps", *J. Pulp Paper Science*, 32 (1): 47 (2006).
12. VINCENT, A.H.D., RIZZON, E., and ZOOEFF, G., "Magnesium oxide driven peroxide bleaching, an economical and environmentally viable process", Appita 51st Annual General Conference, paper n. 3A41: 411-418 (1997).
13. SUESS, J.U., GROSSO, M., and SCHMIDT, K. and HOPF, B., "Options for bleaching mechanical pulp with a lower COD load", Proceedings of the 2001 APPITA Conference, p419-425 (2001).
14. Yu, L., Rae, M., Ni Y., Formation of oxalate from the Mg(OH)₂-based peroxide bleaching of mechanical pulps *J. Wood Chem. and Technology*, 24 (4): 341-355 2004.
15. Yu, L. and Y. Ni, "Partition of soluble and precipitated oxalate and its implication on decreasing oxalate-related scaling during peroxide bleaching mechanical pulps, *Pulp and Paper Canada*, in press.
16. Carlton W. Dence and Douglas W. Reeve (editors) "Pulp Bleaching, Principles and Practice" TAPPI PRESS, Atlanta 1996.

ACKNOWLEDGEMENTS

We would like to thank Dr. Paulo Pavan of Melhoramentos Papéis for kindly providing the pulp sample, and Mr. Mark Wajer of Martin Marietta Magnesia Specialties for the magnesium hydroxide sample for this study.