MICROWAVING LOGS FOR ENERGY SAVINGS AND IMPROVED PAPER PROPERTIES FOR MECHANICAL PULPS

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ABSTRACT

Of the world's total wood-based pulp production for the year 2000, 37 million metric tons (22%) were from mechanical pulps and 130 million metric tons (78%) were from chemical or semi-chemical pulps. Clearly, chemical pulps are preferred for a variety of paper grades, generally for better strength as a result of superior pulp quality (e.g., higher freeness, higher fiber length, and lower lignin content). However, chemical pulps are expensive to produce and fiber yields are generally very low (about 50%). On the other hand, mechanical pulps have fiber yields in excess of 90%, but pulp quality is degraded because fiberization is sometimes not complete and fibers can be severely damaged. Each process has its own inherent advantages and disadvantages, and papermakers must weigh these factors when developing a furnish for a particular paper grade. However, faced with the reality of more restrictive environmental regulations, increased energy costs, competitive pricing, and a more diverse raw wood resource, papermakers are being forced to be more creative in selecting furnish components. Therefore, efforts must be made to develop new technologies that improve the quality of mechanical pulps, making them more attractive as a component in higher quality paper grades.

Previous literature on the microwaving of wood has been primarily confined to chemical pulping processes or drying of lumber. We studied the effects of microwave treatment on whole logs to improve mechanical pulping, specifically TMP, to reduce energy consumption, and to improve pulp quality. We hypothesized that steam pressure would build up inside the logs during microwaving, altering the lignin (possibly through depolymerization) and softening the wood. Subsequent fiberization and refining would occur more easily and fiber damage would be reduced. The following report describes an exploratory investigation of the effects of microwave pretreatment on the mechanical pulping characteristics of commercial black spruce logs.

A high capacity microwave oven was recommended for initial tests. This oven is connected to a variable-power (up to 60 kW) 915-MHz frequency generator. A continuous belt transport system that can accommodate logs up to 30 cm in diameter was available, but it was not used since the treatment timing was unknown. Instead, individual logs were manually placed in the microwave chamber. Various treatment levels were investigated based on power setting (20 to 50 kW) and exposure time (1 to 10 min). After treatment, selected logs were weighed and the temperature profile was measured at three radial positions (near the pith, near the bark, and about halfway between). At the conclusion of the trials, all treated logs were individually shrink-wrapped and shipped to the Forest Products Laboratory (FPL) for further processing.

At FPL, each log was cut in half before chipping. A 5-cm disk was removed from the middle for visual analysis. After soaking in water for 24 h to re-hydrate, the logs were debarked and chipped, producing about 200 L (one 55-gallon barrel) of chips per treatment. Two preliminary TMP fiberization trials were undertaken to establish a suitable pulping protocol. This protocol incorporated an initial TMP fiberization pass to obtain a target freeness of 750 mL Canadian Standard Freeness (CSF), followed by four subsequent atmospheric refining passes to attain 550, 350, 200, and 100 mL CSF, respectively. Power consumption was measured for each refiner pass. Refining conditions selected for all TMP trials are shown in Table 1.

Table 1. Refining conditions for processing TMP pulps

Process		Plate type[a]	Target freeness (mL)	Plate gap (mm)	Speed (r/min)	Feed rate (g/min)	Solids content (%)
Pressurized fiberization (200 kPa)		D2B505	750	0.737	3000	550	50
Atmospheric refining	1st pass	C2976	500	0.457	3000	550	6
	2nd pass		350	0.127	3000	550	6
	3rd pass		250	0.102	3000	550	6
	4th pass		100	0.089	3000	550	6

[a]Both plates were Durametal plates.

Of particular interest were the logs microwaved for 5 min at 50 kW. Within a couple of minutes, splitting became intense and steam jets shot out the ends of the logs. In just 5 min, the logs had lost about 25% of their weight or nearly all of their moisture. A visual examination of the ends of the logs revealed extensive radial checking . A dye penetration test was attempted, but it was ineffective. We unanimously decided that, at the risk of burning the logs, the 5-min/50-kW treatment was the most reasonable maximum power level for the remaining trials. Of the 60 logs available for treatment, 10 logs were used to explore various power levels and about 15 logs were treated at the 5-min/50-kW level.

Based on the results of the exploratory mechanical pulping trials, it was evident that microwave pretreatment can substantially lower refiner energy requirements while improving pulp quality. To verify this, a more extensive evaluation was undertaken using the logs that were microwave pretreated at several different power levels. The logs were debarked and chipped, then refined by the established TMP protocol to produce MwTMP. Of particular interest is the relationship of increased energy savings to increased microwave power levels. Handsheets made from these pulps also exhibited an increase in mechanical properties, with only moderate reductions in brightness (Table 2). As with total energy reduction, an increase in mechanical properties seems to correlate with an increase in microwave power level.

Table 2. Properties of TAPPI handsheets produced from microwave-pretreated black spruce TMP

Trial	Power level (kW·h)	Burst index (kN/g)	Burst index (%)	Tear index (mN·m²/g)	Tear index (%)	Tensile index (Nm/g)	Tensile index (%)	Brightness (%)	Brightness (%)[a]	Density (kg/m³)
Control	0	1.26	0	4.07	00	27.4	0	56.0	0	401
3 min, 35 kW	1.75	1.41	11.90	4.31	5.90	29.4	7.30	53.8	−3.93	415
4 min, 20 kW	1.33	1.31	3.97	4.19	2.95	30.2	10.22	55.1	−1.61	405
6 min, 20 kW	2.00	1.67	32.54	4.75	16.71	30.9	12.77	50.9	−9.11	417
3 min, 50 kW	1.25	1.37	8.73	4.51	10.81	29.0	5.84	51.0	−8.93	410
5 min, 50 kW	4.17	1.70	34.92	4.88	19.90	31.0	13.14	50.7	−9.46	415

[a]Percentage of change from control value.

The strength improvements shown in Table 2 suggest that it may be possible to substitute MwTMP for kraft pulp in an LWC furnish. In producing handsheets, the BLSW component was reduced by 5% and 10% and replaced with an equivalent increase in the TMP/GW component (maintaining a 55% TMP/45% GW ratio). Additionally, the TMP component (control pulp) was entirely replaced by MwTMP (Table 3). The TMP/GW and MwTMP/GW components also required moderate bleaching to achieve a brightness of 74%. Selected material properties were measured on handsheets made from each blend (Table 3). These results show that only moderate reductions in strength result from a 5% kraft substitution when the MwTMP component is unbleached. However, if the MwTMP component is bleached, an increase in strength is observed at the 5% substitution level, with only a moderate decrease in strength at the 10% substitution level.

Table 3. Handsheet properties of LWC blends

Handsheet composition (%)

BLSW	GW	TMP	MwTMP	Power level[a] (kW·h)	Chelated + bleached (% H_2O_2)	Burst index (kN/g)	Burst index (%)	Tear index (mN·m^2/g)	Tear index (%)	Tensile index (Nm/g)	Tensile index (%)	Brightness (%)	Brightness (%)[b]	Density (kg/m^3)
50	22.5	27.5	0	0	0	2.11	0	9.71	0.0	37.4	0.0	65.8	0	559
45	25	0	30	2	0	2.02	-4.3	9.65	-0.6	36.9	-1.3	64.4	-2.1	564
45	25	0	30	4.17	0	2.08	-1.4	9.69	-0.2	37.2	-0.5	64.6	-1.8	562
50	22.5	27.5	0	0	1.5	2.23	0	9.9	0	39.5	0	73.9	0	553
45	25	0	30	4.17	1.5	2.39	7.2	10.23	3.3	40.4	2.3	72.9	-1.4	544
40	27	0	33	4.17	1.5	2.17	-2.7	9.67	-2.3	37.0	-6.3	72.0	-2.6	521
45	25	0	30	4.17	2	2.41	8.1	10.29	3.9	40.5	2.5	74.1	0.3	528
40	27	0	33	4.17	2	2.16	-3.1	9.69	-2.1	37.2	-5.8	74.1	0.3	517

[a]Total microwave energy transmitted to log (PF = 4.17 for 5 min at 50 kW; PF = 2 for 6 min at 20 kW).
[b]Percentage of change from control value.

Significant energy savings were realized for the microwave-pretreated logs. The highest energy savings (15%) corresponded to the highest power levels used. Handsheet strength properties were also increased (up to 35%) with increasing power level, but at a reduction in brightness (−10%). The microwave treatments may have caused lignin depolymerization (either by resonance or high temperatures), which led to the refiner energy savings. This seems to be supported by the observation that fractures in the treated logs occurred predominately through the middle lamella. However, it is unknown whether these treatments caused an unexpected change in fiber morphology during fiberization and refining that improved handsheet properties.

The combination of refiner energy savings and improved handsheet properties (excepting brightness) seemed to indicate that microwave-pretreated thermomechanical pulp (MwTMP) may be an acceptable substitute for some kraft in a lightweight coated (LWC) pulp furnish. Increasing the bleached groundwood aspen market pulp /MwTMP component by 5% improved properties significantly. At the 10% addition level, properties were only slightly below that of the control pulp. A substantial annual savings in pulp cost can be realized if MwTMP is substituted for kraft in an LWC furnish.